Federal Ministry of Economics and Technology

BUSINESS.
GROWTH.
PROSPERITY.

Research for an environmentally sound, reliable and affordable energy supply

6th Energy Research Programme of the Federal Government

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Preface

The earth's reserves of coal, oil and gas supply us with vast energy resources. In addition, we can also harness the power of water, wind and the sun. However, without technological advances and new ideas, we would have been unable to unlock and use the ample resources that nature offers us in a sustainable way. It was, for example, the invention of the dynamo by Werner von Siemens that enabled the generation of electricity using hydropower and wind power.

Innovation and new technologies will pave the way for a new age of renewable energy. It is our intention to complete the transition to a new energy supply much sooner than originally planned. We want Germany to become one of the most energy-efficient and environmentally sound economies in the world. At the same time, we must ensure that this new supply is both reliable and affordable.

By refocusing Germany's energy policy, we have also laid down some new principles for energy research. It is within this context, and to accompany its Energy Concept, that the Federal Government now presents the 6th Energy Research Programme, "Research for an environmentally sound, reliable and affordable energy supply". This programme was developed on the initiative and under the direction of the Federal Ministry of Economics and Technology (BMWi). The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) and the Federal Ministry of Education and Research (BMBF) were also involved in its development.

The 6th Energy Research Programme sets out the guiding principles for the government's future funding of research and development in the energy area, provides information about priority funding areas and gives an overview of the planned funding by the individual government ministries. The Programme redefines priorities in numerous fields. Especially important is the emphasis on the funding of research and development in the areas of "Energy Efficiency" and "Renewable Energy", the strengthening of collaboration between the ministries in fields of strategic importance, in particular in relation to "Energy Storage" and "Electricity Grids", the intensification of collaborative research at an international level, and greater harmonisation and coordination of funding policy.

Research and development are essential if we are to make the transition to a reliable, affordable and environmentally sound energy future. Science and industry in Germany are now called upon to play their part and open the next chapter in the history of energy use on this planet. The Federal Government is ready to support this transition: first, by ensuring that the most favourable conditions are in place and second, by providing additional funds for the research and development of modern energy technologies. I urge you therefore to grasp this opportunity to help shape our energy future!

Dr. Philipp Rösler
Federal Minister of Economics and Technology

Executive summary

In its 6th Energy Research Programme, entitled "Research for an environmentally sound, reliable and affordable energy supply", the Federal Government defines the basic tenets and main areas of focus of its funding policy for the coming years. This programme represents an important step towards implementing the Energy Concept of 28 September 2010, based on which the Federal Government intends to embark on a new age of renewable energy. Its vision is for Germany to become one of the most energy-efficient and environmentally sound economies in the world.

To achieve these objectives, the Federal Government has formulated a new strategic approach to accompany its energy and climate policy. This approach is based on ensuring better funding for the research and development of sustainable energy technologies.

The 6th Energy Research Programme is a joint programme run by the Federal Ministry of Economics and Technology (BMWi), the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) and the Federal Ministry of Education and Research (BMBF). The programme was developed on the initiative and under the direction of the Federal Ministry of Economics and Technology.

The 6th Programme for Energy Research is guided by the Federal Government's Energy Concept of 28 September 2010, as well as its revision following the earthquake in Japan on 11 March 2011 and the ensuing incidents that occurred at nuclear facilities in that country. In the Cabinet decision of 6 June 2011, the Federal Government set out its objective: this was to accelerate the adoption of renewable energy while ensuring a reliable, economically viable and environmentally sound energy supply for Germany. This transition to renewable energy requires political and social change at the deepest levels, with industry and science playing a leading role. Without scientific expertise, a new energy era is simply inconceivable.

Against this backdrop, the Federal Government has refocused its funding of research and development in the energy area in four key ways:

1. Strategic focus: The funds available to the government ministries for fostering research and development are to be targeted even more specifically at technologies and technological systems that are key to the Federal Government's objective of switching to a sustainable energy supply for Germany. Of central importance are the fields of renewable energy, energy efficiency, energy storage technologies and grid technology, the integration of renewable energy into the energy supply and the interaction of these technologies in the overall system.

2. Interministerial collaboration: The government ministries involved in the Programme will develop joint funding initiatives in selected fields of strategic importance to Germany's future energy supply. With close, well-coordinated cooperation, the core competencies that exist within the individual government ministry can be combined more effectively, synergies can be leveraged, and the essential technological breakthroughs can be accomplished through a focused direction of funds. The Federal Ministry of Economics and Technology, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and the Federal Ministry of Education and Research have already established a joint "Energy Storage" funding initiative, and further initiatives in the areas of "Electricity Grids" and "Solar Buildings – Energy Efficient Cities" are to follow. Where research meets innovation, other ministries with different remits will play a key role in interministerial collaboration, as already evident, for example, in the areas assigned to the Federal Ministry of Transport, Building and Urban Affairs.

3. International cooperation: Today, technological developments must increasingly be evaluated from a global perspective. With this in mind, the Federal Government is seeking to extend international collaboration in the area of energy research. Greater integration of research activities within the European Union is of particular importance. International cooperation is vital for Germany in particular, due to the German economy's focus on global markets. To ensure that we plot the right course for the future in this area, the Federal Government will engage with science and industry to determine how international cooperation on researching and developing modern energy technologies can be adapted and improved.

4. Harmonisation and coordination: In Germany, energy research activities are becoming increasingly differentiated and specialised. The "Coordination Platform for Energy Research" will be expanded and reinforced in view of these development processes. It will optimise harmonisation and coordination among the ministries involved in order to maximise the value added by research that is funded by euros from the public coffers. The "Coordination Platform" is also intended to improve collaboration with the German Länder and European funding institutions.

The Federal Government believes that ensuring an excellent level of research and development that is broadly conceived and tightly coordinated – from basic research right through to industrial applications and demonstrations – is one of the key prerequisites for testing new designs, accelerating innovation and bringing forward-looking technologies to market.

The 6th Energy Research Programme is the result of an extensive consultation process. It is closely aligned with the research activities of industry, scientific institutes and energy research in the *Länder*. The Programme's focus incorporates harmonisation with the research activities of the EU and with partner countries in the International Energy Agency (IEA). Germany has a strong record in basic research, highly efficient technical and scientific infrastructure, and an excellent industrial energy research base. This is evidenced by the above-average participation of German partners in the EU's Framework Research Programme and the positive, sometimes excellent, assessments by international experts of the research programmes conducted by the Helmholtz Association of German Research Centres.

The Federal Government funds the research and development of technologies in the energy area in a wide range of programmes across the board. All of these measures are part of the Federal Government's High-Tech Strategy. The Energy Research Programme represents the cornerstone of the Federal Government's funding of energy technologies. It sets the programmatic direction of the Federal Government's energy research policy and the priorities for the aid or funding policies of the Federal Ministry of Economics and Technology, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, the Federal Ministry of Food, Agriculture and Consumer Protection and the Federal Ministry of Education and Research.

Two instruments are used to support research and development, namely, "project funding" and "institutional funding". Project funding is used to support research projects in companies, research institutes and universities that run for a limited period and have clearly defined research objectives. Applicability and marketability are key characteristics of these types of projects. Institutional funding largely comprises the funding of projects in the energy division of the Helmholtz Association which is supported by the Federal Ministry of Economics and Technology and the Federal Ministry of Education and Research. The research institutes of the Helmholtz Association typically examine issues that fall within the category of basic research or which, due to their complexity or need for specific large-scale equipment, can best be handled at large research centres. Project funding and institutional funding can be used in combination and each complements the other. Many believe that this form of collaboration is the reason for the excellent level of energy research in Germany compared with international standards.

The Federal Government's 6th Energy Research Programme attaches particular importance to the realignment of project-oriented funding of the research and development of modern energy technologies. As a result, Germany is in the best possible position to respond flexibly and make rapid progress towards modernising its energy supply and switching to an age of renewable energy.

Close collaboration between the relevant ministries, based on individual specialised programmes, defines the approach to be taken by the Federal Government in future funding of research and development in the energy area:

→ Project funding by the Federal Ministry of Economics and Technology in the area of non-nuclear technologies encompasses the entire energy chain, and focuses in particular on the following fields: energy-optimised building; the energy-efficient city; energy efficiency in industry, commerce, trade and the service sector; energy storage and electricity grids, including key elements in the electricity industry for electric mobility; power-plant technologies and carbon capture; fuel cells/hydrogen; and systems analysis (chapter 3.1). Project funding by the Federal Ministry of Economics and Technology in the area of nuclear safety and final disposal focuses on maintaining and expanding scientific expertise in the relevant fields (chapter 3.2). In terms of institutional funding provided to the

Helmholtz Association, the Federal Ministry of Economics and Technology funds the German Aerospace Center (DLR) in the areas of combustion technology, solar energy and systems analysis (chapter 3.3).

- The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety uses project funding for strategic, broad-based funding of research and development in the fields of wind energy, photovoltaics, geothermal energy, thermal solar energy, solar thermal power plants, and hydropower and ocean energy (chapters 4.1 to 4.6). It also focuses on projects that foster the transition to a renewable energy system (chapters 4.7 to 4.8).

- Project funding by the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) covers the various technologies that make use of bioenergy by harnessing solid, liquid or gaseous bioenergy sources. One focal point for the Ministry's funding is its institutional funding of the German Biomass Research Centre (chapter 5).

- The Federal Ministry of Education and Research (BMBF) is involved in the funding of basic research. In terms of project funding, it focuses on the fields of photovoltaics, bioenergy, wind energy and energy efficiency. The Ministry also funds nuclear fusion to ensure that it has opportunities to play an active role in this field in the longer term. The Federal Ministry of Education and Research supports the next generation of young scientists through its funding of research into nuclear safety and final disposal and radiation research. This ensures that the necessary skills and knowledge are retained in Germany. The ministry is also responsible for important research activities in the energy division within the Helmholtz Association, which contribute in no small way to making Germany an excellent centre of research.

Under the 6th Energy Research Programme, the Federal Government has allocated approximately € 3.5 billion for funding the research and development of energy technologies between 2011 and 2014. This represents an increase of about 75 percent on the period 2006 to 2009. A considerable portion of this large allocation will come from the Energy and Climate Fund – a special fund set up on 1 January 2011. For the period 2011 to 2014, the Federal Government will make additional funding amounting to € 685 million available from this fund, to be used for the sole purpose of research and development projects in the fields of "Renewable Energy" and "Energy Efficiency". The future of state funding of energy research lies in the fields of energy efficiency and renewable energy. In 2014, the Federal Government will invest close to 80 percent of its research budget in these two fields, which are critical to Germany's future energy supply.

The following chapters provide details of how the federal energy research budget is allocated among the individual ministries and technological sectors.

Funding of Research and Development under the Federal Government's 6th Energy Research Programme (in thousand of €)					
	Actual	Planned	Projected Data [1), 2)]		
	2010	2011	2012	2013	2014
Efficient energy conversion and use, energy efficiency					
Federal budget	210,256	218,135	209,433	211,137	208,599
Energy and Climate Fund[3)]	–	28,000	33,500	121,850	137,500
Total	**210,256**	**246,135**	**242,933**	**332,987**	**346,099**
Renewable Energy					
Federal budget	205,142	225,668	255,873	271,493	266,373
Energy and Climate Fund	–	40,000	29,000	130,000	165,000
Total	**205,142**	**265,668**	**284,873**	**401,493**	**431,373**
Nuclear safety, final disposal					
Federal budget	71,543	73,021	73,916	74,930	75,558
Fusion					
Federal budget	131,031	148,148	152,655	154,611	153,599
Overall					
Federal budget	617,971	664,971	691,877	712,171	704,128
Energy and Climate Fund	–	68,000	62,500	251,850	302,500
Total	**617,971**	**732,971**	**754,377**	**964,021**	**1,006,628**

1) Figures relating to the federal budget are subject to parliamentary approval.
2) Funding for the Energy and Climate Fund is subject to change.
3) Also includes contributions for electric mobility.

1. Introduction

1.1 Challenges facing the energy sector

If there is one thing that affects each and every person at the deepest level, something on which the very existence and wellbeing of every individual depends, it is energy. Energy drives every single occurrence on this planet. It is for this reason that the Federal Government and public institutions have always placed energy policy centre-stage, and why energy policy considerations have been consistently, and sometimes controversially, at the heart of public opinion-forming.

At the start of the 21st century, the energy issue is once again on the agenda, and is now more pressing than ever. For the clearest possible evidence of this, we need only look at the history of global developments in the energy sector and the discernible dynamics of that industry. The Federal Government has developed a long-term energy policy and, in the shape of the Energy Concept, established a guiding framework for industry and consumers until the year 2050. It views three developmental trends as critical:

- **Growth in energy consumption:** In 1950, global primary energy consumption was around 100 EJ. Between 1950 and 2008, annual consumption increased more than five-fold (513 EJ). The main reasons for this were population growth and economic development. In 1950, the world population was 2.5 billion people. By 2010, this figure was around 7 billion, and is expected to rise to 9 billion by 2050. Based on these figures, current estimates by the International Energy Agency (IEA) that global primary energy consumption will continue to grow to more than 900 EJ per year by 2050 appear realistic [7, 8].

- **Dominance of fossil fuels:** The wealth of the world depends on fossil fuels. This is true of industrialised countries in particular, but also applies to most developing and emerging economies. Today, coal, oil and natural gas cover approximately 80 percent of the global primary energy demand. The remaining demand is catered for by hydropower, other renewables (in particular traditional biomass energy) and nuclear energy. It is striking that the proportion of fossil fuels used to supply global primary energy demand has even increased slightly over the last 60 years. Coal, oil and natural gas successfully expanded their dominant market position despite the introduction of a new fuel - nuclear energy - and despite the rapid expansion of the latest renewables, such as wind energy and solar energy, in recent years. Evidently the unprecedented economic growth of recent decades has been accompanied by ever-increasing consumption of fossil energy resources. The growth rates are impressive: between 1950 and 2010, the global use of coal increased by more than 200 percent, the use of oil by almost 700 percent and the use of natural gas, which played only a very minor role in 1950, soared by well over 1,300 percent.

- **Carbon emissions and climate protection:** With the technologies available today, the burning of coal, oil and natural gas inevitably produces carbon emissions, thereby intensifying the naturally occurring greenhouse effect. The increase in these emissions is alarming. Global carbon emissions related to energy use have rocketed from 5 billion tons in 1950 to approximately 31 billion tons per year today. Unless the status quo changes, a further increase is inevitable. Studies by the IEA indicate that, by 2050, carbon emissions from energy use may be more than double the figure for 1990 [8]. Given predictions such as these, we are at some remove from the scenario required to protect the earth's climate, namely a rapid and drastic reduction in the trace gases that contribute to the greenhouse effect.

A glance at this data clearly indicates that our current means of generating and using energy cannot be reconciled with sustainable development. Now, after centuries of ever-increasing exploitation of coal, oil and natural gas, there is a growing awareness that this process cannot continue indefinitely. The supply of fossil fuels is not limitless. In the case of oil in particular, the depletion of resources is an ever more likely prospect, even if new discoveries and technological progress may continue to prolong its use, as they have done so often in the past. With a market share of over 30 percent, oil is one of the most important energy sources on the global energy balance sheet.

Limited reserves of fossil fuels are not the only challenge. In the early 1990s, climate experts warned that tighter restrictions should be placed on the burning of coal, oil and natural gas. Today, there is a broad consensus that, by 2050, we need to have reduced the 1990 level of global greenhouse gas emissions by at least 50 percent. In industrialised countries, this figure needs to reach between 80 percent and 95 percent if we are to limit the increase in the global temperature to less than 2 °C compared with the pre-industrial level and avert, as far as possible, the uncontrollable consequences of the climate change already underway [9]. Given this assessment, making the transition to an entirely new global energy system is all the more urgent if we are to protect the earth's atmosphere. Rapid and decisive political action is necessary: it is increasingly clear that the progress of humanity in the 21st century will be shaped, above all, by the decisions facing us in the area of energy and climate policy today.

The Federal Government is developing its energy policy against the backdrop of these large-scale, global perspectives and the resulting opportunities and constraints. It is seeking to support the transition to a new, safe, economically viable, climate-friendly and environmentally sound global energy system. To do so, the Federal Government must also set a good example at home. The vision is for Germany to pave the way for a new era of renewable energy by becoming one of the most energy-efficient and environmentally sound economies in the world.

To achieve these objectives, the Federal Government has formulated a new strategic approach to accompany its energy and climate policy. This approach is based on ensuring better funding for the research and development of modern energy technologies. The Federal Government believes that achieving an excellent level of research and development that is broadly conceived and tightly coordinated – from basic research right through to industrial demonstrations and applications – is one of the key prerequisites for testing new designs, accelerating innovation and bringing forward-looking technologies to market.

By lending the appropriate political support, in particular as part of the "Energy efficiency export initiative" and the "Renewable energy export initiative", the Federal Government strives to ensure that new energy technologies are not only available to investors in Germany, but can also be used throughout Europe and in other countries across the globe. In this way, German policy is making an effective contribution towards achieving the goal of a global energy transition. At the same time, it is creating added value and employment in the field of modern energy technologies in Germany. This basic tenet of the new Energy Research Programme allows it to dovetail perfectly with the Federal Ministry of Economics and Technology's "Technology Offensive" and the Federal Government's "High-Tech Strategy", which have, as their general goal, the unlocking of Germany's enormous potential in science and industry and the provision of sustainable solutions to the national and global challenges facing us [3, 5].

1.2 Energy policy objectives

The Federal Government set out its Energy Concept on 28 September 2010 [4]. The Concept was subsequently updated following the reactor failure that occurred in Japan in 2011. The revised objective is now to achieve the transition to an era of renewable energy within an even shorter time frame. However, the Energy Concept's guidelines for an environmentally sound, reliable and affordable energy supply remain unchanged. The same is true of the quantitative targets that extend as far as 2050 and specify the main features of an energy supply for Germany.

The long-term objectives are of particular importance to the future direction of energy research policy. The key targets for 2050 are as follows:

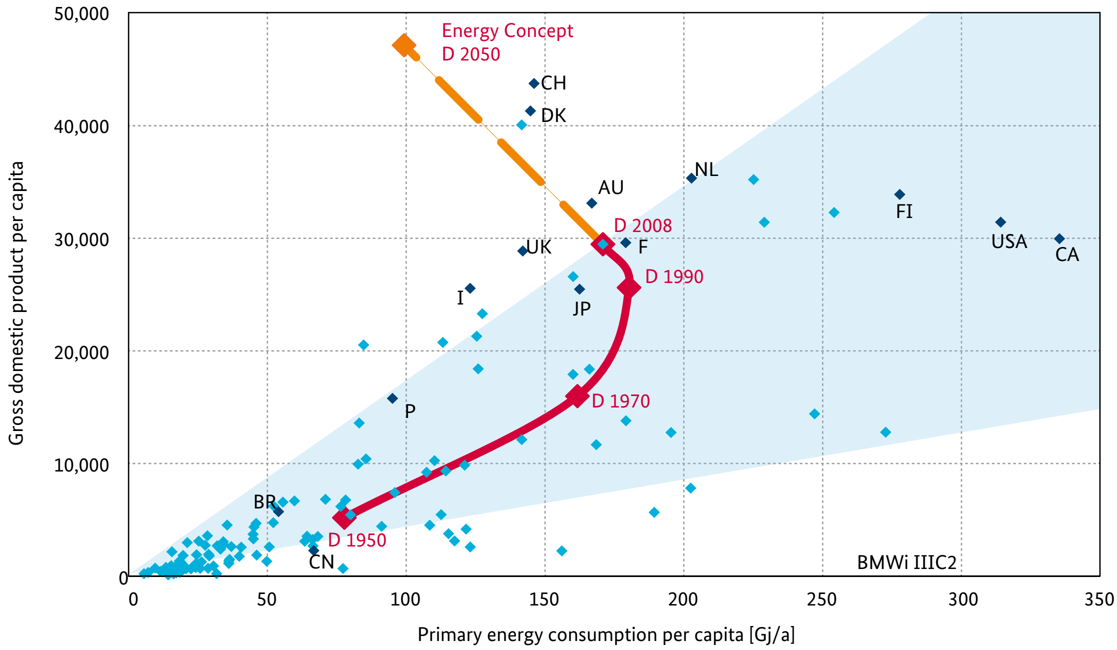
- → Reduce emissions of greenhouse gases by between 80 percent and 95 percent compared with 1990 (by 40 percent by 2020)
- → Cut primary energy consumption by 50 percent compared with 2008
- → Curb overall electricity consumption by approximately 25 percent compared with 2008 (by 18 percent by 2020)
- → Ensure that energy from renewable sources accounts for 60 percent of gross final energy consumption (18 percent by 2020) or 80 percent of gross electricity consumption (at least 35 percent by 2020)

Additional quantitative targets apply to key market segments. These include, in particular, the energy-saving targets for the building sector (reduce heat requirements in building stock by 80 percent by 2050) or for the transport sector (reduce final energy consumption in the transport sector by 40 percent compared with 2005 by 2050). The Concept also defines objectives that apply to the market development of specific technologies, for example, its objective to increase offshore wind energy to 25 GW by 2030, to introduce electric mobility (1 million electric vehicles by 2020, 6 million electric vehicles by 2030) and to start using plants for carbon capture and storage (two demonstration plants for the permanent storage of carbon are to be constructed in Germany by 2020). Within this category of technology objectives, nuclear energy is also defined as a short-term bridging technology. This means that, in the medium term, this form of energy will not have a place on Germany's energy balance sheet.

The number and calibre of objectives defined for the energy sector leave no doubt that the Federal Government is aiming at far-reaching changes to Germany's energy system over the next 40 years. Germany is embarking on a course that is without historical precedent or international parallel (see Fig. 1.1).

This transformation process involves making large-scale changes at a macro level, rather than small changes at the micro level. After all, what we refer to as our energy system is not merely part of our economy – it is, in fact, the foundation of the economy as a whole. The energy system consists not only of mines, power plants, pipelines, wind generators and solar collection systems, grids, vehicles, engines and heat generation plants, but also the corresponding infrastructure, traffic routes, buildings and industrial plants, information and communication technology (an ever more important sector) and, finally, the relevant institutional and organisational structures. Many policy areas will need to be refocused to implement the Energy Concept.

Fig. 1.1: Economic development and energy consumption in selected countries in 2008, plus the course plotted by Germany's energy sector from 1950 to 2050



Source: BMWi

The traditional view is that economic growth leads to a proportionate increase in energy use. This relationship is best illustrated by comparing the situation in different countries. Nations with a large gross domestic product per capita, such as the US and Canada, also have a high level of energy consumption per capita. Nations that have a relatively small gross domestic product per capita, such as Brazil or China, have a relatively low level of energy consumption per capita.

However, Germany proves that there is an alternative. In the 1950s, 1960s and 1970s, the energy sector in Germany was still following the traditional course. However, a new pattern emerged following reunification. In Germany, the gross domestic product per capita rose by almost 30 percent between 1990 and 2010 without a commensurate rise in energy consumption. This trend towards greater energy efficiency must now be continued and accelerated.

By 2050, the Federal Government aims to reduce primary energy consumption by 50 percent with a growth of approximately 40 percent in gross domestic product. To achieve this target, energy productivity must be improved by an average of 2.1 percent per year between 2008 and 2050 in relation to final energy consumption, and by 2.5 percent per year in relation to primary energy consumption.

Regardless of how the transformation of the energy sector progresses over the next 40 years at a micro level, innovation and new technologies are essential. Today's designs and technologies cannot adequately meet the ambitious objectives for energy-saving and the expansion of renewables as set out in the Energy Concept. However, innovation and new technologies will not simply fall into our laps. They require research, development and demonstration if they are to be brought to market. There is simply no alternative.

Energy research policy is rightly considered to be an essential strategic element of any sound energy and climate policy. This is why the Federal Government decided to set out a new Energy Research Programme in addition to fundamentally reframing its energy policy with the Energy Concept. The key objective of this new Programme is to focus the Federal Government's energy research policy and the individual funding programmes of the various ministries with responsibility in this area on the major challenges facing Germany in the 21st century.

1.3 Energy research policy objectives

In funding the research and development of energy technologies, the Federal Government has the following three main objectives:

- The first and most important objective of energy research policy is to contribute to achieving the many targets set by the Federal Government in relation to the energy sector and climate policy. As a result, it prioritises fields and technologies that help improve energy efficiency to meet the target levels and drive growth in the use of renewable energy so that the target market shares can be achieved. Funding policy in this area seeks, in particular, to make these technologies more affordable and pave the way for rapid market penetration. The Federal Government also attaches importance to the environmental soundness and ecological compatibility of energy use.

- The second objective of energy research policy is to enhance the leading position of German companies in the field of modern energy technologies. This scope of this objective is becoming broader as the balance of power is shifting in the development of energy markets. The trends are clear. In Germany, the markets for energy technologies are limited. In the rest of the world, these markets are expanding, in particular in developing and emerging economies, in some cases very vigorously. Strategically focusing energy research and technology policy on global development opens up new opportunities for the Federal Government to support international climate protection policy as well as economic growth and employment policy in Germany.

- The third objective of energy research policy is to secure and enhance technological options. This objective seeks to help improve the flexibility of Germany's energy supply. By ensuring access to a range of options, the Federal Government puts industry and consumers in the best possible position to adapt to changes and re-evaluations. A glance back at Germany's energy history since 1950 clearly confirms that the general framework of energy policy always keeps pace with changing conditions and that individual policy components become obsolete over time. All policymaking must necessarily accept that the future is unknown. In its Energy Concept, the Federal Government therefore commits to ensuring that energy policy is fundamentally technology-neutral. On this understanding, the Federal Government will continue to pursue its broad-based funding of technology in future to create the conditions required for constant innovation. In this way, the Federal Government's energy research policy makes an important contribution to risk prevention for the economy as a whole.

1.4 Framework and structure of Federal Government energy research

It is the Federal Government's view that research and development is primarily a task for industry. The role of the state is to create the conditions under which innovation and technological progress can flourish, and to invest adequately in education and basic research. This division of responsibilities is based on an understanding of the prevailing influence of free-market processes. Industry can offer better incentives for effective research and development projects. Industry is also the main beneficiary of research findings, it knows best the strengths and weaknesses of the technologies, and is thus required to apply the most circumspect measures in a competitive market.

Furthermore, we should remember that industry "buy-in" is always essential if new developments and products are to be brought to market. A funding programme that produces technologies and products that are not wanted by industry and never find their way to the consumer is not a successful one. The pre-eminent position occupied by industry in research and development is also highlighted by Germany's research budget. Almost 70 percent of gross domestic expenditure on research and development is financed by industry.

Beyond this general division of responsibilities, there is also a specific need for strategic state funding of research and development. This need arises from recognised market shortcomings and, in the energy sector, is due in particular to the following factors:

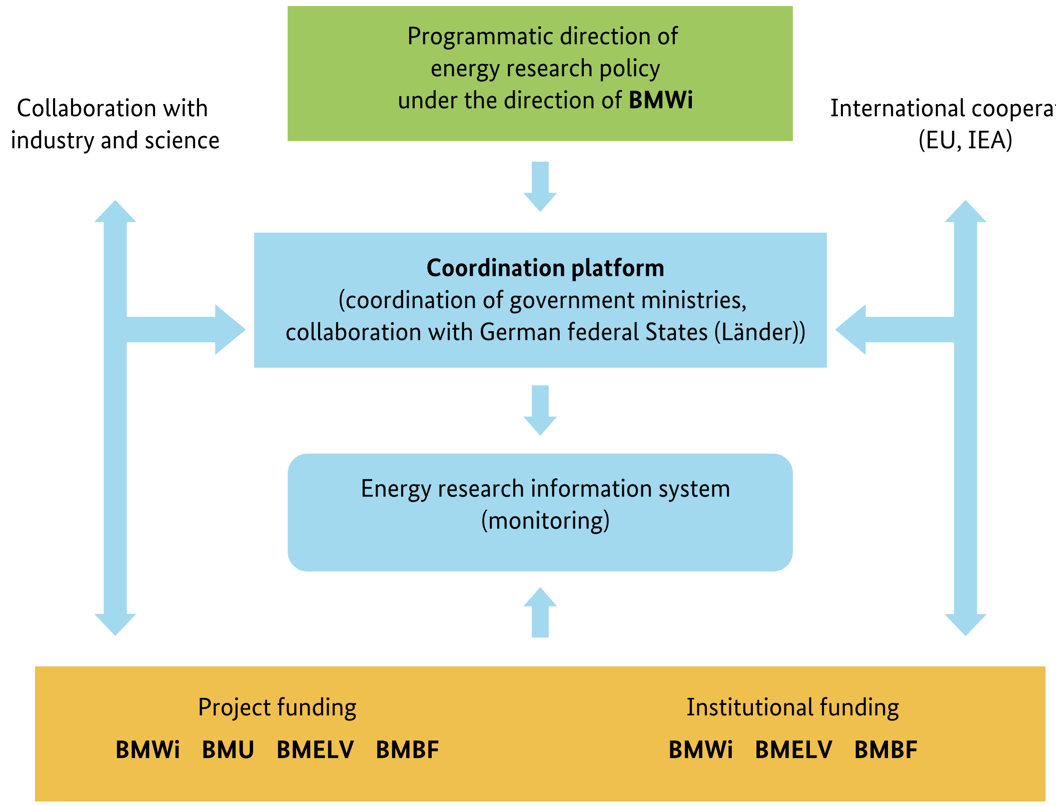
- The long time frames for developments in energy technology from invention to commercial use, which are, in some cases, much longer than the periods normally used in business accounting as a basis for planning and costing
- The high technological and economic risks associated with the research and development of selected energy technologies, which, in many cases are virtually impossible to overlook, and which cannot be covered by the market
- The strategic significance of "energy" as a factor for industry, the environment and society

In Germany, the conditions for research and development of modern energy technologies have improved vastly in recent years. Germany now has an abundance of excellent scientists and researchers working in the energy area; a good, sometimes excellent, research infrastructure; and a growing diversity of research initiatives. The private sector has extended its commitment to research and development. The Federal Government and many federal state governments have reinforced their programmes for the research and development of energy technologies. In the meantime, the processes used for coordination between industry, science and policymakers have improved. Each of these factors has helped Germany achieve and consolidate its leading position in many energy technology fields today. This is particularly true in the field of renewable energy, as well as photovoltaics, wind energy and modern power-plant technologies.

The productive division of labour between the various government ministries in funding the research, development and demonstration of energy technologies has also proven beneficial. This division of labour is based on the following principles:

- Due to its overall responsibility for economic, technology, industrial and energy policies, the Federal Ministry of Economics and Technology (BMWi) acts as the coordinating agency in setting the programmatic direction of the energy research policy and the Federal Government's Energy Research Programme. The Federal Ministry of Economics and Technology is responsible for application-driven project funding of research and development in the fields of "non-nuclear energy research" (not including renewable energy) and "nuclear safety and final storage". This allocation of responsibility provides a sound basis for coherent Federal Government policy in the areas of coal, oil, gas, electricity, grids, energy saving and energy efficiency. The Federal Ministry of Economics and Technology is also responsible for implementing energy research at the German Aerospace Center (DLR) within the Helmholtz Association.
- The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) has responsibility for application-based project funding of research and development in the field of "renewable energy" (not including bioenergy). This means that a single ministry is responsible for funding the research and development of renewable energy, the integration of these into the overall system, and their launch on the market.
- The Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) is tasked with application-based project funding of research and development in the field of bioenergy. This assignment permits a particularly close dovetailing of research policy and agricultural policy in relation to the use of renewable raw materials as energy sources.
- The Federal Ministry of Education and Research (BMBF) is responsible for institutional funding of the research centres within the Helmholtz Association in the "energy" division (not including the DLR) and for project-funded research to answer basic questions in the fields of "energy efficiency", "renewable energy", "nuclear safety", "final disposal", "radiation research" and "fusion". The allocation of these responsibilities to this ministry facilitates effective integration with other areas of basic research, such as materials research, nanotechnology, laser technology, micro system technologies or mathematical modelling. The tasks of the Federal Ministry of Education and Research also include maintaining the excellent level of energy research in Germany by furthering the education of our engineers and scientists.

Fig. 1.2: The Federal Government's Energy Research Programme



The Federal Government also funds the research and development of technologies related to energy outside of the Energy Research Programme. In these cases, the approaches and projects have a different institutional background. In other cases different policies or scientific objectives have priority. Typical examples are research projects in the field of transport research and electric mobility (excluding projects relating to the energy sector), aeronautical research, environmental research, research for construction and housing or projects on information and communications technology. There are also multiple projects relating to energy research that are the responsibility of the individual ministries and serve to provide policy guidance. The same can be said of the research conducted at the Federal Institute for Geosciences and Natural Resources (BGR) and the Federal Institute for Materials Research and Testing (BAM). In addition, issues relating to the energy sector and energy technologies are also being investigated at Germany's universities, the Max Planck Society, the Fraunhofer Society, the Leibniz Association, academies and other institutions.

The Federal Ministry of Transport, Building and Urban Development has a particularly important role to play here, as it has responsibility for the areas of transport, construction, housing and urban development, all of which are heavily dependent on energy. Through its own funding programmes and with the support of its departmental research institutions, the Ministry fosters the introduction of sustainable solutions in the form of practical applications, such as electric mobility or energy-plus homes.

The Federal Government believes that a broad approach to the funding of technology is appropriate and useful. However, in its Energy Research Programme, the Federal Government focuses on specific targets and priorities for the core areas of technology development in the context of the responsibilities described above. In clearly specifying its scope and delineating priorities, the Federal Government has defined an optimum strategic baseline for energy research. This baseline may then serve as a general reference for related or supporting fields of research.

1.5 Guiding principles for future funding policy

Strategic funding of the research and development of modern energy technologies is an important instrument in expediting Germany's energy transition. To rise to these new challenges, the Federal Government has defined a number of general guiding principles for implementing the 6th Energy Research Programme:

- **Strategic focusing:** The funds available within the individual ministries are primarily aimed at particularly innovative energy technologies that promise to be successful in the long term and are important for Germany's transition to a sustainable energy supply. Energy policy will therefore focus on renewable energy, energy efficiency, energy storage technologies and grid technology, the integration of renewable energy into the energy supply and the ways in which these technologies interact with one another. In the field of nuclear safety and non-proliferation provisions, the Federal Government will shape its funding of research so that the expertise currently available in Germany is preserved and developed. By defining these areas of focus, the Federal Government provides science and industry with the predictability and long-term planning perspectives they need for research and development projects.

- **Interministerial collaboration:** The government ministries will develop joint funding strategies in selected fields of strategic importance. This new form of collaboration provides a sound basis for exploiting the core competencies available within the individual ministries, creating synergies, and achieving the essential technological breakthroughs through a focused application of funding. In spring of 2011, the Federal Ministry of Economics and Technology (BMWi), Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and Federal Ministry of Education and Research (BMBF) already published their first joint call for funding applications in the key field of "Energy Storage". Further funding initiatives in the technology fields of "Electricity Grids" and "Solar Buildings – Energy Efficient Cities" are to follow.

- **International cooperation:** Today, technological developments must increasingly be assessed from a global perspective. The Federal Government is keen to take account of this aspect in its funding of technology. At a European level, the Federal Government will support German applicants in their participation in and successful implementation of the Strategic Energy Technology Plan (SET Plan). From the German perspective, priority will be given to projects with a clear European focus. These include, in particular, the research topics of electricity grids, renewable energy, storage technology, energy efficiency and carbon capture and storage (CCS). In addition, Germany will reinforce its commitment to the Energy Technology Network of the IEA.

- **Harmonisation and coordination:** Collaboration between industry, science and state funding policy is vital for the successful development and market introduction of new energy technologies. For this reason, the Federal Government will extend the "Coordination Platform for Energy Research Policy" that is already in place at the Federal Ministry of Economics and Technology. This will facilitate the necessary consultation between the individual government ministries and coordination of the funding activities of the German Länder and European funding institutions. The Coordination Platform is also to be used for collaboration with science and industry. Its purpose is to provide all stakeholders with a forum for the ongoing, all-encompassing exchange of information, to avoid fragmentation and duplication of effort, and to maximise the value added by research funded by the public purse.

- **Transparency:** Many new research initiatives have been set up in recent years, thanks to the political attention that has been focused on the energy question. Against this backdrop, the Federal Government intends to set up a central information system at the Federal Ministry of Economics and Technology to create more transparency in relation to state funding policy and to enable a more accurate assessment of developments in the field of energy technology. The Federal Ministry of Economics and Technology, working with the other ministries, will use this information system to prepare a "Federal Government Report on Energy Research", which will make existing information about energy research available to the public and to parliament. The findings of this report will be channelled into the process defined by the Federal Government for monitoring progress towards implementing the Energy Concept.

- **Flexibility:** Advances in research and development cannot be predicted. The Federal Government therefore makes sufficient provision to ensure that funds can, if necessary, be directed towards specific fields in which new technological possibilities are emerging.

- **Quality control:** To preserve and enhance the high level of research and development in Germany's energy sector, structures, regulations and decision-making processes must be evaluated and optimised on an ongoing basis. Elements of competition play a key role in this context. The 6th Energy Research Programme, "Research for an environmentally sound, reliable and affordable energy supply", is subject to these evaluation and optimisation processes.

Without funding, research cannot take place. The Federal Government will meet its responsibility to make adequate funds available to fund the research and development of modern energy technologies. It has increased its energy research budget significantly in recent years. Between 2005 and 2010, funding was increased by 50 percent, from €407 million to €618 million. The Federal Government intends to top up this figure to ensure that the Energy Research Programme is implemented. Additional funding will primarily be allocated from the *"Energy and Climate Fund"* set up on 1 January 2011. It will be used mainly to expand basic research and application-oriented research in the fields of "energy efficiency" and "renewable energy". According to current plans, the energy research budget for 2014 will be €1,007 million.

1.6 International cooperation in energy research

In today's global economy, national market trends are becoming less significant. Some analysts even predict that in the very long term, there will only be one single market for energy technologies. Such a development would have far-reaching implications, with technology leaders increasingly focusing investment, production and research on growth markets to ensure economic success there through economies of scope and scale.

This trend notably affects Germany. The German energy market as a whole is undergoing a politically motivated process of structural contraction that has been intentionally fast-tracked. Meanwhile, this market is still developing in a different direction in many other countries. Energy requirements are rising in developing countries in particular. The different market perspectives on energy technology resulting from these trends are best illustrated by looking at how Germany's share in global energy consumption has changed over time (Fig. 1.3). At the beginning of the twentieth century, Germany was still consuming around 15 percent of all primary energy used worldwide. By 1950, the figure was approximately 5 percent and it dropped to around 2.6 percent in 2010. Some experts estimate that this share can be reduced to 0.8 percent by 2050.

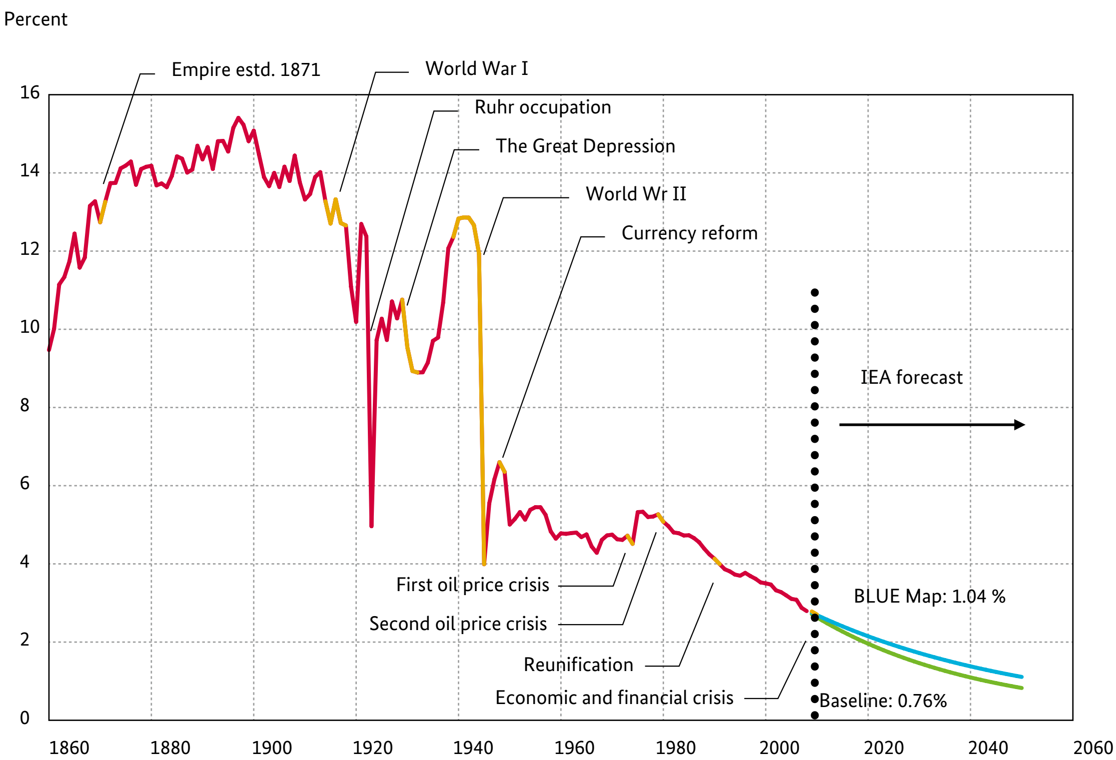
The figures reveal that the largest growth markets for energy technologies are outside of Germany. There is a huge demand for modern technology in developing and emerging economies in particular. This is most clearly illustrated by the IEA's estimate that, even today, around 1.4 billion people (a figure that roughly equates to three times the population of the EU) still have no access to electricity, while 2.7 billion need to burn wood and dung to cook their meals – a process that is both inefficient and harmful to the environment.

Due to shifts in market potential and the resulting new opportunities for the German economy, the Federal Government's energy research policy must be re-evaluated in relation to the question of international cooperation. To further this process, the Federal Government will consult with science and industry to determine the future direction of international cooperation in connection with the research and development of modern energy technologies. These consultations will take account of the information on which the "Federal Government's Strategy for the Internationalization of Science and Research" [1] is based.

The main priority is to determine where the future focus should lie in the following fields:

- **European Strategic Energy Technology Plan (SET Plan):** Companies have formed various European industrial initiatives as part of the SET Plan [6] with the aim of strengthening application-oriented energy research. Initiatives have already been set up in bioenergy *("The European Industrial Bioenergy Initiative")*, wind energy *("The European Wind Initiative")*, photovoltaic and concentrated solar power *("The Solar Europe Initiative")*, electricity grids *("European Electricity Grid Initiative")*, carbon capture and storage *("The European CO_2 Capture, Transport and Storage Initiative")*, sustainable nuclear energy *("The Sustainable Nuclear Initiative")* and Smart Cities *(Energy Efficiency - The Smart Cities Initiative)*. Topics that fall into the category of basic research are investigated by the *"European Energy Research Alliance"* (EERA), a forum for col-

Fig. 1.3: Germany's Share in Global Primary Energy Consumption



Source: BMWi

laboration between the national research centres of member states. The Federal Government will be actively involved in implementing the SET Plan.

- **EU Framework Research Programme:** The Seventh EU Framework Research Programme, which runs from 2007 to 2013, also covers the field of non-nuclear energy research. Under the Programme, funding of € 2.35 billion is available for the research and development of non-nuclear energy technologies. In this Framework Research Programme, the research theme of "Energy" covers research activities in ten areas, ranging from energy efficiency and renewable energy to fuel cells and hydrogen, power-plant technologies, CCS, smart grids, and also cross-sectoral approaches. Preparations towards the 8th EU Framework Research Programme are currently underway. The Federal Government is involved in shaping the content of the new Programme and is committed to simplifying the funding procedure.

- **EURATOM programme:** In the EU, the research and development of nuclear energy technologies are funded under the EURATOM programme, which has at its disposal a budget of € 2.751 billion for the period 2007 to 2011. EURATOM funds research in the fields of nuclear fusion, the disposal of nuclear waste, reactor safety, and other projects in the area of nuclear technologies.

- **International cooperation as part of the International Energy Agency (IEA):** The IEA, which has its headquarters in Paris, has built an extensive network for the development of energy technologies over recent decades. This network consists of "Energy Technology Initiatives" or "Implementing Agreements" and has included Germany's active participation. The most important bodies and groupings within the IEA are the *"Committee on Energy Research and Technology"* (CERT), which answers to the IEA Governing Board and coordinates R&D activities at a political level; the *"Working Parties"*, which provide a forum for the exchange of expert opinion within specific fields (and currently cover the four fields of Fossil Energy Technologies, Renewable Energies, Energy End-Use Technologies and Fusion Technologies); and the *"Implementing Agreements"*, which are projects in which IEA member states (and some non-member states) collaborate on various energy-related topics (Germany is currently involved in 23 of a total of 41 of these "Implementing Agreements").

- **Other international organisations:** In addition to the work carried out by the IEA, which covers almost the entire spectrum of energy technologies, other international organisations and bodies are dedicated to specific aspects of technology development or to particular technologies. The most important of these are the *"International Renewable Energy Agency" (IRENA)*, the *"Carbon Sequestration Leadership Forum" (CSLF)* and the "International Partnership for Hydrogen and Fuel Cells in the Economy" (IPHE). In 2009, the "Clean Energy Ministerial" (CEM) established an international forum for collaboration between the national Energy Ministries, which has set up initiatives on various energy technologies. Germany is also involved in several of these, including initiatives on the topics of "Smart Grid" and "Electric Vehicles".

- **Bilateral collaboration:** Science and Technology Cooperation (STC) Agreements provide a framework for bilateral research activities. These framework agreements regulate, in particular, issues relating to the financing of research staff and student exchanges and the easing of customs and visa requirements for the purpose of such cooperation. By the end of 2010, Germany had already signed 48 STC Agreements with governments across the globe. These agreements are developed and updated on an ongoing basis.

References:

[1] BMBF (2008): Strategie der Bundesregierung zur Internationalisierung von Wissenschaft und Forschung, Bonn/Berlin *(Federal Government's Strategy for the Internationalization of Science and Research)*
[2] BMBF (2010): Bundesbericht Forschung und Innovation 2010, Bonn/Berlin *(Federal Report on Research and Innovation 2010)*
[3] BMBF (2010): Ideen.Innovation.Wachstum: Hightech-Strategie 2020 für Deutschland, Bonn/Berlin (Ideas.Innovation.Prosperity: High-Tech Strategy 2020 for Germany)
[4] BMWi/BMU (2010): Energiekonzept für eine umweltschonende, zuverlässige und bezahlbare Energieversorgung, Berlin *(Energy concept for an environmentally sound, reliable and affordable energy supply)*
[5] BMWi (2011): Technologieoffensive des Bundesministeriums für Wirtschaft und Technologie, Berlin *(Technology Offensive of the Federal Ministry of Economics and Technology)*
[6] European Commission (2007): A European Strategic Energy Technology Plan – Towards a Low Carbon Future, Brussels
[7] IEA (2010): World Energy Outlook 2010, Paris
[8] IEA (2010): Energy Technology Perspectives, Scenarios and Strategies to 2050, Paris
[9] IPCC (2007): Fourth Assessment Report: Climate Change, Geneva

2. Interministerial initiatives

Traditionally, technological developments have been expected to follow an orderly, chronological sequence: starting with basic research, continuing with applied research, product and process development and concluding with an innovative product or service, which is then subject to initial testing before being launched on the market. However, this kind of sequence rarely occurs today. Direct cooperation between research scientists, engineers and marketing experts is increasingly to the fore. Innovations are occurring at a breathtaking pace. While the first generation of a particular innovation is still in the early stages of marketing, the next generation is already at development stage and key questions regarding the following generation are being addressed. Market success is increasingly dependent on how fast the findings from the initial trials of one generation can be incorporated into the development of the next.

However, this trend reflects just one aspect of the growing complexity of innovation processes. Technological progress in the energy sector is currently advancing at lightning speed. Scientific and technological challenges are becoming ever more demanding, while whole systems thinking, or analysis of the interactions and dependencies between systems, is growing in importance. The result is evident in an ever-growing differentiation and specialisation.

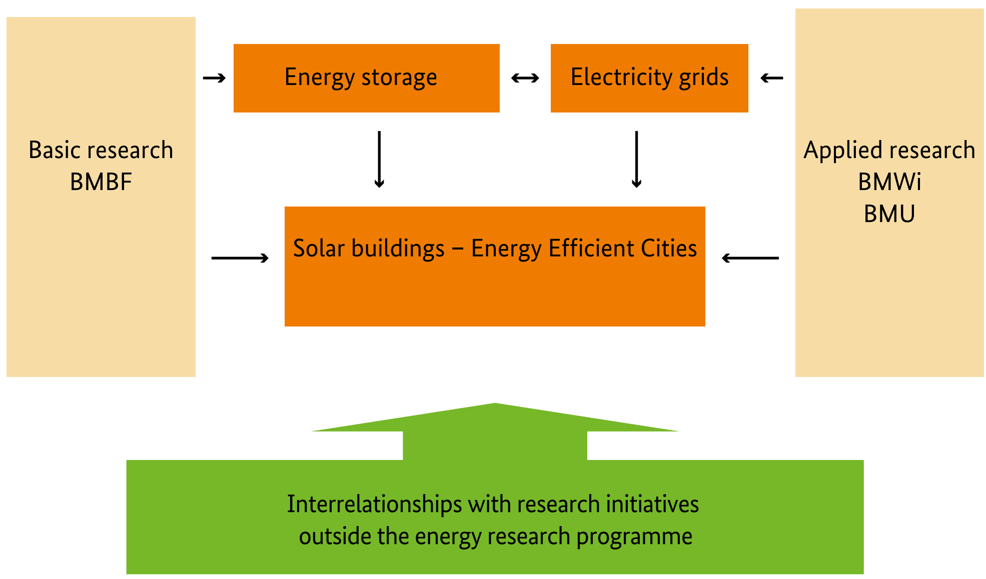
State funding for technology must accommodate these new developments. Interministerial funding strategies thus have an important role to play. Cooperation between different ministries is the best way of using the available expertise, realising synergies and combining forces to achieve the necessary technological breakthroughs in the areas that are vital for Germany's future energy supply.

Joint funding strategies are especially appropriate when the following factors apply:

- the technology is highly complex and system interdependencies must be taken into consideration,
- dovetailing of basic research, applied research, initial testing and marketing is important,
- policymakers want to achieve successful results as quickly as possible.

The Federal Government has resolved to develop and implement interministerial funding initiatives in three

Fig. 2: Interministerial research initiatives



areas initially: "Energy Storage", "Electricity Grids" and "Solar Buildings – Energy Efficient Cities". These initiatives are framed within a technical and political context and must be coordinated appropriately with related or comparable initiatives in Germany (in the individual German *Länder*, for example) and Europe.

In particular, there is an important connection with the Federal Ministry of Transport, Building and Urban Development (BMVBS) funding initiatives in the area of "regional energy strategies". These initiatives mainly concern specific departmental input into regional development and provide a basis for making decisions on additional initiatives, programmes, regulatory frameworks and funding schemes.

Other areas of overlap concern the issue of "electric mobility". Battery-powered and fuel cell-powered vehicles make it possible to exploit electricity generated from renewable energy sources for transport. Efficient storage options such as hydrogen or batteries, which are very specifically integrated into the electricity grid, are required to this end. Research activities relating to storage technologies in transport are closely linked to and coordinated with the projects carried out by the "National Platform for Electric Mobility" and the "National Hydrogen and Fuel Cell Technology Innovation Programme" (NIP).

The joint funding initiatives will focus on the following areas:

2.1 Energy storage

As the Federal Government pursues its strategy of increasing the use of energy from renewable sources for generating electricity to 80 percent by 2050, the electricity demand will need to be adapted accordingly to an increasingly volatile supply. In the medium to long term, energy storage will become increasingly important with the increase in supply of renewable energy.

The issue of energy storage is highly complex and must be considered in the context of whole system thinking, or system interdependencies. Energy storage also plays a key role in an efficient energy supply system that is largely based on renewable energy sources.

The Federal Ministry of Economics and Technology (BMWi), Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and Federal Ministry of Education and Research (BMBF), are funding research and development in storage technologies with different priorities (see also chapters 3.1.4, 4.7.4 and 6.4.2). They are thus laying the groundwork for a high-efficiency energy supply that is based predominantly on renewable energy sources.

Thermal storage is a cross-sectional technology that is relevant to the areas of energy conversion, energy supply and all energy end use sectors. It will play a key role in solar heat supply and solar thermal power plants and also in improving energy efficiency. As part of an integrated approach, thermal storage systems can also help to stabilise the electricity grids and thus reduce the need for electrical storage systems. However, to make a relevant contribution (in the short term) to a high-efficiency energy supply system based largely on renewable energy, significant improvements will be required in thermal storage technology and economic viability.

Chemical storage technology must be developed for the long-term storage of renewable energy that will be required in future. This development will also be vital if conventional energy sources are to become increasingly scarce and expensive, and if the electrical load on power grids has to be leveled. Such systems are designed to convert renewable energy into chemical energy sources such as methane or hydrogen. The Federal Government's ambitious climate policy targets call for the further expansion of renewable energy, a constant increase in the efficiency of the overall energy system, and extensive decarbonisation of mobility. As a result, alternative technologies designed to extract fuels as chemical storage systems for excess electricity generated by wind, for example, look increasingly attractive.

In the long term, electrochemical storage technologies (based on lithium, for example) are also considered as an option for supporting electricity grids. However, batteries are likely to experience earlier market penetration as electrification of vehicles becomes increasingly common (see chapter 3.1.4).

The Federal Ministry of Economics and Technology (BMWi), Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and Federal Ministry of Education and Research (BMBF) launched the "Energy Storage Initiative" in the spring of 2011. This initiative focuses on stationary energy storage. It includes the development of electrical storage technologies (targeting mobile application synergies in particular) and the development of thermal and chemical storage technologies.

Details on the development of the technologies, the funding structure and the research funding priorities are provided in the announcement made about the ”Energy Storage Initiative” [1].

2.2 Electricity grids

Electricity grids must operate reliably to ensure that businesses and private households can access a secure supply of electrical energy. Existing grids will need to be adapted and upgraded to cope with the increased use of renewable energy. There will also be greater exchange of electricity with neighbouring countries, as a result of the European Single Market and Germany’s central location in Europe. Responding to these challenges will entail future large-scale investment in the grid infrastructure.

Strong growth in renewable energy and the increasing decentralisation of the power supply will lead to significant changes in the future electricity grid structures. New technologies will be required to guarantee the efficient, safe and reliable transmission or distribution of electricity. The needs of an energy system that largely uses renewable energy will also have to be accommodated. The research topics cover a broad spectrum: they range from the development of new components (such as direct current power transmission technology and superconductivity technology), to modelling for planning purposes and secure, efficient operation of electricity grids, to the demonstration and assessment of new technologies and systems analysis issues. Since the three government ministries (Federal Ministry of Economics and Technology, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and Federal Ministry of Education and Research) fund research and development on different aspects of the grid (see also chapters 3.1.5, 4.7.3 and 6.4.1), close interministerial cooperation can both maximise synergies and expedite urgently needed technological developments. There is an urgent need to invest now in expanding the electricity grids and adapt these to cope with a high proportion of renewable energy: intensive and coordinated cooperation between all stakeholders in this area is therefore vital. Given the pan-European nature of electricity grids in general, this will necessitate more intensive EU cooperation within the framework of the SET plan.

2.3 Solar Buildings – Energy Efficient Cities

Approximately 45 percent of the world’s population live in cities. In Germany, it is around 70 percent. Therefore, the Federal Government’s targeted expansion in renewable energy and improvement in energy efficiency has to take place primarily in cities. This means that various factors will come into play, notably the demographic trend, new ways of living and working, the question of mobility and ultimately, of course, the key question of how to finance the modernisation of districts and cities in terms of energy. The Federal Government can already rely on a variety of existing programmes in these areas. These include the Federal Ministry of Economics and Technology’s “Energy Efficient Cities” research initiative (“EnEff:Stadt”), the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety’s “Solarthermie2000plus” research programme and the Federal Ministry of Education and Research’s “Energy Efficient City Competition”. The Federal Ministry of Transport, Building and Urban Development’s “Experimental Housing and Urban Development” (“ExWoSt”) research programme also plays an important role. With the aim of combining these existing approaches, the “Solar-powered buildings – Energy Efficient Cities” joint funding initiative is focused on expanding and consolidating efforts in strategic areas.

Within the Federal Government’s Hightech Strategy, these interministerial funding initiatives play a major part in the implementation of the projects “Intelligent restructuring of energy supply” and “Carbon-neutral, energy-efficient and climate-adapted cities”, which are aiming at the future of energy production, distribution and usage.

These projects will be executed in line with the particular technical responsibilities and competences of the relevant federal ministries. Implementation of the projects will require close coordination, sound cooperation and joint management of the research programme.

References:

[1] BMWi, BMU, BMBF, Gemeinsame Initiative zur Förderung von Forschung und Entwicklung auf dem Gebiet von Energiespeichertechnologien of 21 April 2011, Federal Gazette 75/2011, p. 1840 f.

3. Research funding provided by the Federal Ministry of Economics and Technology

3.1 Energy saving and energy efficiency

As part of its Energy Concept, the Federal Government is dedicated to limiting the consumption of primary energy. The aim is to reduce primary energy consumption by 20 percent (compared to 2008) by 2020 and by 50 percent by 2050. tReaching these targets is vital: the level of primary energy consumption in 2020 and 2050 will determine whether the Federal Government's other energy policy objectives can be achieved. The greater the reduction in the demand for energy, the sooner it will be possible to increase the share of renewable energy as required. Furthermore, the less coal, oil and natural gas that is consumed, the more progress we will make towards achieving the objective of reducing greenhouse gas emissions by 40 percent by 2020 and by at least 80 percent by 2050 (compared to 1990 figures).

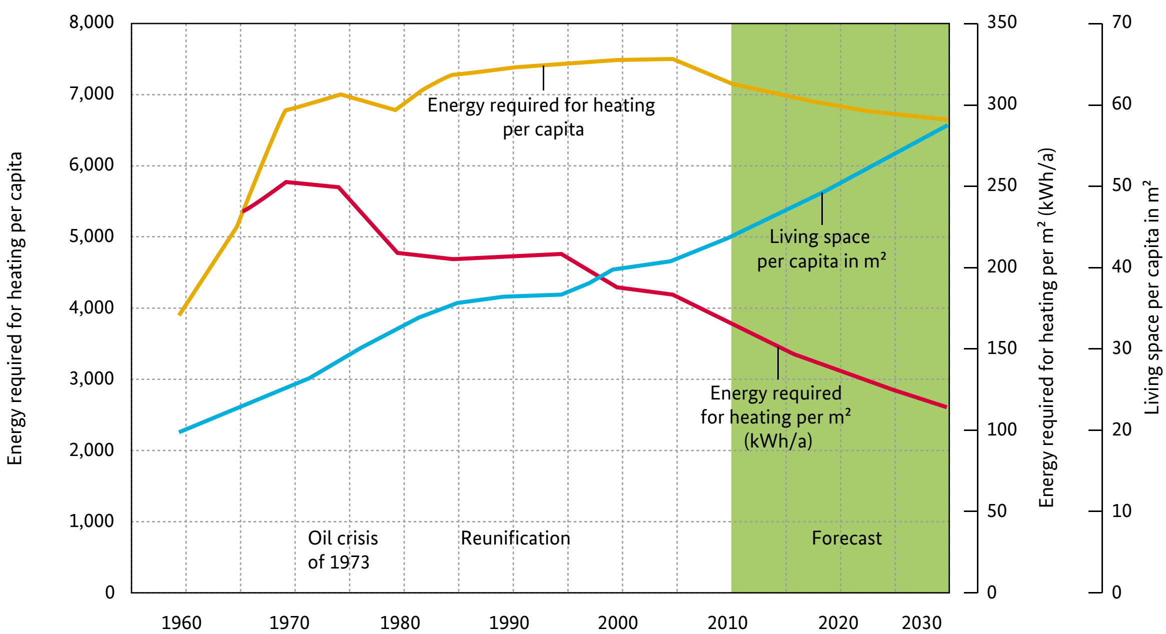
If the Federal Government is to achieve its policy objectives, energy saving must be addressed at all levels of the energy balance sheet: energy production, energy conversion, energy transport and, above all, energy consumption by end users. Funding from the Federal Ministry for Economics and Technology for the research and development of energy-efficient technologies is therefore diversified across a broad spectrum. The Ministry's role is to facilitate access for investors and consumers – at all levels and in all sectors – to high-efficiency, economically viable and environmentally sound energy technologies.

3.1.1 Energy efficiency in the building sector and energy-optimised building

Background and current energy status

Our lives today are inconceivable without buildings. People living in Central Europe spend most of their time in buildings and have high demands when it comes to comfort. More than 40 percent of the total end-use energy in Germany is supplied solely for buildings that accommodate roughly 40 million private households and at least 37 million workplaces. This is equivalent to approximately 3,400 PJ of energy.

Fig. 3.1: Living space and heating requirements in Germany



Source: DETAIL Green Books [2]

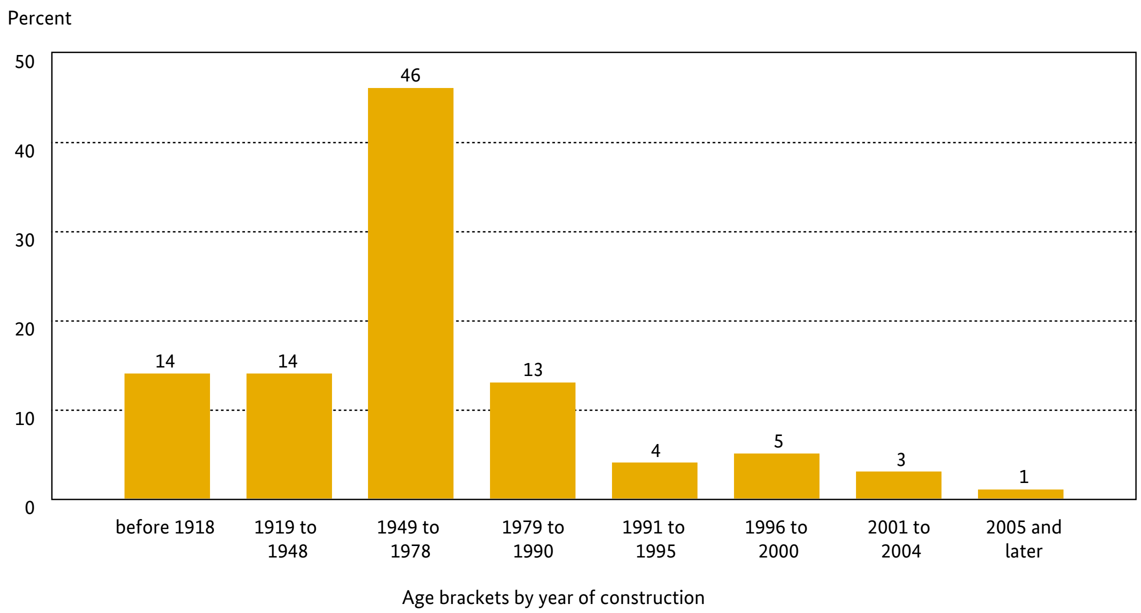
The largest single contribution, some 2,200 PJ of energy, is required to heat private households [1]. This heating energy market has strategic relevance for energy policy. Progress must be made in this area if the Federal Government is to achieve its ambitious targets for reducing total energy consumption and further expanding renewable energy production.

Looking back over recent years, it is clear that both technological advances and the tightening of provisions in the Energy Savings Ordinance (Energieeinsparverordnung, EnEV) enabled by these advances, have helped reduce the annual space heating requirement relevant to living space from 210 kWh/m² at the beginning of the 1990s to a current figure of 160 kWh/m². However, the absolute space heating requirement has hardly changed in the same period. This is due to social, demographic and lifestyle changes. All these factors are relevant in the growing demand for living space. In 1960, the individual floor space requirement in Germany was approximately 20 m² per person, but this had more than doubled to around 43 m² per person in 2009 (Fig. 3.1) [2]. Germany is following a trend apparent not only in industrialised nations but also in developing and newly industrialised countries

The specific age profile of buildings in Germany is a factor distinct from the situation in other countries. Owing to the widespread destruction caused by World War II, 46 percent of the country's building stock was constructed in the post-war period up to 1978 (Fig. 3.2). At that time, there was no relevant legislation in place (the first Thermal Insulation Ordinance or Wärmeschutzverordnung was enacted in 1979). Nor was there any public awareness of energy-optimised building, given the very low energy prices. By today's standards, the energy efficiency of buildings from this period is in need of improvement.

Innovation and new energy technologies are essential for constant advances in the state of the art within the building sector (Fig. 3.3, p. 26). They are also required for further tightening of the regulatory law and to enable the Federal Government's future funding policy for greater energy efficiency in the building sector. The Federal Government is continuing its policy of increasing efficiency and integrating renewable energy in buildings with the Energy Saving Ordinance (Energieeinsparverordnung, EnEV) of 2009, including the proposed revision in 2012, the Renewable Energies Heat Act (*Erneuerbare-Energien-Wärme-Gesetz*, EEWärmeG) and the implementation of the European Energy Performance in Buildings Directive (EPBD). Its aim is to have an almost climate-neutral building stock in Germany by 2050. Climate-neutral means that the buildings require very little energy; also that any energy they require can be covered primarily by renewable energy.

Fig. 3.2: Age profile of the building stock in Germany



Source: PtJ, destatis

To achieve the necessary building modernisation objectives, the above-mentioned legislation must be developed further with regard to economic viability. Analyses based on energy legislation and regulatory considerations are required to this end: these analyses form part of programmes being carried out by the Federal Ministry of Transport, Building and Urban Development and other ministries.

Technological developments and funding structure

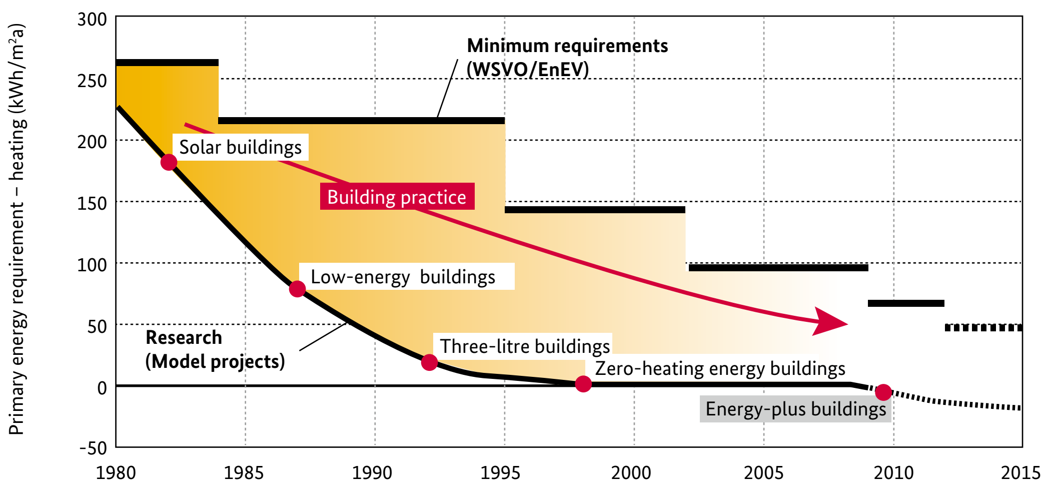
In terms of technology, energy-optimised buildings are not simply some pipe dream in the distant future. Buildings that offer minimum heating and cooling requirements while satisfying high standards of comfort and architectural integrity already exist today. Even energy-plus buildings and zero-energy buildings are also a reality [3]. A combination of the four following measures is important for these energy-optimised buildings:

- → Optimised building envelope (thermal insulation and protection from the sun, airtightness, thermal storage capacity)
- → Efficient construction and technical building services systems (heat recovery, low-exergy systems)
- → Integration of renewable energy (solar energy, near-surface geothermal power)
- → Optimised operation of integrated systems in conjunction with the defined use

The "EnOB – Research for Energy Optimised Building" research initiative summarises the measures designed to promote research, development and demonstration of technologies for greater energy efficiency in the building sector. Its focus is on the entire construction project in pilot and demonstration projects conducted as part of the initiative. The integration of renewable energy represents one aspect of the initiative. Questions regarding the development of solar technologies and individual aspects of the system integration of solar energy are the remit of other funding areas (see section 4.4). For example, the Federal Ministry of Transport, Building and Urban Development's "Future Building" research initiative is an important contribution here. This initiative is concerned primarily with improving the sustainability of buildings and facilities that are to be modernised or constructed [4]. To leverage synergies at this stage, the Federal Government is planning an interministerial, joint research initiative entitled "Solar-powered building – Energy Efficient Cities".

EnOB's mission is to focus on the "building of the future": energy-efficient and energy-optimised, sustainable, functional, comfortable and, not least, architecturally important buildings that are associated with reasonable investment and operating costs.

Fig. 3.3: Developments in research and building practice



Source: Fraunhofer-IBP

The EnOB (Fig. 3.4) research strategy encompasses a number of modules aligned with technical requirements. One priority is the **research and development** of new materials, innovative technologies, systems and concepts. **Model projects** are used to verify the practical application of technological innovations and new concepts. They are also intended to demonstrate a significant reduction in primary energy requirements (compared to the current technologies used in energy-saving retrofits) and a positive energy balance in new buildings. Scientific support (including long-term monitoring, documentation, evaluation, analysis) is provided for all model projects as part of the **MONiTOR** project. Finally, the research programme is completed by **EnBop**, an initiative that targets the energy-oriented optimisation of building operation, and links the application of innovative technologies and concepts with real-world building construction and operation scenarios.

Whole systems thinking, or taking account of system interdependencies, is a topic of increasing importance. A strategic role in this regard is played by the relation with the research initiative **"EnEff:Stadt"** (research on energy efficient cities), which studies the energy situation beyond the confines of individual buildings and the research initiative **"EnEff:Wärme"** (research on energy efficient heating and cooling systems). Research in these areas is particular useful for the interministerial cooperation required by the Federal Government (Solar Buildings – Energy Efficient Cities).

International cooperation and knowledge exchange in the area of energy-efficient buildings are increasing important factors. With this factor in mind, Germany participates in multilateral research cooperation under the auspices of the International Energy Agency (IEA). The Federal Ministry of Economics and Technology is currently supporting the relevant German contributions to the IEA's Implementing Agreements: Solar Heating and Cooling (SH&C), Energy Conservation through Energy Storage (ECES) and Energy Conservation in Buildings and Community Systems (ECBCS).

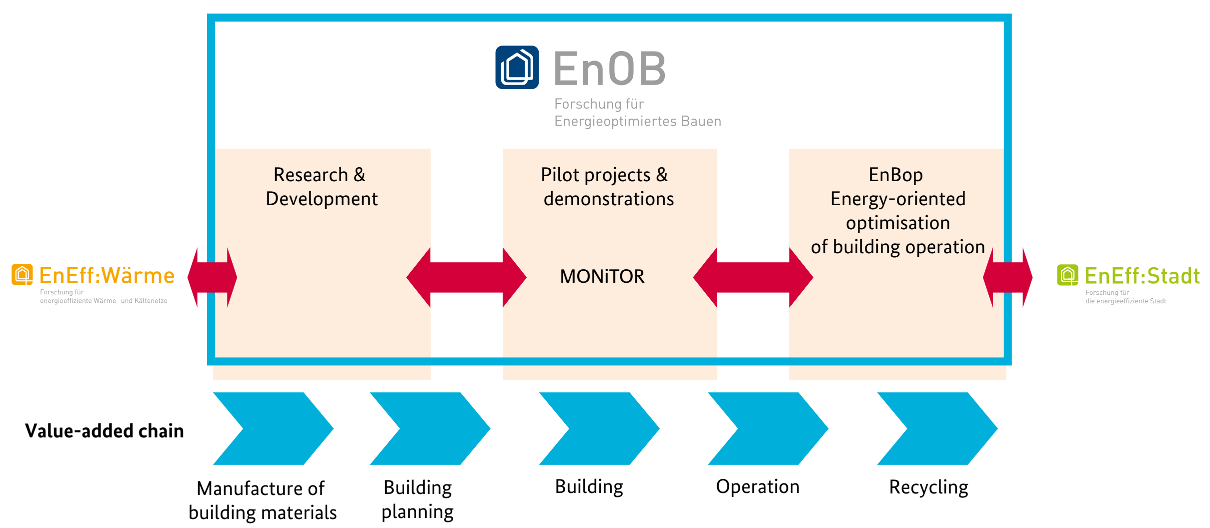
Key strategic funding areas

The EnOB research initiative's funding will focus on the following areas:

- **Reducing the cost** of highly-efficient innovative technologies, particularly for widespread use in energy-saving building retrofits, to prepare the way for market penetration of such technologies

- **Demonstrating** sophisticated energy-saving retrofits, with a focus on using prefabricated modules for a building typology that is differentiated according to location, use and construction type (such as inner-city location, residential buildings, schools, old listed buildings and building materials that merit preservation), especially in cases where a high multiplier effect is very likely

Fig. 3.4: Structure of the EnOB funding programme



- **Systematically examining** the value-added chain (manufacture, planning, building, operation and recycling) to increase energy efficiency throughout the entire life cycle, focusing in particular on the energy-intensive operating phase and energy-saving optimisation by means of moderate investment

- **Holistically studying** the building within its environment to ensure appropriate integration in local energy supply systems as an energy sink, an energy source or an energy storage system

- **Cooperating internationally** in selected and clearly defined disciplines in recognition of the growing importance of global energy markets

Other topics relevant to future funding policy in the categories of *"Research and Development"* and *"Demonstration"* can be summarised as follows:

Passive components: The key objectives here are the development of high-performance insulation materials, such as foams containing nanometer-sized pores, and intensification of the work in innovative coating technologies (including the selective coating of component surfaces).

Active components: The integration of innovative energy conversion technologies in components and the material and system development required for thermal storage are vital here. Further development work is necessary in the switching capability of construction elements, such as smart glass. Work is also continuing on developing efficient ventilation and heat pump technology and on decentralised conversion technology, such as micro CHP systems.

Systems: Sustainable energy efficiency gains are essentially determined by process optimisation during the planning, construction and operational phase of a building. There is a need, therefore, for the scientific community to develop building simulation, building monitoring and building control technology tools. Low exergy (LowEx) technologies that address the exergetic optimisation of energy conversion processes are another key focus.

The research work is supported by using and documenting the innovative technologies in model projects. Both scientists and, in particular, real-world practitioners benefit from the findings produced by monitoring of real-world building operation. The data collected are also made available to interested experts through the **EnOB online** scientific **database**. It is intended that the **accompanying research**, together with analyses and cross-sectoral evaluation, will further integrate related priority funding areas and ensure the exchange of information and knowledge [5].

EnSan: Given the importance of the existing building stock, the demonstration of retrofit technologies is crucial. The purpose of flagship projects is to convert buildings in inner city areas in a way that optimises the energy supply and to use prefabricated construction solutions for energy-saving partial renovations.

EnBau: This programme's mission is to focus on the "building of the future". It aims to promote the "energy-plus" concept in new buildings, underpinning this work with selected model projects. In terms of building use, non-residential buildings are prioritised for evaluation, particularly those buildings that have high energy consumption requirements, such as hotels, shops and other commercial buildings.

References:

[1] Arbeitsgemeinschaft Energiebilanzen, Annual Report 2009
[2] Ebert, Essig, Hauser:"Zertifizierungssysteme für Gebäude", DETAIL Green Books, 2010
[3] Voss, Musall:"Nullenergiegebäude: Internationale Projekte zum klimaneutralen Wohnen und Arbeiten", DETAIL Green Books, 2011
[4] http://www.forschungsinitiative.de/
[5] http://www.enob.info/

3.1.2 Energy efficient cities and decentralised energy systems

Background and current energy status

Approximately 70 percent of the German population currently live in cities. Consequently, most of the building stock and the associated energy infrastructure is concentrated in these areas. According to forecasts, the urbanisation process is set to continue into the future. This means that the success of energy saving and climate policy will be determined in the cities and agglomerations.

However, the urbanisation process in Germany is proceeding at different rates across the regions and is largely dependent on local economic conditions. While the population is growing in some major conurbations in the north and south of the country, it is declining in other areas, notably the eastern regions of Germany. Sustainable solutions for saving energy, improving energy efficiency and protecting the climate therefore need to be found and implemented as soon as possible to address the needs of the varying urban structures. Depending on the initial situation, the main focus is on retrofitting or demolishing urban buildings and updating the energy infrastructure. Two aspects are important in this regard:

- **Greater acceptance** among investors and tenants is necessary before the widespread use of innovative energy efficiency technologies in existing buildings can become a reality. A range of technically and economically appropriate measures must be in place to enable this use.

- A steady reduction in the energy requirements of buildings will threaten the current economic viability of the grid-based energy supply. To ensure financial viability, **municipal energy supply systems must be transformed** into decentralised systems with a high level of combined heat and power generation and the flexibility to adapt to changing demand.

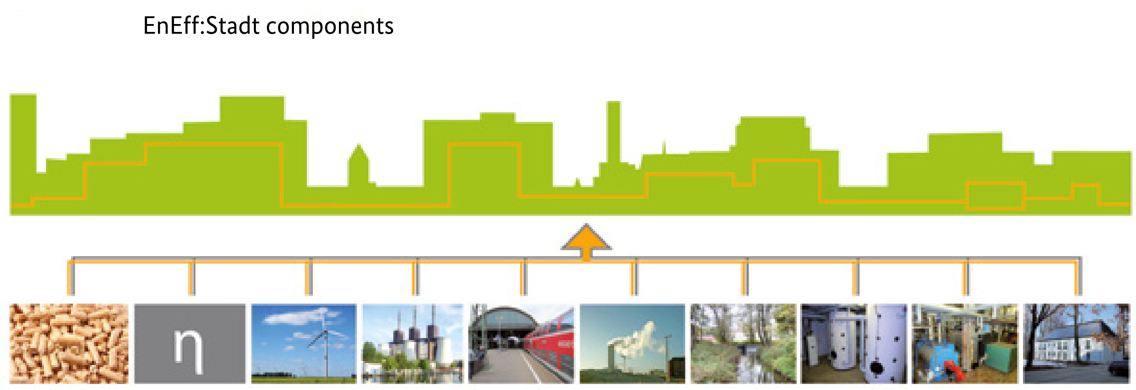
As far as structures go, cities are possibly some of the most complicated possible in terms of developing and implementing optimum solutions for energy efficiency. This complexity reflects the diverse nature of urban districts, which in turn is characterised by a number of factors: the existing building stock, urban planning development objectives, a variety of building functions, diverse energy supply structures, multidimensional ownership structures and the associated and various interests of numerous decision-makers and stakeholders. Moreover, the development of particular districts relies heavily on energy, economic, labour and transport policy initiatives, which are reinforced by current social trends.

Methods to create municipal energy strategies were developed as far back as the end of the 1980s under several Federal programmes. A variety of guides and instructions for creating these strategies, managing local energy requirements and explaining other aspects of municipal energy policy were produced. Empirical experience has shown that energy-saving efforts for urban structures can achieve some measure of success, if not to the extent required. Even cities that enjoy solid political support for the transition to a clean energy economy, including sustainable urban development, have failed to achieve the expected reductions in primary energy use or carbon emissions.

One of the reasons for the limited success to date is the above-mentioned complexity of a "system city" and associated processes. Another reason is the lack of financial resources. Shortcomings in methodology also make implementation difficult, particularly when the aim is to compile energy balance sheets at neighbourhood and district level, identify specific areas of action, extrapolate a long-term strategy from this information and transform it into specific projects at district level.

The demands made on future "Energy Efficient Cities" and the transformation processes involved go beyond energy-saving. Other factors such as demography, city/hinterland conflicts, new forms of living, working and moving around – in particular the introduction of

Fig. 3.5: Merging individual aspects of energy efficient cities in the EnEff:Stadt funding initiative



Source: pro:21 GmbH

electric mobility and architectural demands on the urban fabric and preservation of historic monuments – have a major impact on the energy issue in cities. In future, it will be necessary to tackle energy-saving changes as just one element of the overall transformation of a city and to integrate these into ongoing processes. Even more important is a holistic approach that considers energy strategy as integral to a development strategy for the city as a whole. Ultimately, the methodology chosen must be tailored to the requirements of municipal processes, while energy-saving restructuring must be implemented to the highest quality standards and according to best practice.

Funding structure

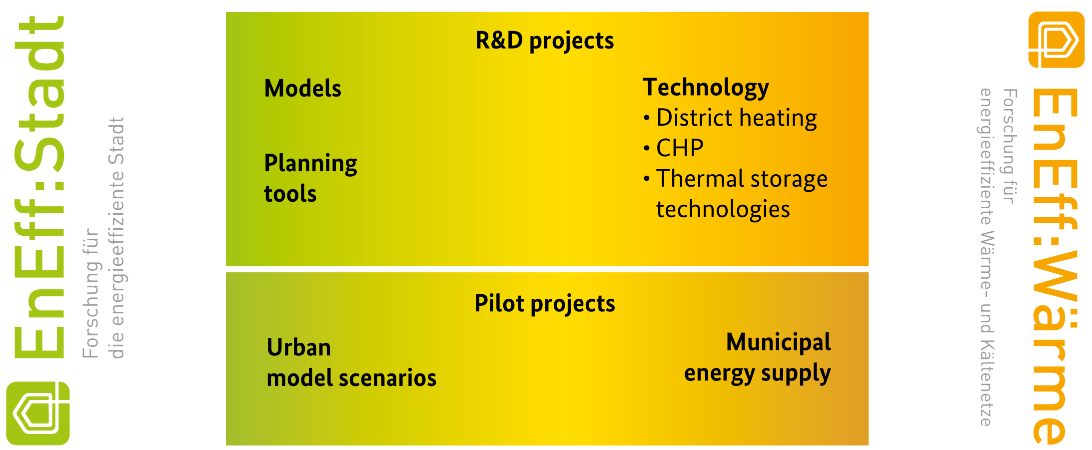
Municipal or development strategies are generally not achieved universally and at once, but in several stages at district level: usually there is a specific trigger for implementing the strategies, such as a large new construction project, or the need for a particular district development initiative.

The Federal Ministry of Economic and Technology's priority funding area **"Energy Efficient Cities" (EnEff:Stadt)** therefore concentrates on locally focused **fully integrated solutions at district level**, which are simultaneously integrated into a long-term strategy for the entire city. The programme will fund best-practice, cost-effective district strategies, their implementation and associated evaluation with the aim of expediting the necessary transformation processes in urban energy supply structures. This approach enables strategies to be decoupled from the overall urban complexities and the planning task to be focused on energy optimisation at district level. With regard to the "system optimisation approach", the EnEff:Stadt funding initiative focuses less on piloting individual innovations in applied district projects, more on deploying an overall, integrated strategy that is technologically and economically sound. This increases the chances of real-life applications and the multiplier effect.

In view of the similarity in focus and the shared objective – to contribute to the development of energy-efficient urban districts – the existing "Energy Efficient Cities" (EnEff:Stadt) and "Energy Efficient District Heating and Cooling Supply" (EnEff:Wärme) funding initiatives have been combined. The resulting synergies help to deploy existing funding resources more systematically and efficiently (Fig. 3.6).

The EnEff:Stadt and EnEff:Wärme funding initiatives are each subdivided into two modules: *"R&D projects"* and *"Pilot projects"*. The EnEff:Stadt "R&D projects" cover the targeted development and evaluation of models and planning tools for general and specific applications. The same module in the EnEff:Wärme initiative focuses on the development and optimisation of decentralised and municipal supply technologies. The "Pilot projects" module supplements both research initiatives. Its purpose is to test innovative technologies and concepts in a relevant context (urban districts in the case of EnEff:Stadt and municipal energy supply technologies in the case of EnEff:Wärme).

Fig. 3.6: Structural linking of "EnEff:Stadt" and "EnEff:Wärme" funding initiatives

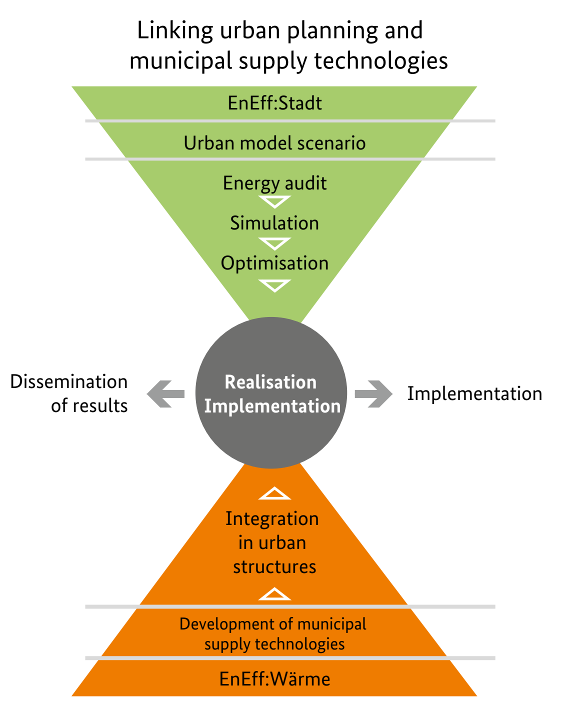


In principle, the pilot projects in both research initiatives comply with the following guidelines:

- **Concentrating** on the principal settlement types in Germany with regard to the main urban development and supply objectives of the future. This involves primarily the areas of energy retrofits, change of use, redensification, demolition and, in only a very few cases, the area of new buildings.

- **Integrating** relevant aspects into all project phases. This relates mainly to the implementation of an "integrated systemic global approach", which incorporates all local and supra-local energy-saving potential and energy efficiency improvements. It also includes the relevant stakeholders in the planning and decision-making processes. In addition to efforts in the building sector and energy supply system, aspects of electric mobility, for example, can also be integrated. Similarly, non-energy-related criteria, such as aspects relating to the urban fabric and preservation of historic monuments as well as public acceptance in terms of general sustainable urban development, are also examined.

Fig. 3.7: Interconnecting topics from EnEff:Stadt and EnEff:Wärme funding initiatives



Source: pro:21 GmbH

- **Communicating** the results. In addition to guaranteeing the availability of data, this involves disseminating information about new methodological developments and findings revealed by the accompanying research to experts and local stakeholders. Further key elements are, on the one hand, the internal project communication enabled by comprehensive stakeholder involvement at city or municipal level and on the other hand, the learning processes facilitated within the projects funded by the programme.

Linking both funding initiatives ensures that urban planning themes are linked to municipal supply technologies, for example, in the area of district heating and local heating usage (Fig. 3.7). EnEff:Stadt supports optimum demand and supply situations by conducting an energy audit or review of the initial situation and simulating potential scenarios. In the meantime, EnEff:Wärme ensures that innovative municipal supply technologies, once developed, are integrated in selected urban structures as part of pilot projects.

This coupling of the two initiatives makes it easier to implement measures that are technically and economically appropriate. Through the close involvement of local users, planners and other relevant stakeholders, a high acceptance of the methodology and the technical solutions is ensured. Disseminating results to the current municipal planners is an important aspect of the research initiative. Only thus can the results can be permanently implemented in practice [4].

Key strategic funding areas

Taking the future challenges facing the transformation of municipal energy supply systems into account, the funding measures for the EnEff:Stadt research initiative will concentrate on the following priorities in relation to the energy economy:

EnEff:Stadt – R&D projects

Planning and optimisation methods for urban districts and the associated planning tools must enable an accurate representation of the actual situation and thus facilitate the balancing of energy supply and demand. By simulating the consequences of a number of different decisions, these tools should provide a basis for choosing the most energy-efficient and economically viable measures. They must be used to illustrate economically sound solutions for optimising systems and for applying these to specific municipal scenarios. The planning tools used must be geared in such a way that they are accepted by planners and municipal authorities. Therefore, it is necessary to develop and test the tools in close cooperation with the practitioners who will be using them.

EnEff:Stadt – pilot projects

The EnEff:Stadt funding initiative focuses on pilot projects, which are also aligned with the systemic approach outlined. They are necessary

- to show how integrated solutions can be developed and implemented effectively in a variety of urban structures.
- to test and improve newly developed system optimisation planning tools and adapt them to actual municipal requirements.
- to measure the results/effects that can be achieved and thus provide the proof for examples of good and best practice.
- to demonstrate how the complex stakeholder and organisational structures involved in such urban planning processes can be developed and utilised.

In addition to previous project types that have targeted urban districts, two new project types have emerged: “cluster projects” and “campus projects”. These project types will be more vigorously implemented in future.

“Cluster projects” function on the assumption that it is often reasonable to use the existing, locally established networks of decision-makers and their practical experience to promote several promising projects simultaneously in a city. These projects can then spark a transformation of the energy system in the city as a whole and serve as an example for other cities. Such a “cluster” approach requires the setup of a very specific network of stakeholders, experts, decision-makers and influencers to generate the type of lasting momentum required for sustainable urban development. Such “cluster cities” are therefore specifically selected to promote the internal momentum and efforts within the municipality, while incorporating the know-how of external experts.

Urban development projects cannot survive without flagship projects. Rather than highlighting issues of cost efficiency, such flagship projects tend to prioritise technical innovations or creative solutions that cannot be implemented in their existing form across an entire urban district. This is where **“campus projects”** have a role to play. These are projects in which several buildings on a college or university campus (or the campus as a whole) are retrofitted or rebuilt. If such projects are linked with sophisticated technical innovations in the building and energy sector and in planning and also used for teaching and research purposes, they become pilot projects for modern district strategies. As such, they are very attractive candidates for the EnEff:Stadt funding programme.

EnEff:Wärme – R&D projects

In the EnEff:Wärme programme, priority is given to research topics that focus on significantly improving decentralised energy supply technologies and district heating technologies from a primary energy, exergetic, economic and environmental perspective. Such topics include the following technologies: CHP technology, heating and cooling technologies, heat exchanger systems, pipeline and pipe-laying technologies, LowEx heat transfer stations including low-loss hot water supply, measuring technology, adapted building technologies, heat transfer fluids, innovative power grids, structures and optimised modes of operation, full-system optimisation. A new area of research is the use of existing and new heating and cooling systems as busbars for decentralised waste heat (for example, input from industrial processes, decentralised CHP plants, solar heat and other renewable energy sources). As decentralised input into heating systems still poses a particular technical problem for district heating utility companies, this topic is the subject of intensive study.

Another priority for future research funding is thermal storage, which is playing an increasingly important role in optimising energy systems. A broad spectrum of innovative technical approaches (such as sorption storage systems, thermochemical storage systems) and applications are being investigated. Future measures will include both the technological development and optimisation of system integration. These measures will focus particularly on the development of suitable storage media and high-efficiency storage processes, formulation of the necessary simulation tools and experimental implementation of new storage strategies. One of the main objectives of the funding measures is to achieve a significant reduction in manufacturing costs. Synergies are exploited in the overlaps between this topic and the “Energy storage” funding area (see section 3.1.4).

EnEff:Wärme – pilot projects

In the area of research on efficient district heating and cooling supply systems, the funding of groundbreaking and exemplary pilot projects (including innovative concepts for using waste heat, multiple options for heat supply and thermal storage) is a high priority. The funding will help to support pioneering planning strategies and the testing of innovative individual components. It will also extend to a related measuring programme that will include evaluation and operation optimisation. Within the framework of the EnEff:Wärme funding programme, selection criteria have been established that are evaluated regularly and designed to ensure the quality standard of the pilot projects.

From an energy sector vantage point, expanding the district heating supply system in developed and built-up areas and areas with low heat density is a priority. This can only succeed if the technical and planning costs of heat distribution can be drastically reduced and the exergetic benefits and energy efficiency gains of this supply can be clearly illustrated. It is crucial also that the buildings to be supplied with heat and cooling are included as part of an integrated analysis that addresses the issues of heat generation, transport, distribution and, if necessary, storage. Priority will be given, therefore, to the demonstration and evaluation (through measurement) of innovative concepts in the areas of “Improving energy and exergy in existing systems” and “Innovative new heating systems”.

Other important R&D topics relating to efficient heating and cooling include the following:

- → Possible uses of large heat pumps in district heating
- → Improvements in micro CHP with regard to the power-to-heat ratio, process optimisation and economic viability, linking with storage systems and, if applicable, integrating them in virtual power plants
- → Thermally driven heat pumps, particularly for using waste heat and supplying district cooling
- → Planning and operation of complex low-temperature systems/cooling systems with several heat sources and storage devices
- → Use of modern ICT technologies, including smart meters and mains surveillance, to optimise operations
- → LowEx systems and total energy system optimisation
- → Testing and validation of storage concepts to optimise system integration and develop appropriate operational strategies for thermal storage systems

Communication, cooperation and wider impact

The practical application of the pilot projects, their methods and planning tools should be proven on the basis of concrete implementations. For the results of such projects to be incorporated widely in planning and decision-making, users, practitioners and decision-makers alike must be involved in the preparation, processing and presentation of results. Manuals and guidelines, conferences and workshops involving the relevant influencers are therefore important enablers for disseminating knowledge to the relevant target groups [1].

To fully leverage the pilot project results, efforts are underway to link several policy areas within the framework of the EnEff:Stadt programme. In particular, aspects of urban development and transport policy are coordinated with the relevant activities of the Federal Ministry of Transport, Building and Urban Development, which is primarily responsible for these policy areas.

The EnEff:Stadt research initiative also operates within the context of several international activities. The IEA Implementing Agreement “Energy Conservation in Buildings and Community Systems” (ECBCS) forms a suitable framework for multilateral research cooperation projects. In 2009, the Federal Ministry of Economics and Technology supported the initiation of Annex 51 “Energy Efficient Communities” and funded the German contribution. The spectrum of activities ranges from exchanging results based on international case studies and pilot projects to the development of planning guidelines for municipal decision-makers and users [3].

References:

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[2] Roth et al.: Wechselwirkungen zwischen Siedlungsstruktur und Wärmeversorgungssystemen, 1980
[3] http://www.annex51.org/
[4] http://www.eneff-stadt.info/en/, http://www.eneff-waerme.info

3.1.3 Energy efficiency in industry, crafts, trade and services

Background and current energy status

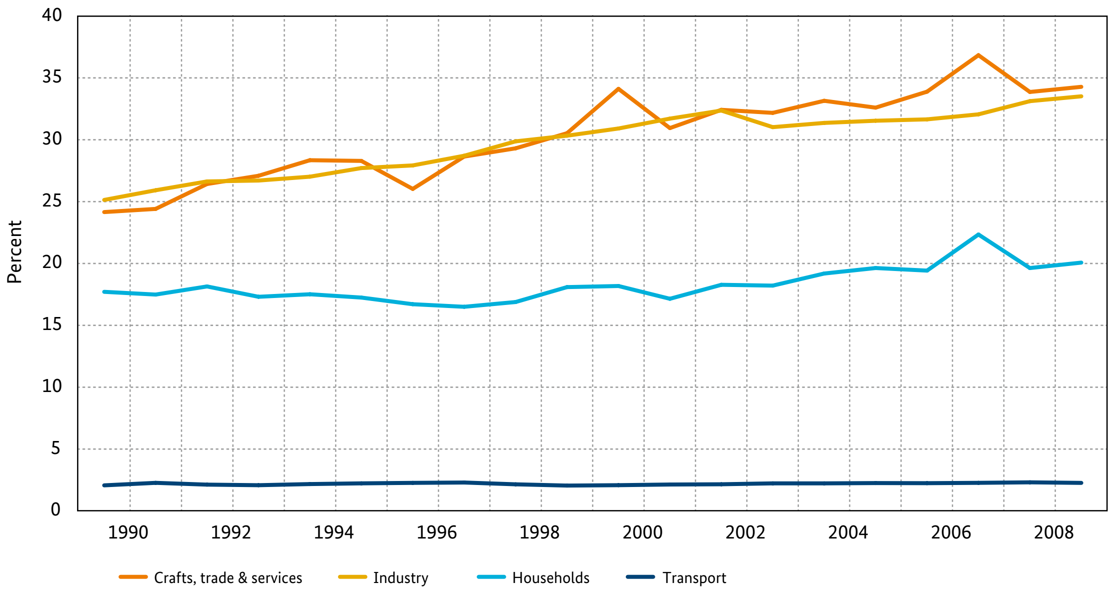
In Germany, the industry, crafts, trade and services sector is one of the largest consumers of energy. However, its share of overall energy demand has fallen in recent years [1]. The sector's share of end-use energy consumption contracted from 50 percent in 1990 to 42 percent in 2009. In absolute figures, this is a reduction of 22 percent in energy consumption, from 4,711 PJ (1990) to 3,675 PJ (2009).

There are several reasons for this downward trend in energy consumption. A key factor is the restructuring of industry in the new Länder and the associated improvement in energy efficiency. Outsourcing of energy-intensive manufacturing abroad has also played a role in this reduction. However, a plethora of technological improvements, which were only made possible by ongoing research and development, have been critical. Industries with high energy requirements have made important contributions to energy savings. This has also meant, for example, that, in raw steel production, during the same period, the increase in energy efficiency was accompanied by a reduction in specific carbon emissions from 1.59 to 1.37 t carbon dioxide per ton of raw steel. Overall, energy requirements fell despite a slight increase in output volume [4].

Electricity is a major energy source in industry, crafts, trade and services [1]: in 2009, this sector accounted for 68 percent of electricity consumption. If the distribution of end-use energy consumption is examined in the individual sectors (Fig. 3.8), it can be seen how, in recent decades, electricity has become an increasingly important source of energy in industry, crafts, trade and services, while the rate of electricity consumed in the other sectors (households and transport) has remained almost unchanged. If one-quarter of end-use energy consumption in industry, crafts, trade and services was covered by electricity in 1990, the proportion of this high-quality energy source has now already risen to one third, mainly as a result of increasing automation. It is to be expected therefore, that with regard to the carbon emissions, measures to increase the efficiency of electricity use in industry, crafts, trade and services are particularly effective.

Due to the growing use of electricity and natural gas in industry, crafts, trade and services, economic performance increasingly hinges on changes in energy costs: Fig. 3.9 illustrates how energy consumption is increasingly also a cost factor for certain individual manufacturing industries.

Fig. 3.8: Percentage of electricity in end-use energy consumption in various sectors



Source: BMWi, according to Arbeitsgemeinschaft Energiebilanzen, data: July 2010

Technological developments and funding structure

Energy savings in the industrial sector are first and foremost achieved by optimising existing processes. Taking the traditional energy chain with its three stages, the processes involved are “supplying energy from the primary energy source”, “using energy in the process” and “dissipation of unused energy”. In cases where no further improvements can be made at reasonable cost by modifying the process parameters through theory, simulation and experiment, new procedures must be developed and implemented to achieve additional energy savings.

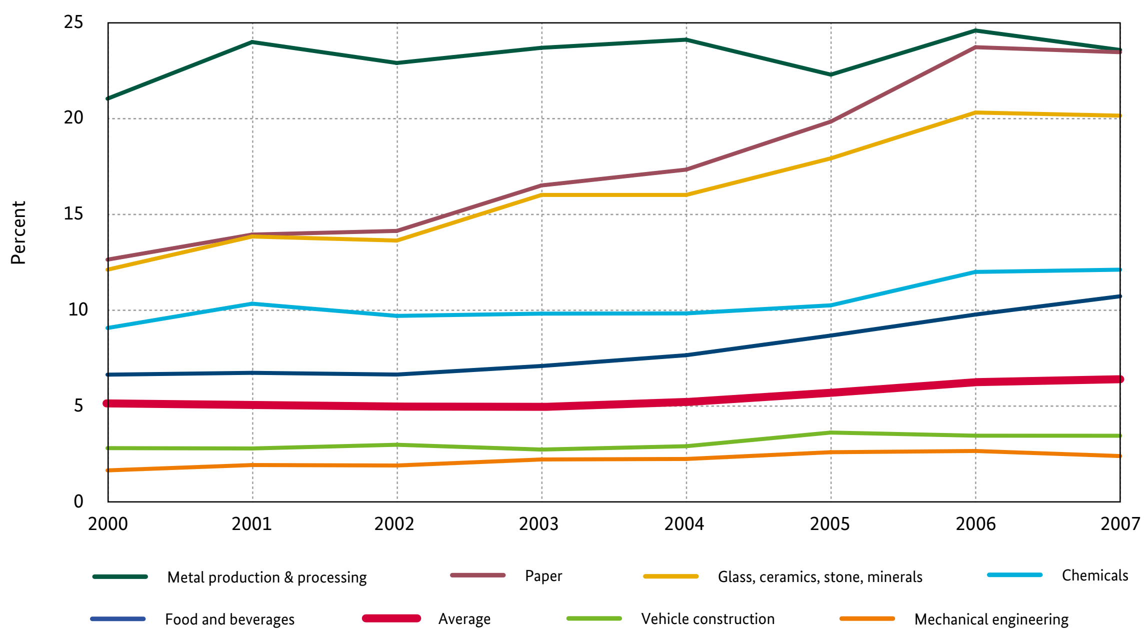
The use of waste heat from thermal processes is a key factor in increasing energy efficiency in industry. Where waste heat cannot be used directly in a subsequent process at low temperatures, it can become an alternative source of energy if it is stored locally, processed by means of heat pumps or converted into electrical energy. Exploiting previously unused residual energy in an “energy cascade” makes the design, construction and operation of plants more complex. One of the funding policy’s key tasks, when implementing the defined energy-saving and climate protection objectives, is to identify and mitigate such technical and economic risks.

As an energy source, electricity currently plays a critical role in industry and particularly in trade and services. With the accelerated transition to renewable energy, electricity is increasingly relevant, as is the need to generate new ideas for its efficient use.

The broad range of topics covered by the funding addresses diverse energy-related processes in industry, crafts, trade and services. Consideration is given to processes based on chemical, thermal, mechanical and electrical energy along the entire process chain. Cross-sectoral themes that do not relate specifically to any one form of energy are also examined.

The target group of the “Energy efficiency in industry, crafts, trade and services” research programme is very heterogeneous: large companies and SMEs, heavy industry and consumers with moderate consumption needs, research institutions and engineering firms. This composition is useful in that similar issues arise on different scales – these can be viewed from different perspectives and resolved by working together. Close cooperation between big industry, SMEs and research institutes also helps to create the financial and organisational prerequisites for developing new approaches, which can then be translated into practice. Only then can the funding injected have the intended effect on the energy and climate balance.

Fig. 3.9: Percentage of energy costs of gross value added in selected manufacturing industries



Source: Federal Statistical Office [2]

The preferred funding approach, from an organisational perspective, involves providing pro rata funding in the form of co-financed collaborative projects in which suitable partners, generally from industry and the research sector, work together. This approach ensures a high standard of work and the broadest possible implementation of any findings. Funding of demonstration and pilot facilities is also an option.

Communication between the numerous target groups of the research programme and the policy makers is facilitated by status seminars and workshops. These take place at sporadic intervals on specific topics, thereby offering a flexible platform for exchanging ideas and for informing political decision-makers. In addition, system analysis results are incorporated into any decisions made [3].

Through its funding of technology, the "Energy efficiency in industry, crafts, trade and services" support programme is also greatly enhancing the global positioning of German companies by helping them to improve their existing technological edge. The particularly high percentage of SMEs in this area (some 20 percent of funding is granted to companies with fewer than 250 employees) is the direct result of a funding policy that has been systematically targeted at the SME sector.

Key strategic funding areas

Future funding measures will focus on four key areas:

- **Reducing the energy used in processes** by developing and deploying new procedures and materials in energy-intensive industries
- **Optimising existing processes** by adapting process parameters, substituting operational materials, using new or enhanced components, and reorganising
- **Efficient use of electrical energy** on the consumption side but also in the decentralised generation of electricity
- **Cross-sectoral issues** on the efficient use of electricity, waste heat and cross-process energy management

The following section summarises additional areas to be covered by the future funding policy.

Measures in energy-intensive industries are particularly important. The following areas will be examined in conjunction with basic research:

- Innovative developments in thermal processing technology (particularly in the iron, steel, non-ferrous metal, ceramics, cement and glass industries)
- Energy-efficient chemical process engineering (including the processing of plastics and rubber), optimisation of reactor technology and process chemicals, streamlining of the process chain
- Energy-efficient manufacturing technology (machine tools, metal forming and forming technology, improved and streamlined processes, surface technology)
- Improved process engineering in the food and beverage industry and in the textile and paper industry
- Innovative treatment technologies for residues, wastes, water and emissions

The following topics are relevant to increasing **efficiency in handling electrical energy:**

- High-efficiency electric motors
- Electrical systems engineering and industrial robot engineering
- Optimisation of heating and cooling by electricity
- Efficient electrical household appliances
- Temporary electrical storage systems for specific industrial applications
- New system, generator and thermoelectric concepts for efficient, decentralised low-power (up to approx. 10 MW) electricity generation
- New technologies in and applications of high-temperature superconductivity, such as, conductors, generators, motors, current limiters and other switching elements, induction furnaces.

At cross-industry level, the following topics are to the fore:

- New technologies to utilise waste heat (high-temperature heat pumps, heat storage systems, ORC)

- New approaches to using substitute fuels (process gas, for example)
- Innovations in instrumentation, control and automation to optimise processes
- New methods of shredding, agglomeration, separation, classification and sorting
- Heating and cooling using compression, adsorption and absorption
- Energy- and demand-side management systems
- Drive technology and mechanical power transmission (engine concepts for stationary applications, optimised industrial motors, transmission technologies)
- Energy efficiency through material efficiency (efficient use of materials, closed loop recycling, strategies for lightweight construction)

References:

[1] BMWi, Gesamtausgabe Energiedaten, 2011
[2] Federal Statistical Office, GENESIS database, statistics 42251
[3] Wietschel et al., Energietechnologien 2050 – Schwerpunkte für Forschung und Entwicklung, Fraunhofer Verlag, 2010
[4] Wirtschaftsvereinigung Stahl, Statistisches Jahrbuch der Stahlindustrie 2009/2010, Verlag Stahleisen GmbH, 2010

3.1.4 Energy storage for stationary and mobile applications

Background and current energy status

As structural changes in the generation of electrical energy emerge, there will be increased demand for storage capacity in the medium to long term. One currently available and economically viable option is pumped hydro technology. Alternative technologies, such as high-efficiency compressed air storage systems are still in the early stages of development.

Lithium-based **electrochemical storage systems** are currently classified as forward-looking technology options for use in hybrid or fully electrically operated vehicles. In line with the targets set by the "National Platform for Electric Mobility", the Federal Government is aiming to have one million electric vehicles on German roads by 2020. In the long term, electrochemical storage technologies will also be able to support the grid. Existing electrochemical storage technologies do not meet the technical and economical requirements necessary for both applications.

Thermal storage technologies are deployed in the energy conversion and energy supply sectors and in all sectors of energy end-use. They represent an important element for the continued rise in energy efficiency and contribute significantly to optimising energy supply systems (CHP systems).

Chemical storage systems, based on hydrogen for example, are an increasingly attractive alternative to conventional fuels, due to the expected scarcity and subsequent increased cost of primary energy sources.

Considerable research and development is required before any of these technologies can be successfully implemented.

Technological development and funding structure

Until a few years ago, research funding for energy storage systems was not a key priority for the energy research programme. One reason was that there was comparatively little need for electricity storage systems to balance the grid and, in the case of electrochemical storage technology, no major breakthrough had been observed.

The situation has changed drastically in recent years. The need for storage systems in the grid will increase in the coming years and new lithium-ion technologies look like promising contenders for use in electric mobility, thanks to their comparatively high energy and power density.

Energy storage covers a broad technology and application spectrum and the technological developments are extremely varied. For this reason, many of the activities aimed at developing stationary energy storage systems are conducted as part of the "Energy Storage Funding Initiative" formulated jointly by the Federal Ministry of Economics and Technology (BMWi), the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and the Federal Ministry of Education and Research (BMBF). The priorities and specific topics involved are already covered in the announcement of this initiative (see chapter 2.1). These apply to the overall energy research programme, irrespective of the duration of the joint initiative, and are assigned to the participating ministries in accordance with their defined responsibilities. The Federal Ministry of Economics and Technology's funding covers applied research, development and the demonstration of systems without any direct connection to renewable energy (see 4.7 in this regard). The research and development measures outlined in the following sections can only be cited as examples and focus mainly on mobile applications. These are not covered by the previously named joint funding initiatives.

Key strategic funding areas

Electrical storage

The main aim of research and development measures for all electrical storage technologies is to increase power and energy density while reducing costs. In the case of electrochemical storage, the focus is also on improving battery cycle stability.

Among the technologies designed to balance and stabilise the electricity grids, adiabatic compressed-air energy storage, flywheel energy storage and superconducting magnetic energy storage systems (SMES) are at the forefront of research. Electrochemical double layer capacitors have been developed for devices that need a large amount of power for a short period, but have comparatively low energy requirements overall. Electrochemical storage systems, particularly those based on lithium technology, will be developed for use in vehicles in the short to medium term. Germany needs to catch up on the advances made by Asian companies and research institutes in developing technologies in this field.

Examples of prioritised activities receiving funding in the "Electric mobility" area are:

- → Further advances in battery development
- → Developing complete battery systems using cost-effective manufacturing processes
- → Establishing and developing suitable infrastructure for accelerating research and development

The scope of research and development topics relating to mobile usage has been extracted from the report produced by the National Platform for Electric Mobility. Under a special Energy and Climate Fund budgetary item dedicated to measures for developing electric mobility, the Federal Ministry of Economics and Technology supports concepts and projects that can be grouped under its energy research programme. These concepts and projects are listed under the heading "Key elements of electric mobility in the energy sector".

Chemical storage

The importance of chemical energy sources that can be easily stored will grow in the years ahead. Some technologies are already available for producing hydrogen: these must be scaled up and their efficiency improved. Likewise, the efficiency of all conversion technology processes must be optimised. Another key objective is to keep conversion technology costs low and thus meet the requirement for affordable energy prices. The focus will therefore be on testing the entire chain involved in the generation, storage and use of chemical storage technologies, including an investigation of the challenges posed by geological storage options.

Thermal storage

Thermal storage technologies will play a much more vital role in the future, particularly in helping to reduce the demand for energy in buildings and increasing the efficiency of the overall energy system. Once heat can be stored at a high temperature, the storage technologies can also be used in power plants or in industrial applications. The main objectives in this area are to increase storage density and cycle stability and also to drive down manufacturing costs. In principle, a wide variety of materials are suitable for thermal storage and the technology offers a vast range of applications. Examples of the funding are the development of thermal storage technologies for high temperatures to store heat in power plants or in industrial processes. Questions regarding energy storage in buildings are covered under the relevant funding areas (see sections 3.1.1 and 3.1.2).

3.1.5 Grids for future electricity supply

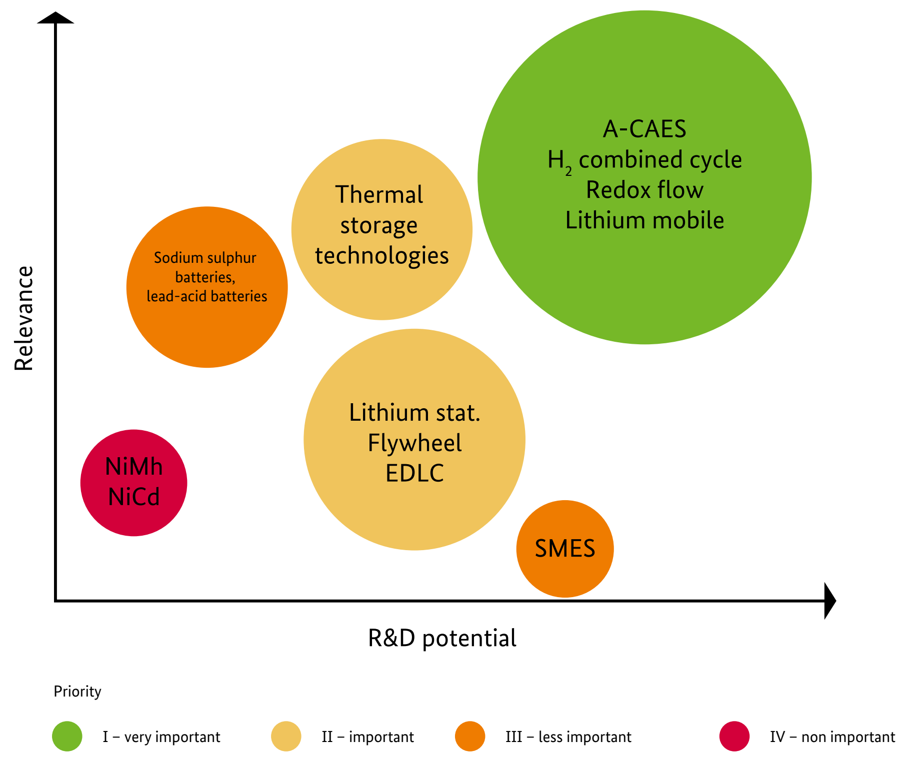
Background and current electrical grid status

Technologies designed to transmit and distribute electrical energy typically have high investment costs and very long payback periods. The existing grid architecture is characterised by an unidirectional power flow from the ultra-high voltage level via the medium voltage level to the distribution grid level. Uncontrollable loads are usually represented by the consumers of electrical energy.

Moreover, the structure of the electrical energy supply will change significantly in the coming decades. The continued expansion in alternative energy, particularly in the area of offshore wind, will result in electricity generation becoming largely decoupled from electricity consumption (see Fig. 3.11, p. 40) on the one hand. On the other hand, the trend towards decentralisation of electricity generation will continue as a result of the significant increase in photovoltaic and combined heat and power (CHP) generation plants. Furthermore, the transmission of electrical energy through Germany will rise significantly in the coming years due to Germany's geographical position in Europe. Finally, a significant increase in the number of local generators is emerging in low-voltage networks.

This changing supply structure and the increased trading of electricity in Europe will have a crucial impact both on capacity and on the organisational and technological structure of the grid. Strong fluctuations in the electricity production structure will intensify the need to adapt the energy supply to demand. To cope with emerging critical situations, the installation of a modern and powerful grid will have to be accelerated. However, improved grid intelligence, i.e. advanced integration and use of modern information and communications technology to optimise the entire system ("smart grids"), is also urgently required to guarantee optimum management of electricity producers, consumers (with respect to load management, i.e. specifi-

Fig. 3.10: Research potential of relevant energy storage technologies



cally controlling demand behaviour in industry, trade and private households – "demand side management"), the grid itself and the electricity storage systems for which demand will increase considerably in the years ahead (see also chapters 2.2, 3.1.4 and 4.7). Furthermore, consideration will have to be given to the increasing electrification of vehicles because of the introduction of plug-in hybrids (PHEV) and fully electric vehicles (EV) that will be charged from the grid.

In the new energy research programme, part of the research focus will be on developing new technologies for the electricity grid. The main objectives of the programme are below:

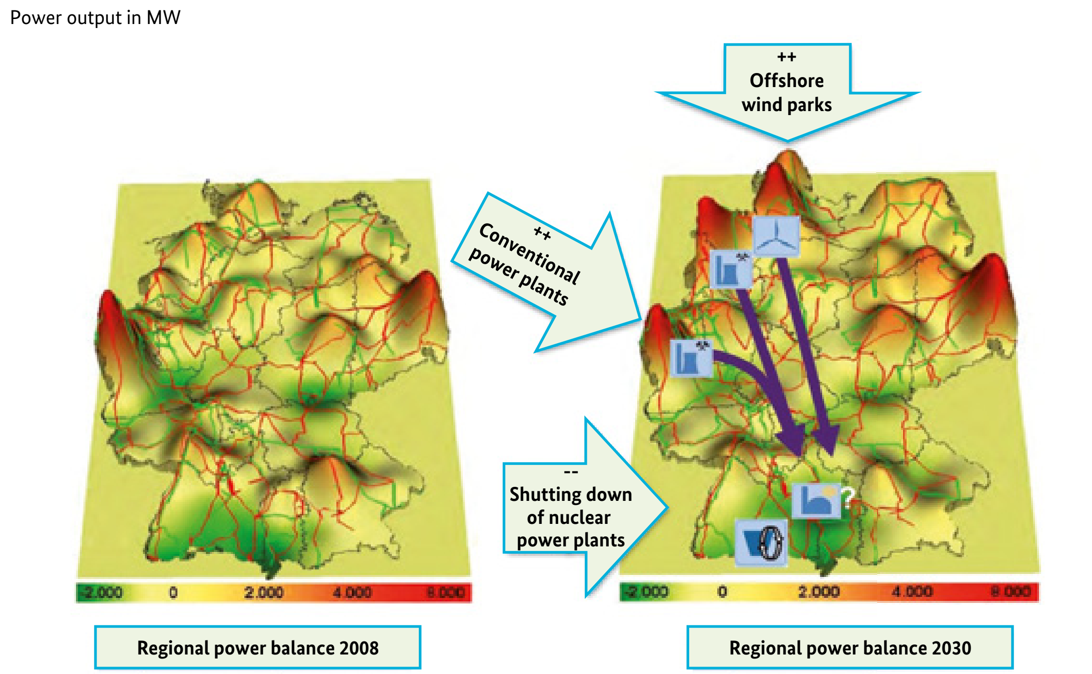
- Accelerating research and development is important to provide the maximum number of innovative, technologically sophisticated solutions to come along with the extensive and long-term investment allocated for this purpose.
- Increasing trans-European exchange of electrical energy calls for greater harmonisation of regulatory frameworks. Technological standards and protocols also need to be defined and elaborated.
- During the transition from old to new grid structures, security and quality of supply that is compatible with current standards must be maintained.

Technological developments and funding structure

From 1980 up to a few years ago, minor or no national funding was provided for R&D in new technologies relating to the transmission and distribution of electrical energy. This is because the economic and technological risks associated with electricity production technologies were low compared with the electricity generation and the Federal Government therefore had no interest in funding this type of research at that time. However, factors including the liberalisation of the energy industry, the effective separation of electricity production, its transmission/distribution as well as the growth in renewables have prompted a re-evaluation of the risks associated with R&D. Securing the reliable distribution of electrical energy is once again a matter of priority for the Federal Government.

The Federal Ministry of Economics and Technology and the Federal Ministry for the Environment, Nature

Fig. 3.11: "Regional power balance" – Further expansion of the grid will be required as increased numbers of conventional power plants (and wind parks in the future) are located at remote distances from the end consumer.



Source: Amprion

Conservation and Nuclear Safety launched the "E-Energy" funding programme in 2007. This funding scheme aims at creating intelligent energy systems ("smart grids") using information and communications technology. The Federal Ministry of Economics and Technology's funding programme, "Netze für die Stromversorgung der Zukunft" (Grids for future electricity supply), launched in 2010, included for the first time the entire system of transmission, distribution and use of electrical energy. The research funding for adapting the grid to handle higher levels of renewable energy has been provided as part of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety's "Integration of renewable energy and renewable energy supply systems" research programme (see chapter 4.7).

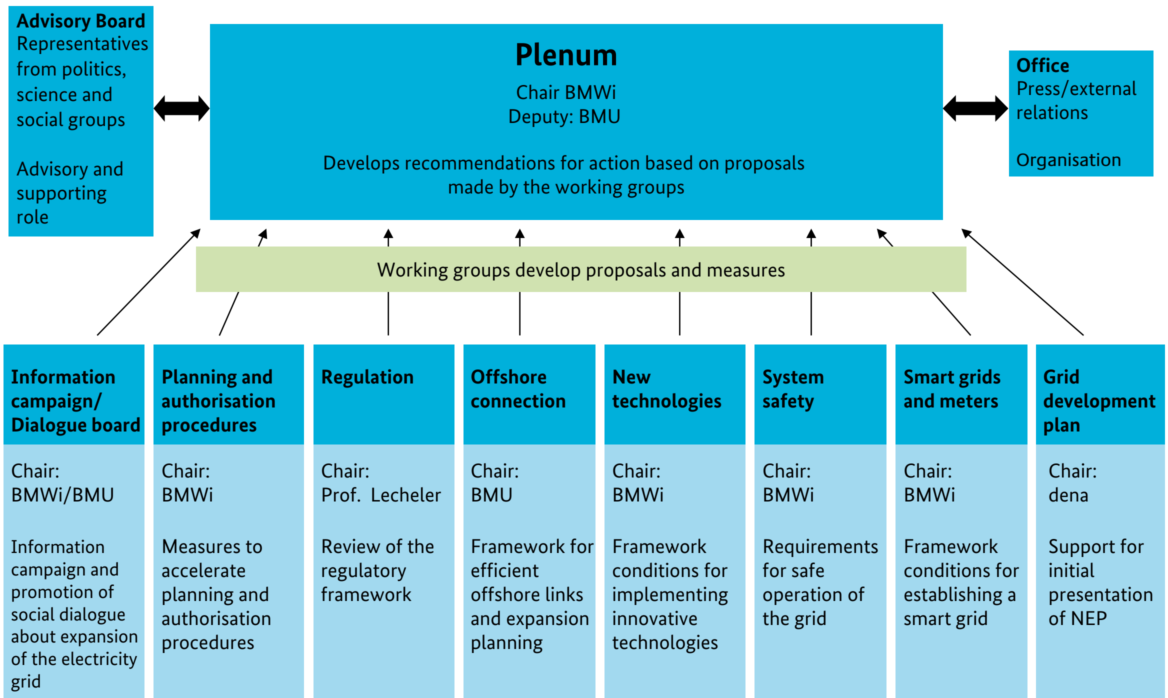
The Federal Ministry of Economics and Technology established the "Zukunftsfähige Energienetze" platform ("Future-oriented grids" platform) to address the urgent issues associated with future grid infrastructures (see Fig. 3.12).

The key stakeholders – grid operators, national and regional institutions and associations – use this platform to work together to find solutions to the expansion and modernisation of the grid. The work of the "Future-oriented grids" platform is conducted in the plenum, which meets regularly, and in working groups that deal with specific topics. In addition, the platform's "New technologies" working group coordinates funding measures and determines R&D priorities. Research funding in the area of "electricity grids" covers a broad range of aspects, including basic research, the development of components, the integration of renewable energy into the grid and modelling of the overall system design. One of the funding initiatives ("electricity grids"), formulated jointly by the participating government ministries, is intended to include the entire value chain (see chapter 2).

Another aspect covered by the energy research programme is the research and development involved in integrating electric vehicles into the grid. This aspect will be included in the energy research programme under the heading "Key elements of electric mobility in the energy sector". The relevant projects for integrating electric vehicles into the grid could also be funded from the Federal Ministry of Economics and Technology's "R&D electric mobility" budgetary item.

Restructuring the transmission, distribution and use of electrical energy is of particular importance to the European Single Market and the European political

Fig. 3.12: "Future-oriented grids" platform



Source: BMWi

system, especially given increased electricity trading across national borders. The European Commission has placed a particular focus on this issue as part of its Strategic Energy Technology Plan (SET Plan). It is therefore imperative that the R&D objectives outlined here are closely aligned with European objectives, more so than in many other technology fields. Cross-border projects are essential, particularly with regard to implementing pilot applications: this work has implications at pan-European level. The actual cooperation will take place under the EU industry initiative *“Electricity Grid” (European Electricity Grid Initiative – EEGI)* in the SET Plan.

In 2010, the *Clean Energy Ministerial* set up the *International Smart Grid Action Network (ISGAN).* The day-to-day detail carried out by this network is conducted as part of the IEA’s ISGAN Implementing Agreement for a Co-Operative Programme on Smart Grids. Germany joined this Implementing Agreement. It acts as a vehicle for international cooperation, in addition to other IEA activities.

Key strategic funding areas

As a priority funding area, the topic “Grids for future electricity supply” covers a broad range of fields due to the complexity of the overall system. Of particular importance are the R&D activities below:

High-voltage direct current (HVDC) electric power transmission, primary components for transmission and distribution grids

HVDC technology is already used throughout the world for power transmission over long distances. HVDC technology is flagged as a high-potential technology that will play a key role as the energy sector develops in Europe, with the increasing trade and exchange of electricity. R&D challenges are emerging as a result of increased interconnections between DC networks and the necessary compatibility with existing AC structures.

In addition to HVDC technology, other technology and component developments are important for the efficiency, economic viability and acceptance of the overall system. To upgrade the grid, overlay networks and grid regulators are important for increasing network capacities and improving their stability at all voltage levels.

Examples of urgent R&D tasks include:

- → Developing VPE cables for three-phase current and direct current, fittings for voltages in excess of 500 kV, DC switches
- → Ensuring system compatibility of HVDC point-to-point connections
- → Increasing power of HVDC systems using advanced voltage converters
- → Investigation and development of a dynamic European network based on (combined) AC/DC technologies
- → Developing overhead power line equipment, e.g. masts, with small electric and magnetic fields
- → Design and evaluation of power line cables with greater transport capacity
- → Investigating new materials and their applications for primary grid components, insulation materials, nano and composite materials and superconducting materials
- → Developing superconducting components such as cables, current limiters, etc.

Modelling, design and monitoring

Advanced tools that can be deployed for a broad range of applications and allow for compatibility with AC and DC networks are urgently needed for the detailed planning of future grid structures. They are also essential for the further development, operation and maintenance of the existing grid. Due to the rising volatility of the production structure and the associated increased loading on the grid, the development of methods and procedures for monitoring, managing and controlling the entire grid structure – from the ultra-high voltage level to the low voltage distribution level – will play an important role. These methods and procedures will enable the reliability, security and quality of supply to be maintained or increased compared to the current grid structure.

The following R&D tasks are a priority:

- → Designing a trans-European grid by 2050
- → Producing power flow calculations with an overlay network with ultra-high voltage
- → Studies on system stability to protect system com-

ponents, particularly following the integration of new technologies

- Developing information technology and systems to enhance network integration and potentially manage equipment and grid customers in an effort to control volatile grid loading.

- Developing innovative, dynamic voltage management strategies (including interacting components) for distribution grids

Demonstration activities

Since the failure of individual components in the overall electricity grid can have an effect not only at local and regional level but also throughout Europe, the demands on new technologies are very high when first used. Demonstration of new components, equipment, methods and procedures is therefore significantly more important than in other technology areas. Existing test facilities therefore need to be developed and expanded. Possible application fields for demonstration actions are:

- Construction of a longer HVDC or AC/DC hybrid test facilities

- Analysis and demonstration of a cross-electrical grid communication network for real-time transmission

- Qualification of superconducting components (for demonstration purposes before their grid integration)

System analyses

System analysis studies are crucial, particularly given the long-term nature of the investments involved and periods of operation, high expectations in terms of safety and reliability and the acceptance of new investments. The following items are examples of possible topics:

- Redesign of the power supply system over an extended time frame

- Environmental comparisons: cables, overhead lines

- Acceptance of new technologies and investments for transmission grid upgrades

Focus on future supply needs

The dramatically changing supply situation will pose new challenges in the future, both for the equipment and components used in the electrical network and for the operation and further development of electricity grids. As a result, the R&D sector is under severe pressure to meet these challenges with the necessary new and innovative equipment and approaches. The following aspects can be identified for example:

- New management and control strategies to increase energy efficiency and ensure the long-term protection of investment in the grid

- Intelligent primary and secondary technology (incorporating information and communications technology, for example)

- New concepts and innovative technical components for grid management, in particular incorporating existing or required quality standards

- Holistic strategies for designing, developing, operating and maintaining distribution grids (for example, taking into account load management strategies and the integration of an increasing number of electric vehicles)

3.1.6 Power plant technology and CCS technologies

Background and current energy status

Fossil fuels (coal, oil and gas) form the cornerstone of the electricity and energy supply in Germany and throughout the world. As far as their future role in the generation of electricity is concerned, a distinction must be made between the targets that are defined in Germany and forecasts for global trends.

According to information provided by the International Energy Agency (IEA) (IEA)[8], 13,680 TWh of electricity were produced worldwide from coal, oil and gas in 2008, accounting for 67 percent of total electricity production. In the European Union, 55 percent or 1,831 TWh, of electricity produced was generated from fossil fuels. The IEA forecasts an increase in the use of fossil fuels in global electricity production by 2035. Provided that the international community implements its long-term energy and climate policy objectives announced in mid-2010 ("New Policy Scenario"), this figure would rise globally to 19,278 TWh, representing a share of 54 percent of the electricity generated. The European Union's contribution would correspond to 1,348 TWh, a share of 35 percent. If the international measures are not implemented and the status quo is maintained ("Current Policy Scenario"), the generation of electricity from fossil fuels would rise sharply throughout the world by 2035 and account for 25,403 TWh, or 67 percent, of the electricity produced. Europe's contribution would rise to 1,886 TWh, accounting for 47 percent of total electricity generated. The generation of electricity from fossil fuels would therefore increase worldwide by 86 percent compared to 2008 figures.

A different picture emerges in Germany. In 2010, 356 TWh of electricity were generated from fossil fuels. This is almost exactly equivalent to the annual average recorded each year since reunification in 1990. This figure represents 57 percent of total electricity production. By 2050, the aim is to reduce overall electricity consumption by 25 percent compared to 2008 figures and for fossil fuels to account for a maximum of 20 percent of gross electricity consumption. This will mean a considerable cut in energy production in Germany, which must resist global trends, particularly those prevailing in developing and newly industrialised countries.

These differing trends in Germany and throughout the world will affect the development of advanced power plant technologies and the erection of modern power plants in the coming years. In Germany, the construction of power plants and the manufacture of components are crucial in terms of industrial policy. Both sectors are building on a modern infrastructure, can benefit from numerous innovative and, in some cases, highly specialised SMEs and together create a large number of skilled jobs in Germany. These sectors are traditionally largely export-oriented. For example, 80 percent of all turbomachinery manufactured in Germany is destined for export. Global market share increased from approximately 15 percent to more than 30 percent over the last 25 years.[1] This success is the result of a long-term, goal-oriented research and development strategy, which can draw on an established research infrastructure in the universities, research centres and industry. For example, the electrical efficiency of gas turbines has increased from roughly 30 percent at the start of the 1980s to almost 40 percent today. Linking the gas and steam process has enabled electrical efficiencies of 60 percent.

In the future development of modern power plant technology in Germany, the following considerations should be borne in mind:

→ Forecasts indicate that, by 2020, gas, coal and nuclear power plants will provide over 80 percent of the guaranteed capacity required to cover peak loads in Germany.[6] Given the rising volatility in electricity production, the entire fleet of fossil-fired power plants will have to be deployed in future to balance the supply-dependent production of renewables and to stabilise the operation of the grid.[7] Fossil-fired power plants will face entirely new challenges with regard to load flexibility and operation. At the same time, the potential of other load-balancing technologies such as smart grids, storage systems and decentralised electricity production will deserve consideration.

→ Most of Germany's power plants have reached the end of their service life and are due to be replaced. However, old plants are remaining in operation for longer as investment in modern, high-efficiency and low-emission power plants is hampered by an uncertain market environment, lengthy authorisation procedures and a lack of acceptance among consumers. The construction of additional innovative conventional power plants will continue to be necessary in Germany.

→ Outside of Germany, the market for power plant technologies will continue to expand. Developments in Germany will therefore also be relevant for European and international markets. Greater international cooperation in research and development is also underway. This relates in particular to the sequestration and storage of CO_2 (CCS: Carbon Capture and Storage).

→ Germany's research infrastructure, in which stakeholders from business and science work together, has expanded over the decades. Universities, non-university research institutes and companies based in the energy industry and plant construction sector work together on research projects. Thanks to targeted state funding, the required leverage is achieved. The financial involvement of the business community creates incentives so that the results can be applied sooner rather than later.

Technology development and funding structure

The "Power plant technology and CCS technologies" funding area can build on the Federal Government's existing funding structures and strategies. As early as 2003, a comprehensive and long-term development strategy for future power plants was developed jointly with stakeholders from business and science as part of the Federal Ministry of Economics and Technology's COORETEC R&D initiative. (COORETEC stands for CO_2 reduction technologies.) [4] The strategy was updated in 2007 with the publication of the "COORETEC Lighthouse Concept" [5].

The following strategic objectives will be pursued in the coming years:

- **Optimising system integration of power plant processes:** On the one hand, increasingly wide-ranging power plant processes (coal drying, CCS, linking with industrial processes) require optimisation. On the other hand, integrating power plant processes into the energy supply system (power grids, storage systems, decentralised electricity production and so on) presents particular challenges. Balancing the increasingly volatile share of electricity production is therefore of the utmost importance.

- **Making power plant processes more flexible:** The key challenges here are improvements in load-follow flexibility in plants, components and processes, fast load changes, short ramp-up times, a high number of load cycles with minimum wear, the provision of balancing power and the enhancement of fuel flexibility.

- **Increasing efficiency:** This area focuses on the huge potential for increasing the efficiency of power plants at component and process level. In particular, it addresses the increase in steam temperatures and pressures and the relevant studies required on materials, material qualification, new welding and joining technology and material testing methods.

- **Reducing emissions:** The priority here is to reduce carbonemissions using CCS technologies and examine the potential use of carbon in the chemical industry for example. Reducing other environment-relevant emissions is another area of interest.

- **Developing new technology options:** Procedures that are not yet considered standard but that show high potential must be explored.

Collaborative research projects involving both the business and the science community are at the heart of the Federal Government's funding policy. Where possible, existing and planned pilot and demonstration projects are incorporated into the development strategy and supported by the relevant accompanying research. The funding measures are also intended to take into account European funding activities.

The activities pursued under the COORETEC initiative are supported by an Advisory Council consisting of representatives from business, science and politics. This Advisory Council formulates research strategy recommendations and monitors research progress. In addition to the national research projects, consideration is also given to European and international activities.

The COORETEC initiative is subdivided into four subject-based working groups (WG).) Working group 4 integrates the carbon storage projects initiated as part of the Federal Ministry of Education and Research's "GEOTECHNOLOGIEN Programm" to ensure that an optimum exchange of information about the ongoing work takes place. The working groups serve as platforms for providing information about current research at workshops and status seminars and for discussing new ideas with potential partners. Joint status seminars for projects funded by the Federal Ministry of Education and Research and the Federal Ministry of Economics and Technology are conducted by WG 4. This process has proven very successful.

In addition to the COORETEC working groups, which focus on the development and optimisation of the relevant **processes,** the "AG Turbo" addresses the **development of components** in the area of turbomachinery. As an association of turbomachinery manufacturers, universities and research institutions, the "AG Turbo" is currently continuing its successful work of recent years.

Key strategic funding areas

Future measures adopted for the "Power plant technology and CCS technologies" funding area will be based on recommendations made by experts [2, 3], including the COORETEC Advisory Council. They will concentrate on the following priorities:

- **Steam power plants:** Materials research and development of joining and manufacturing technologies designed to produce steam temperatures of 700 °C and pressures of up to 350 bar; qualification of new materials in long-term experiments lasting 30,000+ hours; improved understanding of microstructures and long-term stability; models for optimising service life and maintenance strategies; new testing methods for thick-walled components; combustion systems that can use a variety of fuels.

- **Gas turbines and combined cycle power plants:** Efficient cooling concepts and innovative thermal barrier coatings (such as nanostructured thermal barrier coatings) designed to achieve turbine inlet temperatures of over 1,500 °C; development and validation of simulation models for optimising the interaction of cooling technology and materials development; aerothermodynamic optimisation of compressors and turbines incorporating state-of-the-art numerical processes and their validation by experiment; expansion of the fuel range (particularly for hydrogen-rich gases with a view to linking them to chemical storage systems).

- **Carbon capture:** Technology-neutral research into various CCS technologies; “post-combustion” and “oxyfuel” pilot and demonstration projects with the greatest chances of success from a current perspective; incorporation of “carbonate looping”, “chemical looping” or membrane-based processes and environmental and safety-related aspects of various capturing technologies.

- **Transporting and storing carbon:** Storage in various geological formations; information systems for carbon storage systems and cap rock, safety strategies including long-term safety, large-scale monitoring procedures; risk analyses; simulation of the underground spread of carbon; effects of the additives required for carbon capture in the flow of carbon on pipelines and storage systems (corrosion, formation of carbonate, for example).

- **Proof-of-concept studies on the control and load management of power plants:** Dynamic simulations of an energy supply system with a high proportion of renewables; effects on the load flexibility of plants and components; material fatigue and studies on service life.

Other topics with an important future role are [9]:

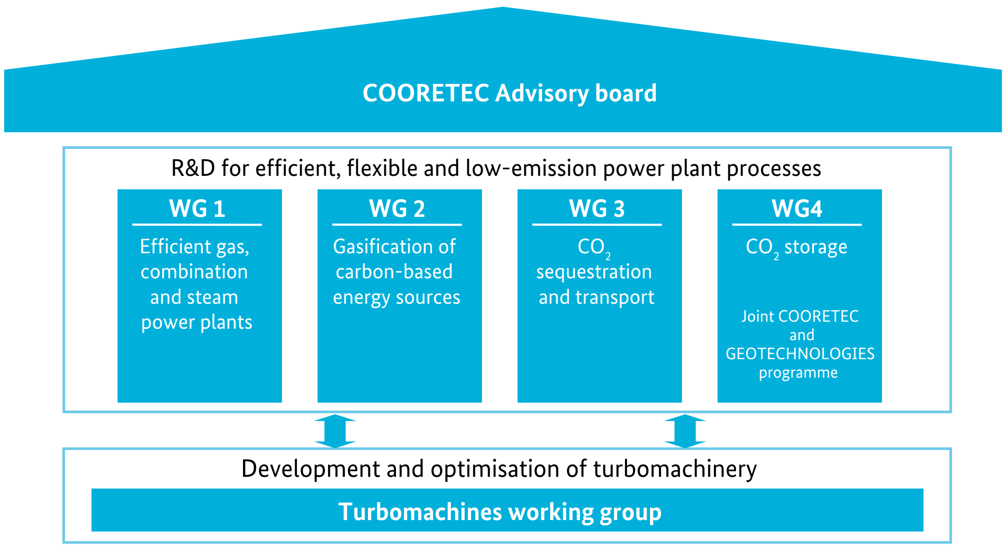
- New synthesis gas technologies (third-generation gasification technologies)

- Combined use of coal as a material and energy source

- New power electronics, superconductivity applications, electric components in power plants

- Optimisation of CO_2 compressors for CCS technologies

Fig. 3.13: COORETEC R&D framework with CO_2 storage projects under the GEOTECHNOLOGIES programme



→ Investigation of processes for using carbon (in the chemical industry, for example)

References:

[1] "AG-Turbo", 12th status seminar, Bonn, December 2010

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[3] "Empfehlungen des COORETEC-Beirates zur Förderung von Forschung und Entwicklung CO_2-emissionsarmer Kraftwerkstechnologien und CO_2-Abscheide- und Speichertechnologien", April 2009

[4] "Forschungs- und Entwicklungskonzept für emissionsarme fossil befeuerte Kraftwerke – Bericht der COORETEC-Arbeitsgruppen", BMWA documentation no. 527, December 2003

[5] "Leuchtturm COORETEC – Der Weg zum zukunftsfähigen Kraftwerk mit fossilen Brennstoffen", *("COORETEC Lighthouse Concept – The path to fossil-fired power plants for the future")*, BMWi research report 566, 2007

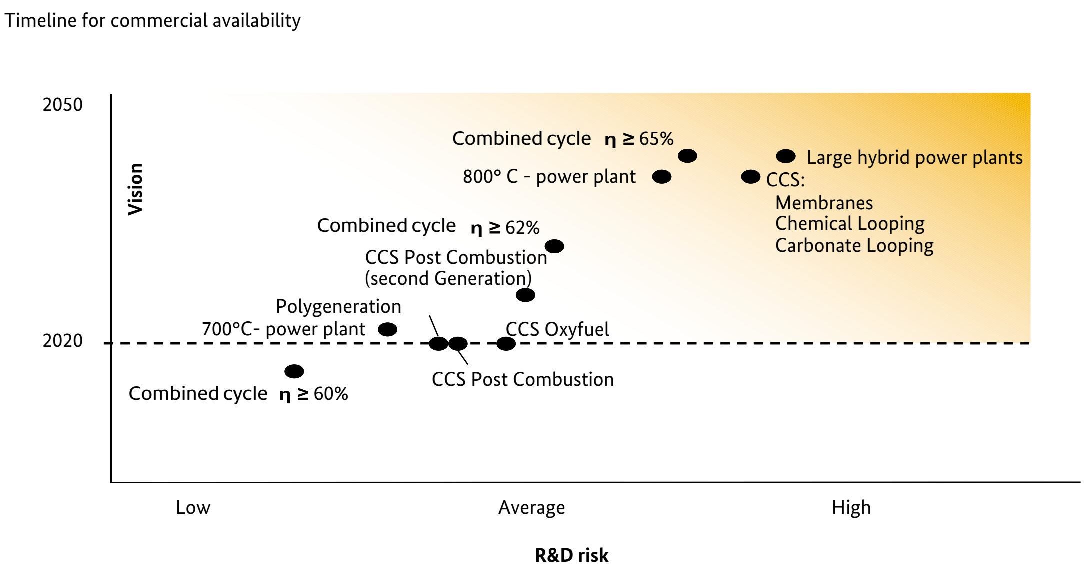
[6] "Monitoring-Bericht des BMWi zur Versorgungssicherheit im Bereich der leitungsgebundenen Versorgung mit Elektrizität", BMWi, January 2011

[7] "Technologische Anforderungen zur Bereitstellung von Ausgleichsleistung für fluktuierende Stromerzeugungsanlagen durch Lastflexibilität von kohle- und erdgasbefeuerten Kraftwerken", COORETEC Advisory Council, 2010

[8] "World Energy Outlook 2010", International Energy Agency, 2010

[9] http://www.kraftwerkforschung.info/en/research-for-a-new-generation-of-power-plants/

Fig. 3.14: Technology roadmap of selected power plant technologies [2]



Source: Birnbaum et al. 2010 [2]

3.1.7 Fuel cells and hydrogen

Background and current energy status

To achieve the reduction in primary energy requirements set out in the Federal Government's Energy Concept, the efficiency of energy supply must be improved significantly, in addition to efficiency gains in energy demand.

It will be increasingly necessary to link electricity production with the use of the heat that is usually produced simultaneously through combined heat and power generation within the energy supply system. The advantage of fuel cell technology over other technologies here is its higher electrical efficiency and high power-to-heat ratio.

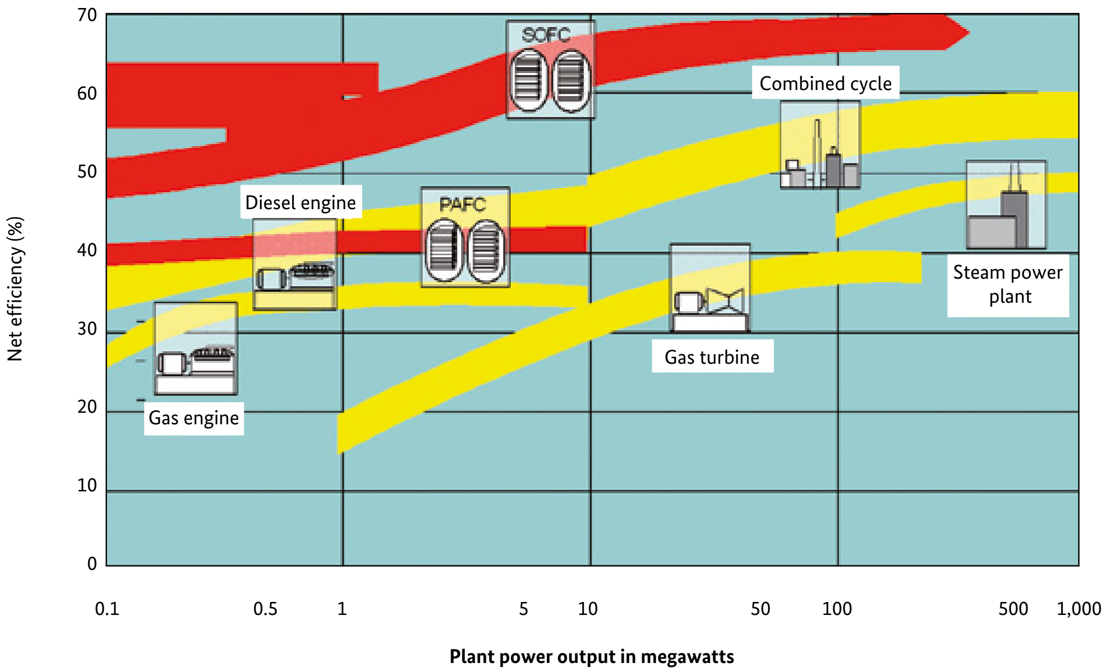
The drivetrains in almost all current motor vehicles are based on combustion engines, which have comparatively low conversion efficiency rates and are virtually 100 percent dependent on oil as an energy source. However, fossil fuel resources are finite. Increasing electrification and the switch to purely electric propulsion is offering a new alternative to oil, which will also enable fundamental efficiency gains.

Fuel cells have been developed for many years in Germany for the decentralised generation of electricity and heat and, in mobile applications, to power motor vehicles. Unlike thermal processes, fuel cell technology is not subject to the Carnot efficiency cycle (Fig. 3.15) – its efficiency is fundamentally higher. One particular advantage offered by the technology is that efficiency remains at a high level at partial loads and in small units.

Stationary fuel cells are generally used for combined heat (cooling) and power production and are now undergoing field testing as household energy systems with a power range of roughly 1 kWel and as industrial energy systems in the 300 kWel power class. A wide range of primary energy sources (such as natural gas, biogas or sewage gas) can be used as fuel.

An electric drivetrain, which is powered by a fuel cell fitted in the vehicle, and used in conjunction with hydrogen as a secondary energy source, is highly effi-

Fig. 3.15: Efficiency of selected energy technologies



Top line: future technology (development targets: gas turbines/combined cycle: 2000; SOFC: 2010)
Bottom line: current status

cient – even allowing for the energy losses incurred by the production of hydrogen. Another advantage of the fuel cell drive is that it reduces dependency on oil for mobility purposes: hydrogen can be generated from a large number of primary energy sources. If the hydrogen is produced electrolytically from carbon-reduced or carbon-free electrical energy, for example, from fossil-fired power plants using carbon capture, both local pollutants and specific emissions from climate-damaging greenhouse gases can be reduced significantly or even prevented completely. Deposited in caverns, for example, hydrogen also offers an ideal storage option for storing excess electricity supplies during periods of low demand. Reconverting the stored hydrogen using stationary fuel cells or hydrogen turbines, mixing it with natural gas or using it as a fuel are possible further options in the medium to long term perspective.

Thanks to previous funding measures, German research institutions and industrial enterprises are international leaders in the area of fuel cell and hydrogen technologies. Intensive research and development measures are needed to maintain and bolster Germany's position at the cutting edge of this technology. Generally, there are high expectations for the transfer to market of these technologies. However, these expectations are focused primarily on the rapidly expanding export market, rather than Germany's own diminishing energy market. In addition to energy policy objectives, the planned funding measures therefore also include essential industrial policy elements in relation to strengthening Germany's export prowess.

These factors also explain why the development of fuel cell technology for the specialised markets (uninterrupted power supply, special vehicles, boats, caravans, etc.) is part of the funding measures. The primary motivation for supporting these areas of application is to pave the way for their implementation in the energy sector, through qualification of technologies and series production in these particular market segments.

Technology development and funding structure

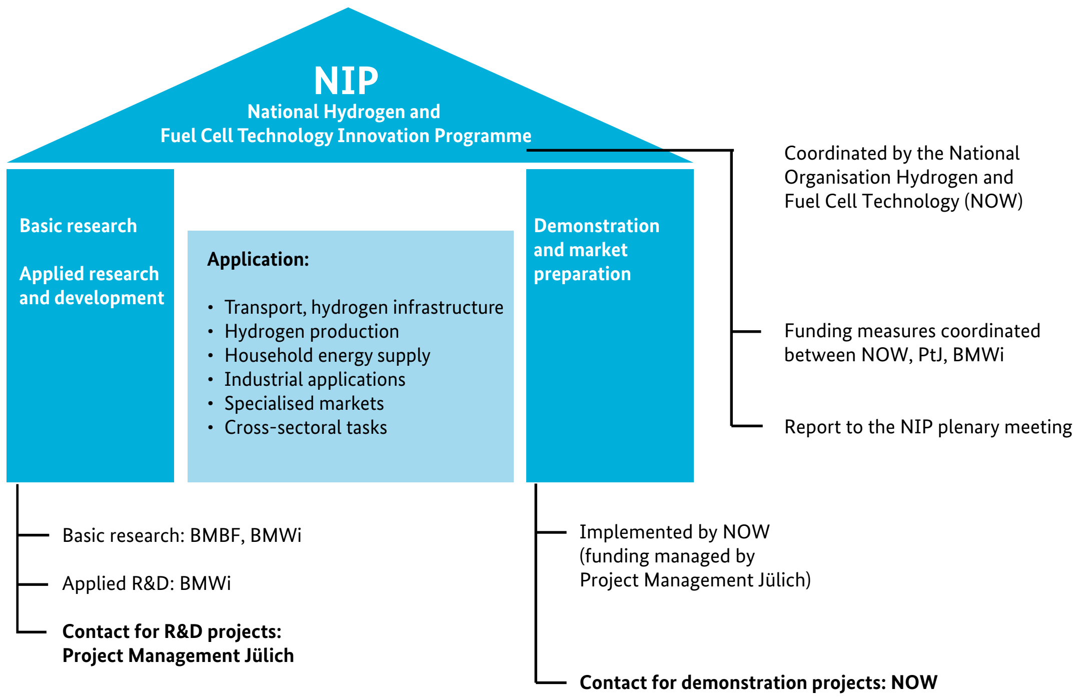
The Federal Government supports the development of fuel cell and hydrogen technologies with targeted funding provided within the framework of the "National Hydrogen and Fuel Cell Technology Innovation Programme" (NIP). This was formulated jointly by the Federal Ministry of Transport, Building and Urban Development (BMVBS), the Federal Ministry of Economics and Technology (BMWi), the Federal Ministry of Education and Research (BMBF) and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), and focused on the period between 2006 and 2016. The "National Hydrogen and Fuel Cell Technology Development Plan" (NEP) describes the NIP's programme of work and outlines the strategic framework for its implementation by 2016. The NEP is divided into the following areas of application and general cross-sectoral tasks:

- → Transport, including hydrogen infrastructure (distribution, storage and refuelling)
- → Hydrogen production
- → Household energy supply
- → Industrial applications
- → Specialised markets for fuel cells
- → Cross-sectoral tasks

The current energy research programme focuses on basic research, applied research and technological development for all areas of application mentioned here and across all cross-sectoral tasks. The timescale of the measures may extend beyond the focus period of the NIP, which covers the years between 2006 and 2016. Consequently, long-term, basic research and development will also be supported.

In addition to the above-mentioned priorities, prelaunch market strategies and measures to demonstrate hydrogen and fuel cell technologies may also be funded by the Federal Ministry of Transport, Building and Urban Development during the lifetime of the NIP (Fig. 3.16, p. 50).

Fig. 3.16: Interconnecting funding mechanisms for research, development and demonstration in the NIP



The National Organisation Hydrogen and Fuel Cell Technology (NOW) is responsible for selecting and professionally supporting the demonstration measures on behalf of the Federal Ministry of Transport, Building and Urban Development. Both the research and development measures and the demonstration measures are closely coordinated. Particular emphasis is placed on the results of the demonstration measures when selecting and funding research and development projects.

The research, development and demonstration measures are based on the contents of the European Union's *Fuel Cell and Hydrogen Joint Undertaking (FCH JU)*. Information is regularly shared and exchanged in various FCH JU committees such as the **Member State Representative Group** or the **Scientific Committee**. Apart from the IEA's established instruments, opportunities for cooperation at international level also exist within the framework of the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE).

Key strategic funding areas

The following section outlines specific funding areas relating to the above-mentioned applications. The list is not exhaustive; support may be offered to new development challenges that were not forecast when the programme was compiled.

Transport, including hydrogen infrastructure (distribution, storage and refuelling)

The automotive industry, including the automotive components industry, is one of the major industry sectors in Germany and its large research and development budget makes a vital contribution to innovative development in the country. Research and development work planned in this area includes fuel cells for vehicles (private cars and buses) and the required provision and storage of hydrogen. Research will also be carried out on vehicle power supply systems (auxiliary power units, APU) for heavy goods vehicles, aircraft and ships, for example.

Projects completed to date have made significant progress, for example, in the area of fuel cell service life and power. Impressive proof of this progress was provided in the tests conducted under the auspices of the *Clean Energy Partnership (CEP)*, a joint initiative of car manufacturers, technology producers and energy companies.

However, there is still a need for considerable further research and development activities, particularly in the area of critical components and processes, in vehicles and in infrastructure. The key objectives of these activities are to trim costs, weight and volume, increase service life and efficiency and improve operating conditions.

Under the heading of vehicles and hydrogen infrastructure, the following areas and components have priority:

- Fuel cell stacks
- Peripheral components and electric drive systems
- Hybridisation of fuel cells and battery storage systems
- Hydrogen storage for vehicles
- Full system integration
- Reforming of energy sources into hydrogen-rich gases
- Materials with reduced corrosion or hydrogen embrittlement
- Service stations and infrastructure

Hydrogen production

To date, hydrogen has assumed only a minor role as an energy carrier, although the total production volume in Germany accounts for approximately 10 percent of fuel consumption. Its potential is expected to grow in the future, driven by the need to store large quantities of electricity, through the expansion of renewables and the option of hydrogen as a fuel in the future. Research and development measures include the electrolytic production of hydrogen, the generation of hydrogen from biomass, the recovery of energy from waste material and the use of hydrogen as a by-product in industrial processes. Another area of interest is the storage of larger quantities of hydrogen in the GWh to TWh range.

Some of the specific measures that will be conducted as part of future R&D activities are:

- Development of PEM electrolysis and alkaline electrolysis for plants in the megawatt (MW) range
- Development of efficient processes for high-temperature electrolysis
- Further development of large-scale storage processes, especially caverns and metal hydrides
- Methanation/hydrogen-based fuel production
- Distribution/supply paths

Household energy supply

Simultaneously generating electricity and heat in individual houses, apartment blocks and business establishments using fuel cells allows the following: first, it is possible to achieve high overall levels of efficiency (>85 percent); second, it is possible to cut carbon emissions by 25 percent and 35 percent compared to electricity and heat supplied by conventional means. Research and development measures include systems with a power capacity ranging from 1 kWel to 5 kWel, which are to be fuelled by natural gas in the short term. It is planned to use biogas and liquid fuels in the medium term. The direct use of hydrogen is only an option in a long-term scenario.

Very high technological standards in household energy supply have already been achieved, thanks to the developments completed to date. By 2015, up to 800 plants should be installed and tested as part of the CALLUX demonstration project, a practical test initiated by partners in the energy industry and heating systems industry. The results of this field test will be systematically incorporated into the additional development work that is urgently required. This development work will continue to focus on two main challenges, namely how to improve the service life and reliability of systems and also reduce system costs and complexity. Research and development activities can be divided into the following key topics:

- Gas production
- PEM fuel cell stacks (low-temperature and high-temperature PEM)
- Solid oxide fuel cell (SOFC) stacks
- Decentralised reformers for household energy supply systems
- Improved components (bipolar plates/MEA interconnectors, membranes)

- → Adapted peripheral equipment (pumps, fans, valves, sensors)
- → Full systems (PEM and SOFC system development)

Industrial applications

Industrial applications of fuel cells generally entail combined heat and power generation (CHP) plants with a power range of between some 10 kW and a few megawatts to supply businesses and industries with energy. Electrical efficiency of over 50 percent combined with high total utilisation rates in excess of 90 percent lead to a significant reduction in resource consumption and carbon emissions compared to traditional CHP plants. Several hundred large plants with electrical outputs of more than 100 kW are in use throughout the world. In Germany, service lives of 30,000 h (MCFC) and efficiencies of up to 60 percent (SOFC) have already been recorded.

MCFC and SOFC technology has been developed in Germany primarily for industrial applications. Increasing numbers of companies involved in PEM technology, both low-temperature PEM (LTPEM) and high-temperature PEM (HTPEM), are involved in this field. Research and development measures are determined by the need to cut costs, increase reliability and service life and reduce system complexity. The objective in the industrial CHP plant segment is to achieve competitiveness compared with established technologies.

In addition to technological innovations, cost reductions can also be achieved by systematically developing manufacturing technology for series production and through economies of scale. Applications must also be identified and developed in which industrial fuel cell plants can offer added value compared to other CHP plants.

The following key R&D activities are required:

- → **MCFC technology:** Improving cell power and efficiency, increasing service life, reducing degradation, simplifying the entire system, improving components (inverters, for example), using biogenic fuels
- → **SOFC technology:** Developing planar stack technology, scaling up to units with electricity outputs of several kW with the option of grouping them together into larger plants, managing and controlling the entire system
- → Developing concepts and components for competitive manufacturing technologies for large-scale production
- → **PEM technology (LTPEM and HTPEM):** Scaling up small plants to the 100 kW or megawatt output range, optimising entire systems and components
- → Introducing hybridisation with micro gas turbines or thermoelectric generators

Specialised markets for fuel cells

Specialised markets are defined as markets for fuel cell systems in various different application fields that cannot be categorised under any of the areas already described here. These include plants for telecommunications, information technology and traffic engineering, electricity supply in the leisure industry (auxiliary power units for caravans, camping sites), logistics vehicles (fork-lift trucks, industrial trucks, lift trucks) and special vehicles or light electric vehicles.

A distinguishing feature of these areas of application is that, in some cases, high sales revenue can be generated due to the specialised nature of the market. With such potentially lucrative market opportunities, the specialised markets act as a bridge in overcoming economic barriers in the energy applications, as more narrowly defined above. Meanwhile, the wide variety of applications has given rise to a broad range of fuel cell technologies and consequently a myriad of research and development activities, which are centred around the following key issues:

- → Optimising operational management, energy management and reliability
- → Developing hydrogen supply stations and logistics/infrastructure systems
- → Developing and adapting electrolysers, hydrogen storage systems and peripheral components
- → Miniaturisation

Cross-sectoral tasks

Cross-sectoral tasks refer to general, superordinate activities that cannot be classified under the previously mentioned applications, or activities that have benefits for all applications. The following key research and development activities qualify as cross-sectoral tasks:

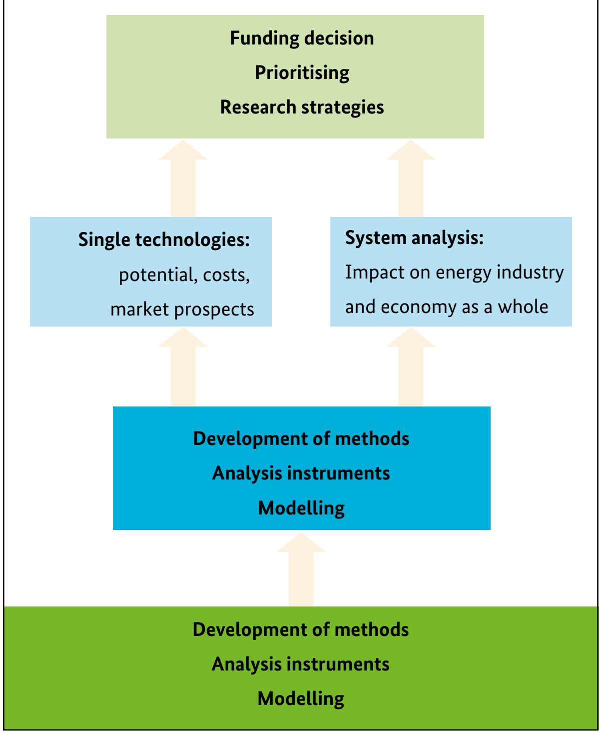
- Basic research on fuel cell and system components (for example, cutting costs by reducing or substituting platinum, innovative membrane materials or interconnectors, cost-effective bipolar plates, MEA)
- Developing and testing fuel cell components and systems independently of specific applications
- Developing methods to predict and improve the service life of fuel cells
- Developing time lapse tests
- Developing standardised test procedures/facilities to compare different fuel cell systems
- Using fuel cells in distributed systems for virtual power stations

3.1.8 System analysis and the dissemination of information

System analysis

An efficient energy research policy must be based on extensive and detailed background knowledge. This requires facts, figures and analyses that

Fig. 3.17: System analysis for optimising energy research policy



- Record the potential, costs and market opportunities of various energy technologies
- Evaluate the interaction of individual technologies or technology systems and their potential contribution to a safe, economically efficient and environmentally friendly energy supply as well as their foreseeable overall economic effects
- Support the design of research strategies, justify priorities and help make specific funding decisions
- The role of system analysis is to provide this background knowledge.

The Federal Government has access to extensive existing groundwork in the area of energy-related system analysis. Two projects launched by the Federal Ministry of Economics and Technology in recent years are particularly important:

- New approaches for defining priority funding areas have been developed as part of the “EduaR&D” (energy data and analysis R&D) project.[1]
- Working in tandem with the business community, the “Energy technologies 2050” project has compiled a comprehensive manual of facts and figures. This manual describes the current state of development and also outlines requirements for future research into key energy efficiency technologies and technologies for exploiting renewable energy sources.[2]

The Federal Ministry of Economics and Technology will build on these results in its “En:SYS – System analysis in energy research” priority funding area. It will also update and develop system analysis activities in the area of method development and technology assessment.

New initiatives are underway in the following areas and jointly implemented with other government ministries:

- **Greater integration of social science research results:** Decisions regarding the energy supply situation have a major impact on society as a whole. This must be borne in mind regarding every aspect of the use of new technologies and adapting supply structures. Energy-related projections must, for example, take account of changes in energy demand or mobility caused by demographic factors. Social aspects relating to acceptance research are also an important field of energy system analysis. This entails an understanding of acceptance processes and requires extensive and scientifically sound concomitant research on the acceptance of innovative energy technologies.

- **New approaches for modelling and scenario analysis:** Models designed to analyze complex technological and economic issues relating to energy have been developed to a very high standard in Germany. Future challenges will revolve about the specific requirements of the Federal Government's Energy Concept. This sets out, in particular, a targeted decline in energy usage in Germany within a global trend of increased energy consumption. The Energy Concept also draws attention to the learning cost curves of new technologies. Greater consideration must be given to the dynamics of the European energy market and the interaction of developments in Germany and the other member states. The aim is to establish an "Energy Model Germany 2050" that will particularly focus on both of these aspects. As regards scenario analyses, the focus is on the system modelling of potential technological and economic developments. This system modelling covers both the entire energy system as well as specific areas such as individual end-use sectors (industry, transport, households) or special supply tasks (heat, power, light, information). Scenarios can be used to map the application and integration of innovative energy supply and energy usage strategies. Analyses that address competing technologies or help resolve conflicts resulting from countervailing technology effects are especially important. This research priority also involves integrating new developments in information technology and new mathematical methods that provide greater knowledge about the complex interactions in individual energy issues.

- **Studies on adapting the energy networks:** Expanding and adapting the grid to meet future requirements is crucial. Proper grid infrastructure is essential if we are to achieve a dynamic energy carrier structure with a growing proportion of renewables, without sacrificing quality and stability. The purpose of the system analysis is to formulate advanced strategies to operate and expand the grid with the aim of increasing the efficiency of energy usage. Depending on the system's limits, these observations consider one energy source and its associated transmission and distribution system or a combination of several energy sources. The integration of thermal and electrical storage systems is vital. In the field of energy demand, for example, better use of load management options delivers benefits in the area of energy efficiency. Advanced information technology options for controlling and managing the grid *(smart metering, smart grids)* are also being examined. In conjunction with research activities relating to the development of components, assessment of individual technologies such as high voltage direct current systems, flexible alternating current transmission systems (FACTS) and applications of superconducting materials are also a possibility.

- **Greater transparency in relation to state funding policy:** Part of the Federal Ministry of Economics and Technology's Energy Concept focuses on establishing a central "Energy research and energy technologies" information system (EnArgus). The main aim of the new central information system is to ensure greater transparency surrounding the Federal Government's funding policy and good record-keeping for the parliament with regard to efficient allocation of resources. Other objectives include evaluations of energy technologies for the Federal Government's future funding policy based on department-specific evaluations. Finally, the new information system, once equipped with the appropriate add-ons, is intended to contribute to a comprehensive overview of energy research activities in Germany as a whole. No new data will be collected for the information system. Instead, existing information will be systematically compiled, analyzed and made available on an ongoing basis. The EnArgus information system supplements the existing reporting systems in this area, which also include the *"Strategic Energy Technologies Information System" (SETIS)* developed in the European context of the SET Plan. The Federal Government will unveil a "Federal Government report on energy research" based on the new information system.

Other research funding priorities emerge in the field of international cooperation. In accordance with the observations outlined in section 1.6 on German involvement in the International Energy Agency's (IEA) research programme, global cooperation is also taking place in the area of system analysis. Germany is thus participating in the "Energy Technology Systems Analysis Programme" (ETSAP) and "Energy Conservation through Energy Storage" (ECES) Implementing Agreements. The goal of these is to support energy policy decisions with systems analysis instruments and studies. To this end, the MARKAL/TIMES models are being developed as part of the ETSAP Implementing

Agreement and within the framework of ECES, storage models currently worked on by various participating countries.

Dissemination of Information (BINE Information Service)

The Federal Government fosters the presentation of results and systematic dissemination of information in the energy sector primarily through the BINE Information Service (www.bine.info) and its various **energy research portals.**

The BINE Information Service communicates practical aspects of the energy research findings on energy efficiency and renewable energy in a variety of publications aimed at different target groups. It reports on energy research projects in its brochure series and newsletter:

- The four-page **BINE-Projektinfos** (BINE project information) documents contain information on the latest results from research and demonstration projects.
- The 20-page **BINE-Themeninfos** (BINE topic information) brochures document the current status of energy research priorities.
- The **BasisEnergie** (basic energy) series provides precise and clear information about approximately 20 key issues in energy saving and renewable energy.
- **BINE-News** reports on the latest advances and results in ongoing research projects.
- The information series is supplemented by the **BINE series of specialist books.**

The BINE Information Service's expert editorial team also manages the Federal Ministry of Economics and Technology's research portals:

- www.enob.info – research on energy-optimised building
- www.eneff-stadt.info/www.eneff-waerme.info – research on energy efficient cities, including energy-efficient heating and cooling supply systems
- www.kraftwerkforschung.info – research on new power plant generations
- www.eneff-industrie.info – research on energy-efficient technologies and processes in the industry

The Federal Ministry of Economics and Technology will continue to support the dissemination of research results and thus promote the development and expansion of the information service. Its efforts will include, in particular, integrating new media and dissemination channels for information, in addition to engaging with other institutions and associations in the relevant sectors to enhance the multiplier effect. Another priority will be to promote the international transfer of information.

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[1] Forschungszentrum Jülich: Das EduaR&D-Projekt: Energie-Daten und Analysen R&D, 2009
[2] Wietschel et al.: Wietschel et al., Energietechnologien 2050 – Schwerpunkte für Forschung und Entwicklung, Fraunhofer Verlag, 2010

3.2 Nuclear safety and repository research

Background and current energy status

The nuclear power plants operated in Germany and in the EU contribute up to a quarter of the total supply of electric energy. However, when the power plants' 24-hour availability is taken into account, their actual share of the base load is considerably higher.

To achieve the ambitious climate targets set by the Federal Government and ensure a reliable electricity supply, it is planned to use nuclear energy for a limited period until it is technically and economically viable for renewable energy to take its place.

Extremely stringent safety requirements apply to the operation, decommissioning and waste disposal of nuclear power plants and research reactors, as well as to the final storage of radioactive waste. In this area, it is not just the existing state of the art of technology that counts, but also ongoing state-of-the-art developments in science and technology, in line with § 7d of the German Atomic Energy Act (Atomgesetz). Legislators have thus entrusted nuclear safety researchers with a vital role, since science and technology can only advance on foot of ongoing research and development efforts.

The objective of state reactor safety research is to ensure, as part of the provision of vital public services, independent state expertise to test, evaluate and, if necessary, further develop the safety concepts of manufacturers and operators.

Research and development in this field are continuously forging ahead and are closely interconnected at international level. The German science community has played a crucial role here. Currently, the research agenda is increasingly influenced by the following factors: first, the service lives of existing nuclear power plants worldwide are being extended and second, a new generation of nuclear power plants is either under construction or being planned in many countries, including countries adjoining Germany.

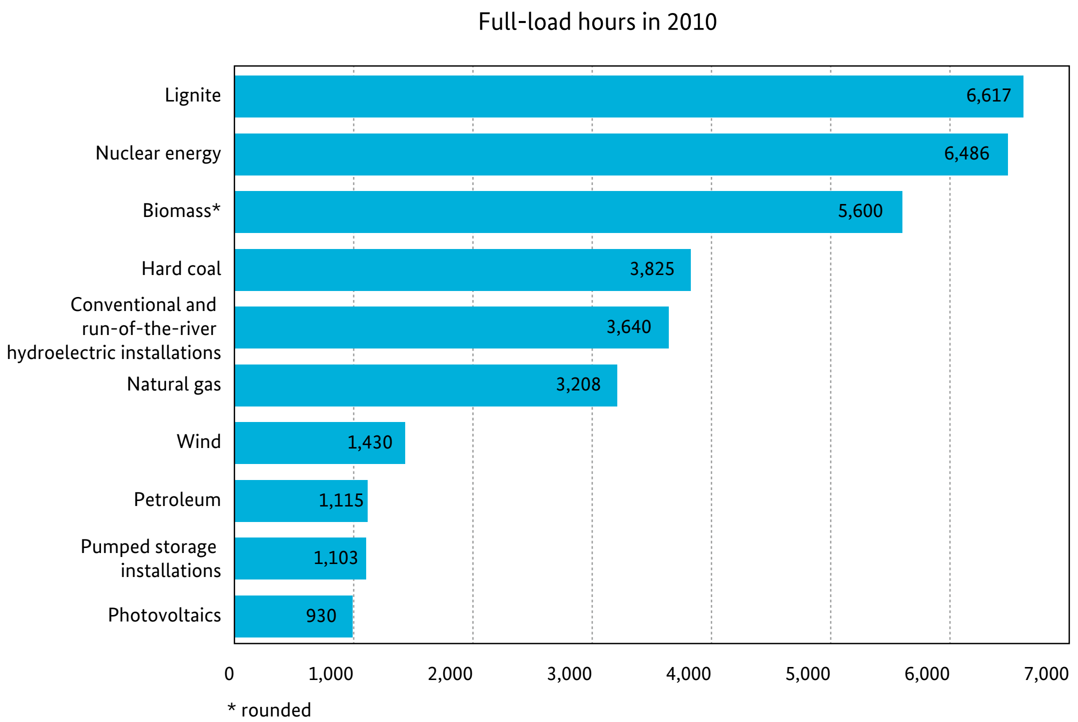
In the longer term, Germany can only continue to influence the safety standards of existing and newly designed nuclear facilities worldwide by focusing on maintaining and expanding German involvement in international research projects and cooperation with foreign partners. The necessary nuclear engineering expertise can only be acquired and maintained through independent national research. Consequently, the Federal Government must assume responsibility for acting and taking preventive measures in this area, by funding intensive research into nuclear safety.

The priority funding areas "Reactor Safety Research" and "Repository Research" of the Federal Ministry of Economics and Technology were reassessed in 2000 by an evaluation committee for "Nuclear Safety and Repository Research" appointed by the Federal Government. With dwindling financial resources and the need to maintain the effectiveness of research policy and expertise in mind, the committee made recommendations on setting research priorities and on collaboration between research establishments [1]. The recommendations issued by the evaluation committee regarding reactor safety have since been regularly updated by the Nuclear Engineering Competence Network [2, 3]. This process ensures that research activities are harmonised and efficiently carried out. The network also helps maintain and advance German expertise in nuclear safety.

3.2.1 Reactor safety research

The aim of state reactor safety research is to guarantee, as part of the provision of vital public services, inde-

Fig. 3.18: Electricity generation from various energy sources converted into full-load hours in 2010



Source: German Association of Energy and Water Industries pendent state expertise to test, evaluate and, if necessary, further develop the safety concepts of vendors and utilities. Through its support measures over the past decades, the Federal Government has helped German reactors gain a reputation as among the safest in the world. The results of these funded research activities have in turn further stimulated many other improvements in nuclear safety and promoted a stronger safety culture. As regards reactor operation, the scientific principles required to assess reactor safety must be further developed with a view to future developments and in accordance with the latest advances in science and technology.

Project-funded research on reactor safety continues to focus on R&D activities concerning the safety of reactors operated in Germany. In addition, investigations are being conducted into the safety of new nuclear power plants planned in neighbouring countries as well as the safety-related potential of innovative reactor and proper disposal concepts.

Future activities must also incorporate all safety-related aspects of the operation, decommissioning and waste disposal of nuclear reactors. These include in particular:

→ Ageing and obsolescence of components and materials as well as principles for effective ageing and obsolescence management

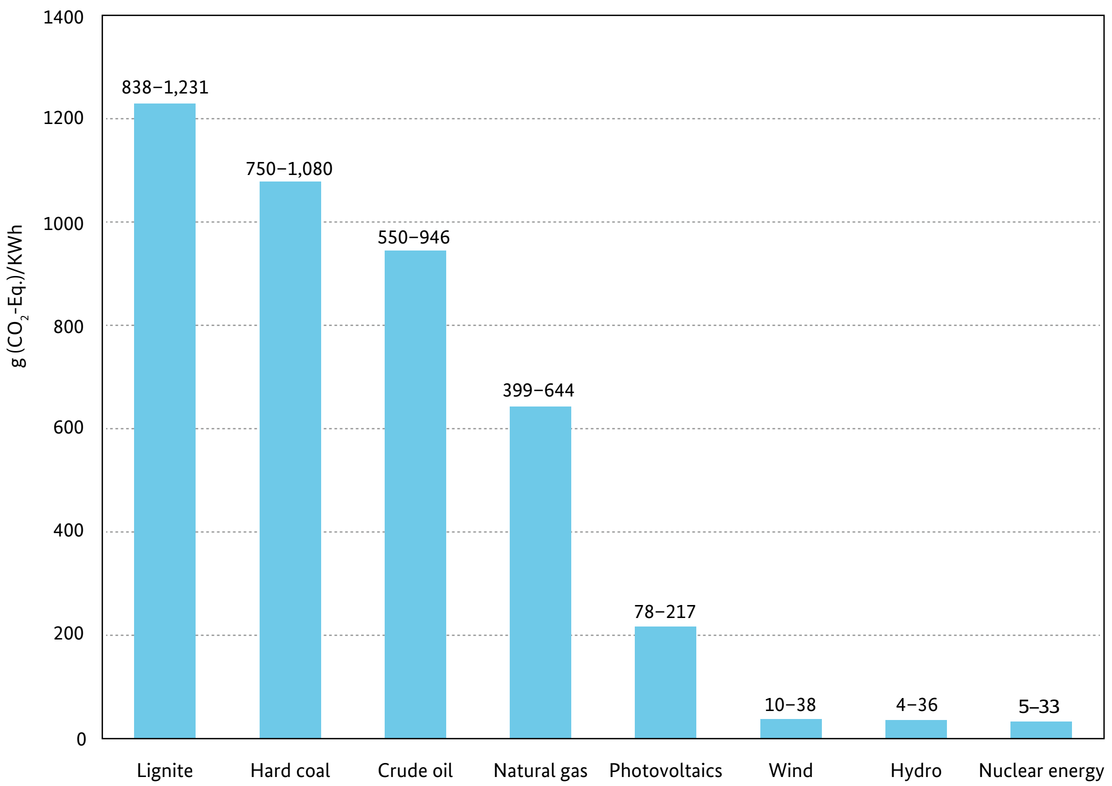
→ Realistic description of processes in the reactor core and coolant loops in the event of an accident

→ Use of advanced, more highly enriched nuclear fuels, extended service lives and increased burnup

→ Optimising the loading strategy to preserve the reactor pressure vessel and load following operation

→ Integrity of the containment structure as the final barrier against leakage of radioactive substances into the environment

Fig. 3.19: Specific CO_2 releases from various energy sources during electricity generation. The figures reflect the ranges of the values measured by the institutions mentioned.



Source: PSI (2004; 2007), ILK (2004), IER (1997; 2000), EU (2007), Öko-Institut (2006)

- Safety issues regarding the use of modern (digital) safety control and monitoring technology
- The influence of organisational and personal factors on the safety of nuclear facilities
- Probabilistic methods for improving the tools used to identify weak points in plant design and process control; reduction of the uncertainty margin in assessment.

Since many countries have either decided or are planning to extend the lifetime of reactors, the issues of ageing and ageing and obsolescence management, the nuclear core and fuel, materials, as well as the digitalisation of control technology in particular are the subject of greater attention internationally.

Over the next few years, new nuclear power plants will be installed and commissioned around the world and in Germany's immediate vicinity. Increasing numbers of these reactors will incorporate more advanced safety-related (Gen III) and innovative concepts (Gen IV) in their design, including, for example, passive i. e. inherent safety components. It is in Germany's interest to retain its capacity to evaluate and, where applicable, support these and other innovative safety features, also and in particular by participating in international research. By doing so, Germany can voice its legitimate concerns with regard to safety standards and safety-related design in new facilities, both within international committees and the larger international community. Meanwhile, the insights gained could be applied to facilities operated in Germany.

3.2.2 Repository research

The final storage of radioactive waste in deep geological formations offers decisive advantages over other waste disposal options. It takes into account the principle of concentrating and isolating the waste and its feasibility has been verified in scientific terms both nationally and internationally. A long-term and safe solution for the disposal and final storage of radioactive waste is a prerequisite for nuclear power plant operation. Although this waste disposal or final storage would theoretically be feasible today in many countries - including Germany, political and public controversy has prevented rapid implementation of these solutions. Political and public reservations about this topic include a lack of trust in the reliability of scientific findings and insufficient public involvement in decision-making processes. Since it is unlikely that final storage in a repository for highly active waste will be implemented without social consensus, the science and technology communities must intensify their efforts in this area. Long-term protection of humans and the environment is the primary objective of final storage: more research and development activities are required to this end. Further research and developments should deliver technical improvements and maintain, expand and deepen current expertise.

Future strategic research goals to be tackled by German R&D institutions, as part of the IGD-TP European technology platform, are:

- Updating the Safety Case tools and methodology
- In-depth investigations into system behaviour and the development or improvement of system descriptions
- In-depth investigations into technical feasibility and the long-term behaviour of repository components
- Measures to guarantee operational safety and for monitoring the repository system and its environment
- Governance and involvement of interested members of the general public and politicians
- Participation in international activities (component development) aimed at reducing or eliminating radioactive waste by means of partitioning and transmutation (P&T)
- Further development of nuclear material safeguards and adaptation to the conditions of direct final storage

3.2.3 International cooperation, maintaining the skill-base and retaining expertise

At present, cutting-edge analytical and experimental methods are developed and deployed in reactor safety and repository research. The findings are made available to all institutions working on nuclear safety for the further development of safety technology. German research institutions in the field of reactor safety and repository research cooperate efficiently towards set goals, thanks to the foundation of the "Nuclear Pool for Nuclear Technology" in 2000.

By making intensive use of opportunities for international collaboration and scientific exchange, the effectiveness of German research stands to improve further. German research centres are therefore expressly encouraged to participate in invitations to tender issued by the European Union (Euratom) and become involved in consortia dedicated to the following goals: first, mutually beneficial use of scientific findings; second, collaboration lasting beyond the term of the specific project and third, securing a leading role for Europe in issues of nuclear safety. This motivation also applies, in particular, to the intensive collaboration required to improve the safety of Russian-designed nuclear power plants and, increasingly, the safety of more advanced and new reactor concepts.

Measures must be taken to tackle the risk of a serious shortage of qualified young scientists and engineers in the field of nuclear technology and the consequent possible loss of expertise and skill among German public authorities, experts and research institutions. The Federal Ministry for Economics and Technology's initiative for "Maintaining Competence in Nuclear Technology" (Kompetenzerhalt Kerntechnik KEK) will therefore be continued. This initiative will give young engineering and science graduates the chance to obtain further qualifications by familiarising themselves with current issues and becoming involved in ambitious project-funded research on reactor safety. Experience has shown that the only way to attract and retain high-calibre young scientists and professionals is to offer them hands-on experience in innovative projects.

German experts participate actively in international institutions such as the International Atomic Energy Agency (IAEA), the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD), and the European Union (EU). This ensures that Germany can assume a competent and influential role in international discussions relating to safety aspects of nuclear technology.

In the OECD-NEA research projects, several countries bring together their interest in finding solutions to safety issues by sharing the cost of using internationally available test facilities. Experts from various countries discuss the planning of projects down to the technical details, steer their implementation and interpret the safety implications of the project results.

Several European and overseas states that have not yet had their own nuclear energy programmes are planning to replace fossil energy sources with more environmentally friendly nuclear energy in the future. It is in Germany's best safety interests to ensure that these countries also share the in-depth experience and high level of expertise acquired by German research institutions in the field of nuclear safety.

References:

[1] Report of the Working Group convened by the Federal Ministry of Economics and Technology (BMWi), Evaluation Commission (2000): Nuclear Reactor Safety and Repository Research in Germany

[2] Nuclear Technology Competence Pool (2003): Issues of Nuclear Safety and Repository Research in Germany 2002 – 2006, Reactor Safety Research

[3] Nuclear Technology Competence Pool (2007): Issues of Nuclear Safety and Repository Research in Germany 2007 – 2011, Reactor Safety Research

3.3 Institutional energy research carried out by the Helmholtz Association

The tasks of institutional funding

The research centres of the Helmholtz Association of National Research Centres (HGF), Germany's largest scientific organisation, are committed to tackling the major questions facing science, industry and society and securing life-sustaining resources in the long term. In this context, the "Energy" research area, one of a total of six research fields, plays a key role. Recommendations from the HGF are important drivers in the further development of the Federal Government's energy research policy [2].

Through collaboration by national research centres within the HGF, it is possible to achieve critical masses for long-term research topics and deploy the synergies generated. This approach is copper-fastened by joint research programmes – known as programme-oriented funding (POF) – and by longer-term institutional funding of the research centres. Ninety percent of the funding for the Helmholtz centres comes from the Federal Government with the remaining 10 percent provided by the relevant individual Land. Federal Government funding of the centres is provided by the Federal Ministry of Education and Research – with the exception of the German Aerospace Center (DLR), which falls under the remit of the Federal Ministry of

Economics and Technology (BMWi). The agreed research programme and funding for the second phase of programme-oriented funding (POF II) for the period 2010 to 2014 are aligned with the Federal Government's research policy requirements. These requirements shall still apply, but are subject to evaluation with regard to the third programme phase (POF III) and then further developed by the Federal Ministry of Economics and Technology in consultation with the other responsible ministries.

In addition to long-term institutional funding, flexible instruments are available to facilitate important short-term research topics. These include what are referred to as portfolio topics, the Initiative and Networking fund of the HGF and the raising of external finance in the context of project funding.

In the "Energy" research area, eight research centres with almost 4,000 employees, of which over 1,000 are scientists, are currently working together in five joint research programmes. Thanks to its leading international position in research, the HGF has a particular duty to train young scientists. In 2009, a total of 424 PhD students were supervised in the "Energy" research area. This type of cooperation between research centres and universities has proved to be especially beneficial in terms of training.

Federal Government research policy requirements

The Federal Government's current research policy requirements for the "Energy" research area serve as a baseline for developing research programmes for the second period of the programme-oriented funding (POF II). These requirements stipulate that the "Energy" research area should focus in particular on those fields where it offers a particular strength or USP, the greatest expertise and where it can make a particularly effective contribution to securing long-term energy supplies. In particular, this applies to the following [1]:

- → Aspects of basic research that play a pivotal role regarding possible breakthroughs in the development of energy technologies
- → Issues whose complexity, scope and requirements in terms of research equipment and infrastructure mean that they are ideally handled by the HGF research centres
- → Technologies that are relevant to long-term and very long-term energy supplies that can be expected to reach market maturity after 2020 or after 2050

In this context, efforts must be made to develop the structural links, integration and cooperation between universities, non-university research institutions of other science organisations and industrial research institutions.

The research policy requirements are the result of a comprehensive consultation and discussion process including policymakers and representatives from industry and science. Preparations on the research policy requirements for the third programme period (POF III) have already started. Further progress is discussed in dialogue platforms both at research field and HGF association level with representatives from science, industry and the funding agencies.

With regard to the third programme period for the "Energy" research area, the focus will be on further streamlining procedures at the HGF and introducing greater flexibility to improve responsiveness within the programmes. Cross-programme activities and cross-sectoral topics will also be brought more sharply into focus to avoid a strict separation of research structures. The integration of energy research using national research equipment is an important element here, in addition to strategic development investments from other research programmes.

"Electrochemical storage" will feature as a priority research field in the current programme period POF II. The portfolio topic *"Materials Science for Energy"* has been identified as another important cross-sectoral theme.

Under the "Energy" research area, there are five research programmes: Renewable Energy, Efficient Energy Conversion and Use, Nuclear Safety Research, Nuclear Fusion, and Technologies, Innovation and Society.

Research funding of the German Aerospace Center (DLR)

Energy research is a key plank of the overall DLR strategy, which profits from synergies in transport research and aerospace. The DLR covers a broad spectrum of energy research topics. These range from energy storage (particularly thermal storage and batteries), the development and application of fuel cells, the development of turbomachines and decentralised power plant systems, and also solar research (especially in the area of solar thermal power plants) through to system analysis.

The DLR is involved in the portfolio topic of "Electrochemical Storage" and will expand its activities over the coming years. In addition, studies are being carried out on thermal storage concepts for various temperature levels and applications such as adiabatic compressed-air energy storage, thermal storage for solar thermal power plants and low temperature storage for short-distance (local) district heating networks or near-surface geothermal energy.

In the field of solar research, solar thermal applications will be to the fore. This area will be supported by a new institute for solar research. Over the next few years, the Jülich solar tower will join other DLR projects and serve as a research platform for developing a new generation of power plant systems. Topics under investigation include new power plant generations that use solar direct steam generation in parabolic troughs, the development of high-temperature receivers, integration of heat storage systems, and solar hybrid CHP (combined-cycle) plants. The DLR is also stepping up its international involvement in the area of solar research.

Developments in the field of combustion and gas turbine technology are focusing on delivering greater efficiency, reducing emissions, ensuring combustion stability and fuel flexibility. Key fields of application include decentralised power plant systems using micro gas turbines and CHP or the decentralised coupling of micro gas turbines and fuel cells. The development of turbines for hydrogen-rich gases is also in process.

In the area of system analysis, the DLR is developing methods and instruments for mapping and evaluating the transition to sustainable energy supplies. This work will provide a roadmap for developing the technical, economic and ecological potential of new technologies.

The Federal Ministry of Economics and Technology is providing around €99.3 million in funding for the "Energy" research area of the DLR for the period 2010 – 2014. The breakdown of these funds is summarised in chapter 3.4.

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[1] BMWi, BMBF (2008): Forschungspolitische Vorgaben für den Forschungsbereich Energie, beschlossen vom Ausschuss der Zuwendungsgeber am 8. April 2008 (Research policy requirements for the Energy research field, agreed by the committee of financing partners on April 8, 2008)

[2] HGF (2009): Eckpunkte und Leitlinien zur Weiterentwicklung der Energieforschungspolitik der Bundesregierung, Empfehlungen der Helmholtz-Gemeinschaft (Cornerstones and guidelines for the continued development of the German Federal Government's energy research policy, recommendations of the Helmholtz Association)

3.4 Budgetary funds

BMWi energy research (in thousand of €)	Actual 2010	Planned 2011	Projected Data [1), 2)] 2012	2013	2014
Project funding					
Efficient energy use	118,276	119,294	120,894	115,144	122,494
Electric mobility [4)]	16,819 [3)]	21,190 [3)]	–	–	–
Energy and Climate Fund [4)]	–	22,000	28,500	103,250	113,500
Nuclear safety and repository research	32,980	33,280	33,680	34,080	34,080
Total	168,075	195,764	183,074	252,474	270,074
Institutional funding (DLR in the Helmholtz Association)					
Efficient energy use	12,700	14,200	14,600	15,330	15,987
Renewable energy	3,500	3,600	4,200	4,470	4,713
Technology, innovation, society	1,200	1,200	1,200	1,200	1,200
Total	17,400	19,000	20,000	21,000	21,900
Total	**185,475**	**214,764**	**203,074**	**273,474**	**291,974**

1) Figures relating to the federal budget are subject to parliamentary approval
2) Funding for the Energy and Climate Fund is subject to change
3) Includes funds from „Konjunkturpaket II“
4) Electric mobility integrated in the Energy and Climate Fund from 2012 onwards

4. Research funding provided by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

With competitive energy prices and a high standard of living, Germany is set to become one of the most energy-efficient and environmentally compatible economies in the world. Renewables such as wind power, solar energy, geothermal power, hydropower and biomass – combined with significantly improved energy efficiency – are the key to achieving this goal.

The past few years have already witnessed a huge increase of renewable energies. In 2010, renewables provided some 17 percent of the electricity consumption and over 10 percent of final energy consumption. These figures have almost tripled within 10 years. The use of renewable energy in Germany saved around 120 million tons of carbon dioxide emissions in 2010. Energy from renewable sources is already making an important contribution to the lowering of greenhouse gas emissions.

It is intended that renewables will comprise the majority of the energy mix in the future. In the next 10 years – up to 2020 – their share of gross final energy consumption is set to reach 18 percent, with the share of electricity generated from renewable sources accounting for 35 percent of gross electricity consumption. The Federal Government envisages that Germany's energy supply will be largely based on renewable energy by 2050: its share of gross final energy consumption is due to increase to 60 percent, and as high as 80 percent in the case of gross electricity consumption. According to the Energy Concept set out by the Federal Government, this objective will be achieved on the basis of concrete measures that will be subject to review.

Ultimately, this goal will require a fundamental overhaul of the current energy supply system. In addition to the massive reduction in greenhouse gas emissions, modernisation on this scale offers enormous potential for innovation, growth and employment. Research funding for renewable energy thus represents a strategic investment in future technologies, in economically valuable knowledge and expertise and, consequently, in the sustainable economic development of Germany.

The Federal Government is committed to making the expansion of renewable energy as environmentally sound and ecologically acceptable as possible. In addition to respecting climate protection requirements and taking account of environmental impacts on water, soil and air, the expansion strategy will factor in protection of biodiversity, natural balance and the landscape, and make provision for ecologically sound flood control measures. This will also foster a broader acceptance of the expansion of renewable energy.

Strategic and operational targets

Research funding provided by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) for renewable energy also contributes to reducing greenhouse gas emissions and modernising Germany's energy supply.[1] Within the research policy objectives mentioned above, research and development funding for renewable energy is targeting the strategic objectives below:

- → Reducing greenhouse gas emissions and achieving the expansion targets of renewable energy
- → Lowering the costs of the technologies used in renewable energy. First, this means increasing the efficiency of the individual technologies. Second, it involves making entire production processes more efficient and cost-effective, while increasing the long-term operational safety of the plants and systems.
- → Strengthening the competitive edge of German companies, particularly in the future markets for renewable energy and creating sustainable jobs,
- → Optimising the energy systems in order to cope with an increasing share of renewable energy
- → Ensuring the expansion and use of renewable energy is environmentally sound

1 Additional funding instruments include the Renewable Energy Resources Act (Erneuerbare-Energien-Gesetz, EEG) or the Programme for Market Incentives, for example.

The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety is also keen to ensure that results from research projects are swiftly transferred to practical applications.

The Ministry holds regular strategy discussions with representatives from industry and research institutions regarding research funding in the various areas and takes into account these deliberations when defining and setting its funding priorities.

Key strategic funding areas

Application-oriented research funding for renewable energy is targeted mainly at the areas of technology that offer significant potential for expansion, innovation and greenhouse gas reduction. For this reason, funding for research in the area of **wind energy** – both onshore and offshore – is continuing to grow. There is a particular focus on cost efficiency and on environmental impacts. **Photovoltaics** remain a second key priority. The focus in this case is to promote application-oriented research and transfer developments from the laboratory directly into industrial production to support Germany's competitive position. Support for research and development in the area of **geothermal energy** will continue to raise the potential of geothermal energy, which is distributed unevenly across Germany's regions. Energy extracted from this source is constantly available and thus an important addition to intermittent renewable energy sources. Furthermore, geothermal energy offers major potential as a low-emission heating supply. With regard to funding **the solar thermal supply of heating and cooling services,** the further development of collector engineering is key. Issues of integration into buildings, solar heating and cooling, plus seasonal storage of energy are also paramount. The import of solar electricity, particularly from countries in North Africa, could also contribute to the future energy supply in Germany. For this reason, but also to expand the knowledge base in the area of **solar thermal power plants** is also in receipt of funding. Projects in the area of **hydropower and ocean energy** are funded too, with a particular spotlight on ecological optimisation in the case of hydropower.

Continued, ongoing expansion of renewable energy is vital. This will require constant optimisation in the way that different types of renewable energy interact with each other with conventional energy sources. It will also hinge on intelligent balancing of electricity generation and consumption. The Federal Government is firmly committed to an energy system with predominantly renewable content and recognises the unique challenges posed by energy and electricity supplies drawing on a high share of renewables: it is therefore extending the funding priority of **integrating renewable energy and renewable energy supply systems.** Improved grid infrastructure and technology, smart grids, storage technologies and system services derived from renewable energy are core elements of an energy system that is based largely on renewable energy. Given the overarching role of grids and energy storage systems across all energy carriers, joint funding initiatives are conducted with the Federal Ministry of Economics and Technology and the Federal Ministry of Education and Research (see also chapter 4.7).

The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety also supports funding for **cross-sectoral topics of a more general nature** as part of the overall strategy for the further expansion of energy from renewable sources.

Application-related research funding by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety is complemented by basic research conducted by the Federal Ministry of Education and Research.

4.1 Wind energy

In Germany and around the world, wind energy is harnessed primarily by wind energy conversion systems (WECS) or wind turbines, as they are generally called. These use rotor blades and generators to convert the kinetic energy of the air into electrical energy. In this field, wind turbines featuring a horizontal axis that deploys aerodynamic lift have become more widely established.

Background, current energy status and technology developments

Over the past ten years, electricity output generated from wind has increased five-fold, from 7.55 TWh in 2000 to around 36.5 TWh in 2010. (1990: 0.071 TWh). At present, Germany has more than 21,500 wind turbines with a total output of approximately 27.2 GW. Virtually all of these are installed onshore. Until 2009, most of Germany's wind energy originated from onshore installations. Germany's first offshore wind farm, alpha ventus, opened on April 27, 2010.

In the foreseeable future, wind energy is likely to contribute most to the planned expansion of renewable energy in the electricity sector. The Federal Government has projected potential output from wind energy to be 104 TWh annually up to 2020, with 32 TWh of this is to be generated offshore (from 10 GW installed capacity) and 73 TWh onshore (from 36 GW installed capacity). (These figures are taken from the national renewable energy action plan). The Federal Government's Energy Concept also recognises the major potential of wind energy, and refers to the enormous expansion of wind power capacity required, both onshore and offshore.

The expansion in offshore wind energy in Germany has been subject to some delays over the last few years. However, a solid legal framework is now in place for the development of offshore wind energy, at least since the 2009 amendment to the Renewable Energy Resources Act (Erneuerbare-Energien-Gesetz, EEG). Delays were also caused, in no small part, by the international financial crisis, which had a noticeable impact on the market after 2008. This situation is expected to ease over the next few years. Meanwhile the first commercial German offshore wind farms are under construction.

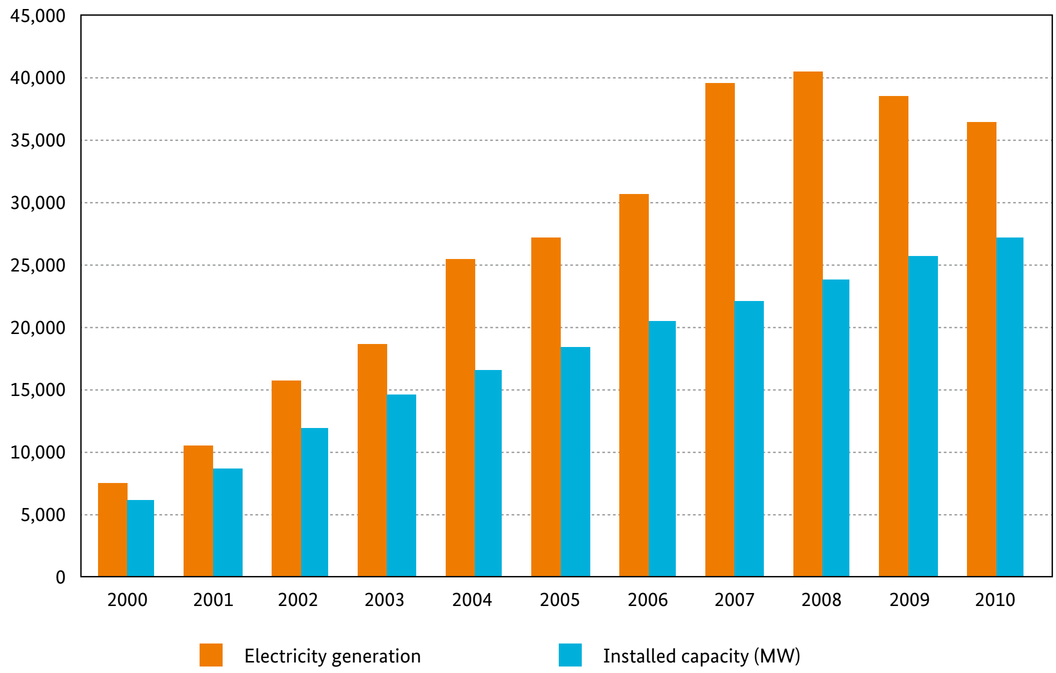
It is the Federal Government's goal to accelerate the expansion of offshore wind energy significantly: offshore wind capacity is to reach 25 GW by 2030.

In the short to medium term, onshore wind energy offers the most economical potential for expansion in the renewable energy sector. Previously, most of the newly installed capacity was harnessed by new turbine locations and constructing new turbines. Nowadays, however, land that is available and suitable for wind energy is in shorter supply. For this reason in particular, the Federal Government's second priority is to expand capacity at existing locations (repowering).

Research funding objectives

The aims of research and development funding in the wind sector are two-fold: first, to improve the technological basis for the exploitation of wind energy both offshore and onshore; second, to help further reduce the cost of wind power generation in terms of construction and operation. German companies and research institutions are global leaders in the field of technology. If Germany is to retain this position, continued technical progress is vital. At the same time, accompanying environmental research will help

Fig. 4.1: Development of wind energy in Germany 2000–2010



Source: BMU based on an analysis by the German Wind Energy Institute (DEWI) ensure that the expansion and use of wind energy are environmentally sound.

Key strategic funding areas

Priorities of research funding in the wind sector include general technological development spanning both offshore and onshore use, specific technological development for offshore use of wind energy in particular, and accompanying ecological and acceptance research.

4.1.1 Further development of technologies for onshore and offshore use

To help reduce specific costs, increase yields and improve availability of wind turbines, the following priority funding areas shall apply:

- Support will be provided for the improvement of individual components in wind turbines, in particular

  - Application-oriented development and use of suitable materials
  - Innovative tower construction concepts
  - Further development of the drivetrain in wind turbines with or without gears
  - Development of innovative nacelle concepts
  - Further development of rotor blades, particularly with regard to the optimisation of aerodynamics, acoustics and weight

- In addition to the further development of individual components, improvements to the overall system are critical. The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety is therefore also prioritising general aspects, in particular:

  - Improvement of wind farm aerodynamics (such as wake effects)
  - Determination of flow conditions at high altitudes (> 100 m)
  - Production automation and quality assurance in production
  - Optimisation of plant operations and maintenance
  - Improvement of the grid properties of wind turbines (see also chapter 4.7 "Integration of renewable energy and alternative energy supply systems")
  - Environmentally sound dismantling of turbines
  - Collection and evaluation of data and experiences from operating the system turbines to achieve systemic improvements

To investigate the practical application of the technologies, funding can be provided for a range of areas including:

- Research installations and wind farm test sites (particularly prototype test sites), which allow various prototypes to be tested in practice by alternating the turbines in use

- Test stands incorporating flexible test facilities for individual components

4.1.2 Wind energy exploitation at sea

Research and development of **wind energy exploitation at sea** is supported by various activities including the operation of the three research platforms FINO 1, 2 and 3 in the North Sea and the Baltic Sea. Important issues are also being investigated and data acquired by the research initiative at the alpha ventus RAVE (Research at alpha ventus) offshore test field. The experience gained from planning and construction, tests and normal operation has already highlighted additional issues, for which research funding can be provided by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. These issues can also be usefully investigated in the context of offshore test fields situated alongside commercial wind farms. This applies in particular to:

- Foundation variants and support structures

- Environmentally and ecologically sound system design

- Wind physics and improved output forecasts for offshore wind farms

- Computer-aided simulation of meteorological conditions including wave loads at sea

- Logistics concepts

- Optimisation of concepts and technologies for construction, operation and maintenance

- Technologies for reducing specific investment and operating costs

- Data acquisition from commercial offshore wind farms

4.1.3 Accompanying research on environmental impacts and on acceptance

The development and expansion of wind energy must respect the environment. With this in mind, accompanying research has already been extended over the past few years, as part of the research conducted into energy from renewable sources, and is set to continue. Accompanying environmental research includes testing and developing long-term effective precautions and standards to ensure environmentally sound expansion of renewable energy. This type of research also yields valuable insights into how further expansions of or upgrades to existing turbines can be designed to minimise impact on the environment. This research focuses in particular on:

- Noise reduction measures especially during plant construction
- Environmental evaluation of new foundation types
- Bird migration and flight patterns, with regard to illumination of wind turbines, for example
- Analysis of findings regarding bat strikes in the development of planning regulations for wind turbines
- Impact of wind turbines on sea birds and fish, including, for example, loss of habitat
- Influence of future offshore expansion on the ecosystem/microclimate
- Standardisation of measurement procedures
- Evaluation of cumulative impacts of wind farms, with a particular emphasis on developing avoidance and mitigation measures and defining critical limits.

Fully integrating wind energy into the energy system is vital for its use (see also chapter 4.7).

4.2 Photovoltaics

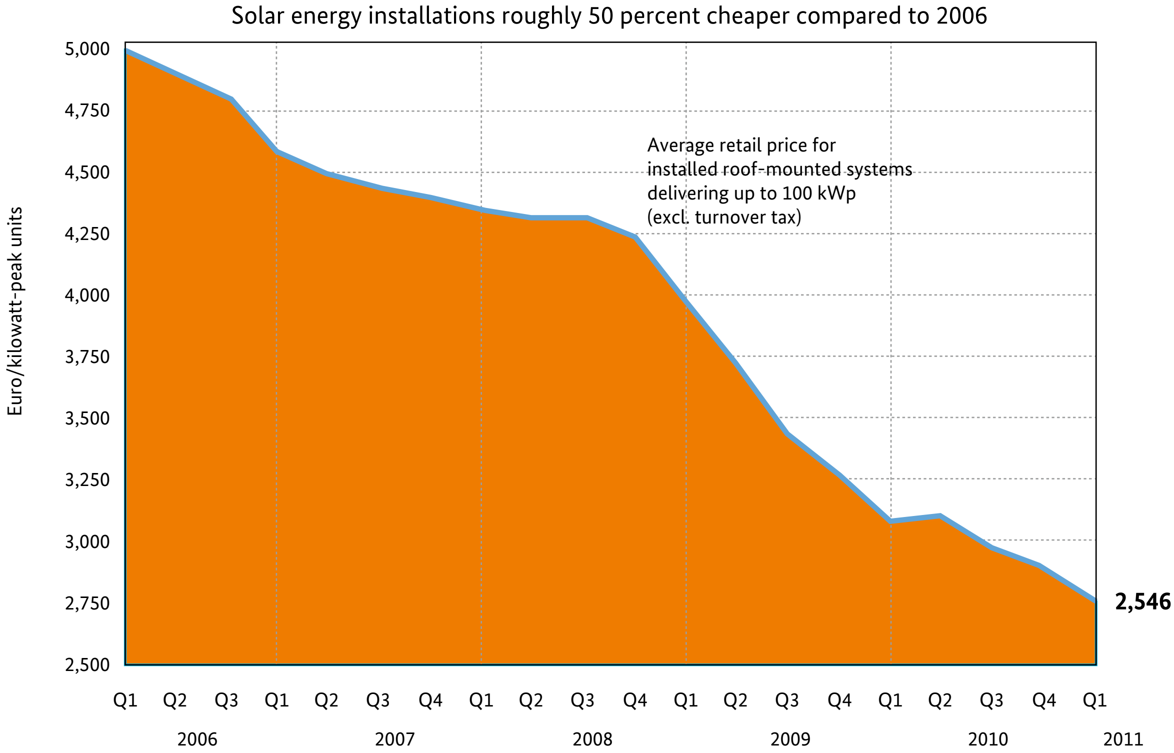
Photovoltaics (PV) is a technology that converts sunlight directly into electricity using semiconductors, or solar cells. The semiconductor material silicone is predominantly used for this purpose, although other materials such as compound semiconductors in particular are also used.

Background, current energy status and technological developments

The global market for photovoltaics has experienced dynamic growth over the last few years. From a base of just 1.8 GW produced in 2005, output had reached 17–20 GW by 2010. Development is being driven by various mechanisms designed to support market introduction, many of which are modelled on Germany's Renewable Energy Resources Act. Consequently, Germany is currently the lead market for photovoltaics. The feed-in tariff rates for photovoltaics under the Renewable Energy Resources Act are continuously adjusted to facilitate expansion in the wider economic context. Whereas the cost of electricity generated by photovoltaics in Germany was still around 0.50 to 0.60 €/kWh in 2005, a cost of around 0.30 €/kWh forecast at the time for 2010 was indeed achieved in 2010.

Although Germany is hardly one the world's sunniest regions, there is significant long-term potential for expansion in this area. The "National Renewable Energy Action Plan" compiled by the Federal Government in 2010 envisages an installed capacity of 51.7 GW in 2010, or the equivalent of an electricity output of 41.4 TWh. Further progress in this area will hinge on the actual implementation of the framework conditions in the Renewable Energy Resources Act (revised version to enter into force on 01 January 2012). In addition, photovoltaics represent a set of technologies that offers major export opportunities. In its study "Solar photovoltaic energy technology roadmap", the International Energy Agency IEA has forecast annual market growth of new installed capacity of over 100 GW per year worldwide, as of 2030.

Fig. 4.2: Cost degression in PV



Source: Independent, representative survey of 100 heating technicians by EUPD-Research, commissioned by BSW-Solar.
For more information, see: www.solarwirtschaft.de/preisindex

Further cost reductions are necessary to enable profitable and efficient expansion of photovoltaics and achieve the expansion targets. By 2020, the cost of electricity from photovoltaics should be around 10 cents/kWh. Reaching this target will require a continuous reduction in system prices. In 2010, a level of almost 3,000 €/kW was achieved. This figure is set to contract more than half to between 1,300 and 1,500 €/kW by 2020.

The long-term target is a considerably more realistic system price of below 1,000 €/kW, which allows an electricity price of less than 10 cent/kWh. Research funding can make a vital contribution towards achieving this goal.

German research institutions and companies have exerted an essential and dynamic influence on global markets. German research institutes are justifiably ranked among the most internationally renowned development laboratories, while German plant engineering industry delivers production systems that set the bar worldwide. The photovoltaic companies themselves constitute a dynamically growing sector with revenues that have more than tripled since 2005 and that is responsible for creating vital high-tech jobs in Germany.

Research funding objectives

In light of the above factors, research funding provided by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety has the following goals:

- Further increasing efficiency levels and, in particular, closing the gap between efficiency levels achieved in laboratories and those achieved in commercial production
- Achieving further cost reductions by introducing more efficient production methods and using new process steps such as lasers or automation technologies
- Reducing material inputs through efficiency measures and by using new materials and combinations

- Extending the lifetime of components in photovoltaic systems to boost their efficiency

Faced with foreign, lower-cost, off-the-shelf products, the only way manufacturing operations in Germany can survive is by successfully and continuously investing in product innovation. Maintaining Germany's technological lead across the board will require further investment in research and development. In particular, the results already obtained at laboratory level must be transferred to the field of commercial production. For this reason, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety is focusing on precompetitive research, which can be accessed by the maximum number of German companies.

With this precompetitive approach in mind, the Federal Government has also launched the "Innovation alliance photovoltaics" in 2010. This initiative attaches particular importance to strengthening cooperation within the process chains and between the equipment and photovoltaics industries. Projects carried out by "Innovation alliance photovoltaics" under the joint coordination of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and the Federal Ministry of Education and Research are expected to support industry efforts to achieve a steady reduction in production costs, while maintaining international competitiveness.

Key strategic funding areas

Silicon wafer technology and thin-film technologies both have the potential to achieve the necessary cost savings and thus secure greater market share in the future. It is as yet unclear which of the current technologies will dominate the market. The priorities of research funding are first, to support the further development of established solar cells made of crystalline silicone and second, to promote various thin-film technologies that high potential.

4.2.1 Silicon wafer technology

The value-added chain for silicon wafer technology starts with the raw material silicone, followed by the wafers and cell production, through to module construction. Material and energy consumption must be significantly reduced across all process steps. The key performance indicator is the ratio between the silicone material input and the subsequent output achieved in the module. In 2005 this figure was 12 t/MW, but has fallen to 7 t/MW since then. A further reduction to 5 t/MW appears necessary to achieve the planned cost savings. Funding is directed at the following activities in particular:

- **Raw material, crystallisation and wafer production:** Solar silicone must be of sufficient purity to achieve high levels of efficiency later on in the cell and in the module. At the same time, however, cost savings are also essential at this stage. The priority during wafer production is to apply the individual sub-processes with minimum material consumption. A possible alternative to slicing the silicone into wafers is to crystallise silicon wafers in the form of thin ribbons directly from the silicon melt.

- **Cell production:** The standard processes used in cell production today still use relatively simple structures that achieve efficiency levels of up to 17 percent. In the meantime, cell concepts that achieve efficiencies well in excess of the 20 percent mark have been developed at laboratory level. It will be necessary to transfer these concepts to production, while cutting specific production costs. This will be a particularly challenging task in the area of process technologies.

- **Module production:** The final step involves further processing the solar cells to create PV modules. Priority targets for the next few years include: elimination of environmentally damaging substances; improving quality assurance so that a nominal production output of at least 90 percent is achieved over a lifetime in excess of 25 years; adapting the module technology to new cell concepts.

Potential cost savings in design must be supported by high process yields and reduced material input in all sub-processes. Improved process technologies have a key role to play in this respect. Furthermore, overall production must be structured to reduce energy consumption and avoid ecologically damaging substances.

4.2.2 Thin-film solar cells

Future research into thin-film technologies will prioritise the area of production technologies. Higher process yields and longer system lifetimes will be regarded as critical. In one of the production technologies, thin-film cells are deposited onto flexible substrates as part of a cost-effective and virtually endless roll-to-roll process. Increasing deposition rates and further reducing consumption of material and energy are other important factors. As with silicone wafer technology, studies must be carried out on long-term stability of the modules. In addition, environmentally damaging substances must be avoided during production.

Within the field of thin-film technologies, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety is focusing its support on the manufacturing of solar cells based on silicone and chalcopyrites.

→ **Silicone thin-film solar cells** are an impressive technology, due to the virtually unlimited availability of the basic material silicone and also because of the additional developments expected through by-products of the flat-panel industry, for example. Production capacities have expanded significantly over the last few years to include cells made of amorphous and micromorphous silicone and production technology has already benefited from advances in the flat-panel industry. Nevertheless, there is still plenty of scope for efficiency gains in this technology. Today, good modules achieve an efficiency level of 8.5 percent compared with just 6 percent in 2005. However, values of at least 12 percent should be feasible. This would also open up significant potential cost savings.

  Crystalline silicon thin-film cells are still at the research stage; it is not yet possible, even in economic terms, to predict when the technology will reach production maturity.

→ **Chalcopyrite thin-film cells (CIS)** potentially offer high levels of efficiency. With efficiency levels in commercial production of up to 13 percent and a proven potential in excess of 20 percent, CIS solar cells can compete with the efficiency of crystalline silicone cells. The primary aim of this technology must be to improve production and process technology and exploit the recognised efficiency potential, while achieving cost-effective overall production. This approach also includes the substitution of more expensive materials.

→ **Thin-film solar cells of cadmium telluride (CdTe)** are currently the leading thin-film technology in terms of cost and production volumes. The technology is considered to have less potential for further development than thin-film solar cells based on silicone or chalcopyrites. In addition, the ecological impact of this technology has not yet been adequately determined.

While the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety focuses on funding application-oriented research, its efforts are supported by the Federal Ministry of Education and Research, whose funding is more geared towards basic research in the development of thin-film solar cells (chapter 6.4.3). The respective funding measures from both ministries are closely coordinated.

4.2.3 Systems technology

The systems technology for supplying solar electricity to the electric grid has reached a high degree of technical maturity. Questions concerning the interaction between various decentralised electricity feeders with the grid and among one another are covered under the priority funding area "Optimisation of energy supply systems" (chapter 4.7).

Future development work is therefore focused on the further development of power electronics for decentralised grid feeding, for example, high-efficiency inverter topologies and their adaptation to future module generations.

4.2.4 Alternative solar cell concepts and new research approaches

With a system efficiency level of 25 percent, the use of concentrating photovoltaics in regions with high levels of direct solar radiation is an interesting alternative. Even if these systems are only used in exceptional cases in Germany because of the prevailing diffuse solar radiation, there is an attractive export market. Developments completed by German research institutions, cell manufacturers and system providers have already reached an advanced stage. For example, GaAsP/GaInP/Ge triple-junction solar cells have been manufactured with efficiency levels of over 40 percent. The topic of concentrating photovoltaics therefore deserves consideration, with a view to increasing system efficiency and reducing manufacturing costs.

New, innovative cell concepts continue to play an important role in research. These also include organic solar cells and dye cells. To enable potential development of these solar cell designs in the long term, the Federal Ministry of Education and Research has turned its attention to the necessary tasks (see chapter 6.4.3). Research objectives are: transferability to an industrial production scale, a lifespan relevant to the energy source and environmental compatibility.

In the case of ground-mounted photovoltaic installations, accompanying ecological research must focus on determining the impact of the construction and operation of the installations, including minimum ecological requirements and accompanying acceptance research.

Cross-technological research fields:

Photovoltaics are ideally suited for integration into buildings (BIPV – building integrated PV). In this case, photovoltaic modules assume the functions of the building envelope. With substitutions of this type, savings can be made in overall building cost. Although potentially an attractive proposition both economically and architecturally, building-integrated photovoltaic systems are still very much the exception rather than the rule. The objective in this case should be to develop standardised modules that can be integrated into buildings to meet the requirements for zero-energy or plus-energy buildings.

Aside from the considerations above, some general issues must be addressed before we can consider photovoltaics as a clean energy option. What measures can be taken to avoid substances that are damaging to health and the environment in system components, to reduce energy consumption during production of components and to manage recycling?

4.3 Deep geothermal energy

Geothermal energy is energy that is derived from the natural heat of the earth and used for heating purposes (useful heat) or to generate electricity. “Deep geothermal energy” is the term given to geothermal energy extracted from geothermal reservoirs at depths of over 400 metres using deep drilling techniques. Hydrothermal systems primarily tap the energy of underground warm and hot water, while hot dry rock technology uses the energy stored in rocks.

Background, current energy status and technological developments

In Germany, three specific regions have potential for geothermal exploitation: the North German Basin, the Rhine Rift Valley and the South German Molasse Basin. As demonstrated by the results of current research projects, the characteristic features of each of these regions present different opportunities and challenges for exploiting geothermal energy. While moderate flow rates, moderate temperatures and occasionally very high salinity are characteristic of the thermal water in the North German Basin, the South German Molasse Basin features high flow rates (to some extent), high temperatures and generally low salinity levels. Owing to its heterogeneous geology with fault zones and a higher risk of seismic activity, the Rhine Rift Valley is more difficult to explore and the thermal water is often highly corrosive. On the other hand, the area’s high temperatures and high flow rates offer good conditions for the commercial exploitation of geothermal power.

The 2004 increase in the feed-in tariff for geothermal-derived electricity under the Renewable Energy Sources Act triggered a surge of activity in deep geothermal energy in 2005 and the years that followed. Geothermal electricity generation projects concentrated on the Molasse Basin around Munich and the northern Rhine Rift Valley. At the end of 2006, 80 projects focussing on deep geothermal electricity and heat production had been established, with 150 projects in various stages of development by the end of 2007.

Drilling commenced at several locations (Offenbach, Speyer, Unterhaching and Landau) in 2004 and 2005. This was followed by more drilling operations in Groß Schönebeck, Bellheim, Sauerlach, Dürrnhaar, Kirchstockach and Mauerstetten. To date, however, only three such projects – Landau (2007), Unterhaching (2008/09) and Bruchsal (2009) – have advanced to the electricity production stage.

In the wake of the financial crisis and the ensuing funding difficulties, along with concerns over seismic activities in Landau and Basel, little progress has been made in the development of geothermal energy in recent years.

The costs associated with deep geothermal energy vary greatly from project to project. No statistics are yet available to corroborate information on average costs. It is expected that developments in techniques to create production-ready boreholes and systems to convey thermal water will have the potential to drive down the cost of geothermal energy projects. Furthermore, radiation protection aspects must also be considered given the concentration of naturally occurring radioactive substances in the rocks.

From a medium-term perspective, heat and electricity derived from deep geothermal power systems can play a key regional role, particularly in a system primarily based on renewable energy, since the useful heat or electricity produced is always available. This is in contrast to intermittent renewable sources, such as wind and solar power. The Federal Government estimates that geothermal energy, which can provide power at any time of the day or year, has the potential to produce 1,654 GWh of electricity by 2020. Its potential to generate heat and cold is estimated at 696,000 t COE (crude oil equivalent). As it matures, the long-term potential of this technology is likely to be far higher.

Research funding objectives

For geothermal energy to become a significant player in meeting future heating and electricity needs, more projects must be implemented in the coming years and, drawing on practical experience, advances must urgently be made in this field. Aside from increased compensation rates under the Renewable Energy Sources Act and possible financial solutions to hedge against the investment risk, research funding can help to ensure that this renewable energy source is exploited commercially and can contribute to securing a sustainable energy supply.

The aim of research support provided by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety is to further advance the cost-effective extraction and use of heat and power from deep geothermal reservoirs. To boost the market penetration of geothermal energy, heat production from geothermal resources is a principal focus of research funding provided by this Ministry. Over the medium term, this is the best way to ensure that this non-intermittent renewable source can secure a foothold in the energy market, and significantly increase sales of geothermal energy in Germany.

Key strategic funding areas

Research funding in the field of geothermal energy focuses on the development of specific technologies in this sector (drilling, pump development, exploration methods, measurement techniques etc.), with priority given to projects to reduce the exploration risk and risk of failure when exploring sites (new methods, models, catalogue of geothermal data) and to increase public acceptance of this energy source (seismic activity, disposal issues).

4.3.1 System components and exploration technology

→ Accounting for roughly 80 percent of the investment cost, drilling is the primary cost factor when erecting a geothermal power plant. It is therefore critical to develop **drilling technology** further. Projects should strive to cut the cost of drilling by developing new technologies and by refining processes and techniques currently found in natural gas and oil exploration.

→ Conventional pumps used in hydrocarbon exploration are not designed to withstand the tough conditions present in geothermal systems, i.e. the high temperatures, high flow rates and the highly corrosive effect of high-salinity thermal water. The possibility of borrowing and adapting pump technology used in the oil sector is limited due to the pumps' particular design. Therefore, there is a need to **develop pumps that are specially designed for geothermal environments** and to develop new approaches to the design and sizing of drill wells (diameter, completion etc.).

→ **Stimulation measures** continue to be eligible for funding from the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. Such measures involve creating or maintaining pathways in the rock, or expanding them by connecting to natural fault zones (e.g. opening the underground rock by pumping high-pressure fluid, such as water, down an injection well, as in the hot dry rock (HDR) method, acidification and other techniques). Funding is also provided for the development of water-compatible chemical additives used in stimulation activities.

→ Furthermore, funding continues to be granted to the development of systems to **generate electricity** in geothermal power plants, i. e. organic Rankine cycle (ORC) and Kalina cycle systems.

4.3.2 Underground data

To ensure that the exploration risk, failure risk and the risk of damage from drilling operations can be properly assessed, applications for funding are also accepted from projects that focus on the ongoing collection and processing of geological, geophysical, petrophysical, mineralogical and microbiological data with the aim of compiling a comprehensive catalogue of geothermal data in Germany.

4.3.3 Seismic activity and disposal issues

The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety also lends support to projects which aim to:

- Clarify the relationship between the exploration or operation of geothermal plants and the incidence of seismic activity
- Develop solutions to avoid, immobilise and ultimately dispose of low-activity and medium-activity products from the operation of geothermal plants
- Prepare the results of such studies for the wider public
- In addition, projects focussing on the following areas are also eligible for funding:
- Mitigation of adverse effects on the groundwater system
- Impact of naturally occurring radioactivity in the rocks used

Other areas of support include:

- The prevention of corrosion and scaling
- The monitoring of geothermal plants and plant parts, such as pumps, heat exchangers etc., to optimise the operation of geothermal power plants for heat and electricity production
- The enhancement of mathematical models for modelling and simulating geothermal reservoirs and their operational performance
- The development of methods and procedures to reduce the exploration and failure risk when exploring geothermal sites
- The development of measuring equipment and techniques that meet the requirements of geothermal systems
- The development of low-maintenance instruments, equipment, machines and pumps, in particular, that operate reliably and efficiently in the high temperatures, pressures and corrosive conditions that are typical of geothermal environments

The grid integration of geothermal plants is supported in the "optimisation of energy supply systems" priority research field.

4.4 Low-temperature solar thermal power

Solar thermal energy uses solar thermal collectors to concentrate light from the sun to create heat. Deployed either directly or stored temporarily, this energy is used to heat spaces and domestic and industrial water, to generate solar process heat, or is fed into short-distance heating systems or used for cooling purposes in thermally driven cooling and refrigeration systems.

Background, current energy status and technological developments

More than one half (approx. 54 percent) of final energy consumed in Germany is for heating or cooling purposes. When combined with other renewable energy sources – particularly biomass – solar thermal energy can make a key, long-term contribution towards the sustainable, secure and environmentally sound supply of heating and cooling power. Currently, however, it only accounts for 0.4 percent of the heating/cooling energy consumed, with over 90 percent of solar thermal energy concentrated in small systems in residential one- and two-family homes. The technology for large-scale systems has been developed as part of the "Solar Thermal Energy 2000/2000 Plus" research funding project. Designed for use in multi-story residential buildings and housing estates in conjunction with seasonal heat storage systems and heating networks, this technology has already been demonstrated in several applications. Of the systems installed, roughly 90 percent use flat-plate collectors and approx. 10 percent use evacuated tube collectors for pitched-roof or flat-roof installations. In the future, solar collectors must be integrated on a large scale into building roofs and facades in order to also perform an increasing number of structural and architectural functions.

At the same time, the efficient energy technologies currently available can dramatically reduce the demand for heat energy in energy-efficient buildings. Used consistently, low-temperature solar thermal power and efficient energy technologies combined can complement one another and make low-energy or zero-energy buildings and active solar designs technically and economically viable. Such buildings are very well insulated, equipped with high-efficiency air-conditioning and ventilation technology with heat recovery systems, and use renewable energy sources, particularly solar technology, to cover all additional energy needs. While two out of every three buildings constructed in 2010 were low-energy buildings, zero-energy buildings or active solar buildings are currently part of research and demonstration projects.

Supported by the Market Incentive Programme launched by the Federal Government, the installed thermal power increased to roughly 10 GW in 2010. With slumps experienced in 2009 and 2010, market growth over the past ten years has been very volatile, averaging about 20 percent, and bringing revenues to approximately €1 billion. In the last 15 years, it has been possible to halve solar heat production costs to between €0.10 and €0.20 per kWh, depending on the system used. The German Solar Thermal Power Technology Platform (DSTTP) believes it is possible to halve these costs again by 2020, making solar thermal power cheaper than fossil fuels.

To tap this potential, priority must be given to broadening the fields of application and expanding the scope of low-temperature solar thermal energy to include larger systems for apartment buildings and the commercial sector. At the same time, there must be greater focus on energy retrofitting, the deployment of larger collector fields in connection with heating networks, or district-specific solutions.

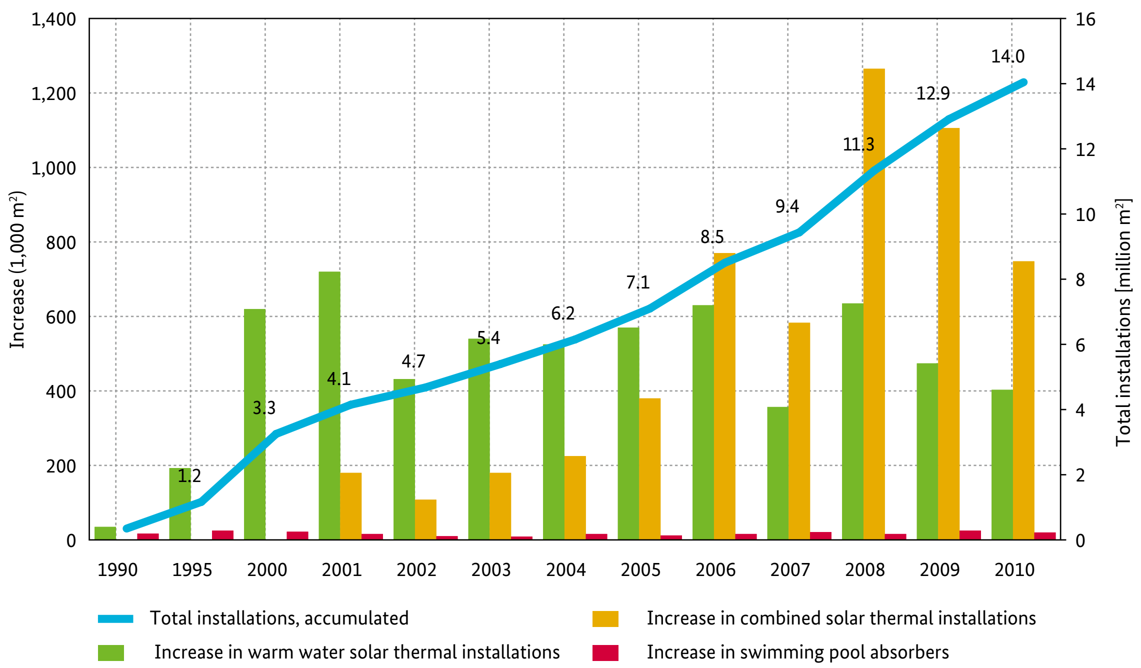
Research funding objectives

In supporting research into low-temperature solar thermal energy, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety aims to significantly increase the use of low-temperature solar thermal energy by further reducing the costs and boosting the efficiency of collectors, storage modules and the system overall. Furthermore, the aim is to improve the integration of low-temperature solar thermal energy into conventional heat supply systems and use this form of energy in tandem with energy-efficient buildings.

Key strategic funding areas

Research funding by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety assigns priority to the development and enhancement

Fig. 4.3: Development of the increase in solar collectors in Germany since 1990



Graphic factors in the dismantling of legacy installations; combined solar installations; domestic and industrial water heating; and backup heating

Source: BMU based on ZSW, ZfS, BSW

of collector technology, specifically the rationalisation and automation of collector production, advanced systems technology and the integration of solar heat production systems into buildings. The use of solar power for district heating networks, the development of new fields of application, such as solar cooling and solar process heat supply, as well as the enhancement of thermal storage technology are particular priority areas.

With regard to building integration and the enhancement of storage technology, in particular, the specific research funding measures of the Federal Ministry of Economics and Technology and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety are interlinked and approaches are harmonised with each Ministry having specific priority areas ("priority principle"). Looking to leverage synergies between technological developments and the integration of these technologies into larger, energy-efficient systems, the Federal Government plans to launch a joint, interministerial research initiative, entitled "Solar-powered buildings – Energy Efficient Cities".

4.4.1 Collector technology

The DSTTP estimates that collectors currently account for roughly 25-30 percent of the costs of a standard solar system. It is expected that new innovations could cut collector costs by 50 percent by 2030. This will be achieved, in particular, by using new materials for the absorber, introducing novel collector designs and ramping up industrial mass production.

Funding is provided for a range of themes, including:

- → The use of new materials, particularly plastics, in connection with innovative designs and new copper and aluminium alloys for ultra-thin-film absorbers
- → Selective glass and absorber coating and vacuum technology to further increase efficiency and reduce heat loss
- → The development of methods to protect against overheating if hot water is not used for several days and to improve freeze protection by using smart controller systems and switchable smart glass
- → New collector design principles to enhance efficiency depending on the operating or working temperature, such as mirror or hybrid systems (CPC/compound parabolic concentrator)
- → The rationalisation and automation of collector production

4.4.2 Systems technology/low-temperature solar thermal power in buildings

Research funding provided by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety in this field complements eligible areas that focus on energy-optimised construction and energy-efficient heating and cooling systems (see also sections 3.1.1 and 3.1.2). Following the priority principle, it specifically focuses on the following themes:

- → The development of new system designs and controller solutions to enable solar energy to cover up to 100 percent of heating energy needs, also in conjunction with innovative backup heating systems and the integration of large storage modules.
- → The development of suitable tools for planning and appraising buildings with a solar energy coverage of between 50 and 100 percent in line with the Energy Saving Ordinance *(Energieeinsparverordnung, EnEV)* and the Act on the Promotion of Renewable Energies in the Heat Sector *(Erneuerbare-Energien-Wärmegesetz, EEWärmeG)*, and the demonstration and monitoring of such system designs.
- → The use of solar thermal energy in district heating networks in conjunction with heat from renewable heat and power cogeneration systems. This is accomplished by developing suitable approaches to supply heat to the grid and optimise the grid infrastructure, and by integrating seasonal heat storage systems and heating pumps where necessary.

Integrating the solar components and the components of energy efficiency technology in buildings is central to boosting the potential of low-temperature solar thermal power. For this reason, a joint interministerial research initiative focussing on "Solar–powered buildings – Energy Efficient Cities" is currently being planned (see Section 2).

4.4.3 Solar cooling and solar process heat

Solar thermal energy at temperatures between 90 °C and 250 °C offers excellent potential to power refrigeration equipment and provide process heating or cooling solutions for industrial/commercial processes.

Both areas are receiving more and more attention as ways to increase the commercial uptake of solar thermal energy in the future. Furthermore, the potential to export solar cooling solutions to warmer countries is also growing.

For this reason, funding is provided in the following areas:

a) With regard to solar cooling systems, specifically:

- → Research into the use of new materials for adsorption and absorption cooling processes driven by solar thermal energy, and related heat transmission and fluid and gas transport systems
- → The development of efficient recooling systems
- → The standardisation of systems technology and the development of suitable planning and monitoring instruments
- → Field tests and monitoring techniques to test systems

b) With regard to process heat, specifically:

- → The development of standardised solutions for high-potential industries (e.g. for cleaning and drying processes)
- → The development of hydraulic and systems technology concepts for supplying solar thermal energy to industrial processes, while also factoring in the potential of existing industrial waste heat
- → The development of design and simulation tools for integral planning and analysis, as well as supervision, control and monitoring of processes with integrated solar thermal energy

c) With regard to comprehensive quality assurance, specifically:

- → The development of suitable procedures and methods to secure quality and output, to increase operational safety, to optimise operations and to enable the overall energy-specific and ecological appraisal of solar-powered systems (planning, simulation and optimisation tools)

4.4.4 Heat storage

For a building to be heated primarily by solar power, the building itself must have low heating requirements and the solar thermal energy produced in the summer must be stored for colder months of the year when heating is needed. Therefore, heat storage is central to the higher uptake of solar thermal energy as a heat source to enable the use of solar thermal energy, and other thermal energy sources, that is adapted to specific processes and is independent of actual sunshine hours. Heat storage systems are also a feature of the overall “Energy-optimised buildings” system and therefore a focal area of different funding programmes (see sections 3.1.1 and 3.2.2). The resulting synergies will be leveraged in the joint “Energy storage” interministerial funding initiative (see section 2). Following the project funding priority principle, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, for its part, promotes thermal storage systems in connection with solar power supply with a focus on the following areas:

- → The development of thermal storage systems with far higher specific storage capacities compared with water
- → The development of solar warm water storage systems with enhanced heat insulation to reduce heat loss, particularly for seasonal heat storage systems
- → Innovative design principles and new solutions for low-cost tank materials and efficient charging and discharging technologies
- → Smart storage solutions for integration into existing buildings or underground for “solar retrofits”, and integration into solar heat distribution systems
- → The further development of storage systems for different temperature levels, ranging from below 0 °C for refrigeration storage systems to up to approx. 250 °C for process heat storage

4.5 Solar thermal power plants

Solar thermal power plants use solar radiation to generate electricity in an otherwise conventional power plant process. Mirrors focus the sunshine onto a central receiver and heat a heat-transfer fluid. Turbines and generators then convert the energy of the heat-transfer fluid to electricity. Solar thermal power plants present an efficient solution for converting solar energy to electricity in hot and dry areas that receive a lot of direct sunshine. When used in conjunction with heat storage systems or configured as hybrids (plant uses both solar energy and fossil fuel), they enable on-demand electricity generation, help guarantee the base load capacity of the power grid, and allow large quantities of electricity from other intermittent renewable sources to be supplied to the power grid. Therefore, solar thermal power plants have the potential to play a central role in the global supply of energy in the future.

Background, current energy status and technological developments

At the end of 2010, solar thermal power plants with a capacity of roughly 1 GW were in operation worldwide. Plants delivering over 600 MW are currently under construction in Spain, with 1,300 MW planned by 2013 under the provisions of the Spanish Electricity Feed-in Act. Several countries in the Mediterranean and the Middle East and North Africa (MENA region) are currently developing strategies and programmes to harness the high levels of sunshine they receive, with the aim of increasing the share of renewables in the energy mix. As part of the “Mediterranean Solar Plan: Union for the Mediterranean” strategy, the EU and its Mediterranean neighbours are working to develop the framework needed to import solar electricity from the MENA region. The American Southwest also has enormous potential for solar thermal power plants. With many leading German companies affiliated as partners, the Desertec Industrial Initiative (DII) in Germany is also working to examine the possibility of provisioning Europe with electricity from solar power plants in North Africa.

Research funding objectives

Germany’s geographical location makes it unsuitable for solar thermal power plants. The high percentage of diffuse sunlight, average sunshine hours of between 1,300 and 1,900 depending on the particular latitude, and frequent cloud coverage are conditions that do not permit a continuous power plant process and the economically viable generation of electricity.

Nevertheless, over the long term the prospect of importing solar electricity from North Africa could make a key contribution to securing the supply of energy in Europe, and could also act as a building block in Germany for future, demand-based energy from renewable sources. Furthermore, the technology needed for solar thermal power plants has a high potential for export sales. German companies and research centres are among the technology leaders in the field of solar thermal electricity production. Power plants are planned and designed, and system and location analyses created, on the basis of research results compiled over several years. Key components of solar thermal electricity systems developed in Germany are supplied to many solar thermal power plant projects.

For this reason, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety promotes measures that bring about a further significant reduction in specific investment costs and thereby electricity production costs. Furthermore, the labour and costs involved in running and maintaining plants must be kept to a minimum. Industry-led research and development projects are of particular interest to the Ministry.

Key strategic funding areas

The focus is on the three primary areas of technology:

- Parabolic trough systems
- Fresnel systems
- Solar towers

Research funding in these areas aims to drive down costs by modifying the collector design, improving power plant design and optimising and automating plant operation and maintenance. In particular, higher operating temperatures can boost overall plant efficiency, which can help cut the costs of electricity production. This requires specific technological approaches, such as alternative heat-transfer fluids for parabolic trough plants to replace the heat-transfer oil currently used, or receivers for power towers that allow operating temperatures of up to 1,000 °C and could increase the efficiency of power plant processes if used in conjunction with a gas turbine, for example.

4.5.1 Parabolic trough systems

Over 95 percent of all commercially operated solar thermal power plants are parabolic trough plants. Despite the fact that the heat-transfer oil currently used has a maximum operating temperature of 390 °C, and despite the resulting maximum live steam temperature of 370 °C, this type of power plant has proved its worth and is becoming increasingly popular, with different product versions and improved components available. The electricity production costs at all the plant sites are still well in excess of 20 ct/kWh. For this reason, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety primarily supports projects that help cut costs further by:

- Modifying the collector design, improving power plant construction and optimising and automating plant operation and maintenance
- Enabling higher operating temperatures which help boost plant efficiency. At present, water/steam and molten salt are being examined as alternatives to the oil currently used exclusively as the heat-transfer fluid.

4.5.2 Fresnel systems

Fresnel systems are a variant of parabolic troughs. The Fresnel systems currently in operation have a total global capacity of close to 10 MW and a further 30 MW are under construction. The production costs for Fresnel collectors are lower than for parabolic troughs. A primary difference lies in the lower concentration of solar radiation, which results in higher optical loss on Fresnel collectors and thereby lower efficiency levels. Water/steam is the heat-transfer fluid used. Fresnel power plants currently in operation produce wet steam with a temperature of roughly 280 °C. Projects that help deliver the energy production opportunities expected at live steam temperatures of 450 °C and pressures of 70 bar are a specific funding area.

4.5.3 Solar towers

Solar towers can achieve high operating temperatures of up to 1,000 °C. High-efficiency solar thermal power plant processes are therefore possible in conjunction with a suitable gas turbine. The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety assigns priority to supporting projects that refine and advance the power plant concept with a volumetric air receiver and further develop and test the components necessary for a tower power plant. Germany has the necessary technical framework in the Jülich experimental power plant.

4.5.4 Integrated storage modules

A key advantage associated with solar thermal power plants is the ability to integrate storage systems into the power plant. By buffering energy, it is possible to produce electricity to match market needs, regardless of the availability of wind or sunlight. Solar thermal power plants can store heat, which will be cheaper than storing electricity for the foreseeable future. Research into solar thermal power generation is therefore closely linked to work on thermal storage modules. Salt-based thermal storage systems, like those used in the Andasol power plants in Spain, are the current state of the art. Concrete storage modules designed to accommodate temperatures up to 400 °C have been developed in recent years. The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety specifically supports the development of low-cost thermal storage systems for higher temperatures which are adapted to the particular power plant process and heat-transfer medium.

General cross-sectoral issues

Furthermore, funding is also provided to projects which focus on:

- The development of measuring and qualification methods, including the development of standards and norms to safeguard development
- The development of maintenance strategies that are central to efficient, low-cost plant operation
- The modification of conventional power plant components to suit the mode of operation of solar thermal power plants

In this connection, research funding measures of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety also support research into the hybrid operation of solar thermal power plants which involves the additional use of fossil fuels or renewable energy sources to ensure continuous electricity generation in the power plant.

4.6 Hydropower and ocean energy

Apart from wind energy, **hydropower** is a time-tested source of renewable energy in Germany, accounting for over 20 percent of the renewable-derived electricity produced in 2009. Hydropower plays a particularly important role in the energy mix in the base load range. An advantage of using these energy sources compared with renewable energy from wind and the sun is that a fairly constant supply of energy is available at all times.

The technology used in hydroelectric plants is largely mature.

Technical innovations for turbines and generator configuration improve plant efficiency in particular. Hydropower has to meet increasing environmental and ecological requirements. For example, hydropower plant operators are now required to take suitable measures to protect the fish population and ensure upstream and downstream passability even if suitable knowledge or technology is not always available to deliver on this obligation. For this reason, research funding provided by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety in the field of hydropower continues to focus on the more environmentally and ecologically compatible design of hydroelectric plants in order to optimise the plants from an ecological perspective and reduce plants' impact on fish and sensitive floodplains.

In contrast to the conventional utilisation of hydropower on land, the exploitation of **ocean energy** is still in the demonstration stage worldwide, although there is great global potential for harnessing the power generated by tides, ocean currents and waves to produce electricity. Both the tidal range (the periodic rise and fall of the sea level) as well as the energy carried by currents and waves can be used to produce electrical energy. Due to the low flow rates of the ocean currents, the low wave height and the low tidal range, the German North Sea and Baltic Sea do not hold much promise for obtaining energy from waves and ocean currents. The future of such plants is in regions with a relatively constant, strong flow pattern and a wave climate. Suitable sites in Europe are found along the coasts of Great Britain, Ireland, Norway, Spain, France and Portugal. However, German industry can capitalise on opportunities presented by growing export markets in this field. Therefore, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety provides support on an appropriate scale to research projects that concentrate on the development and demonstration of ocean current turbines and wave energy converters, with a particular focus on the environmental impacts of the technologies.

4.7 Integration of renewable energy and alternative energy supply systems

Background and current energy status

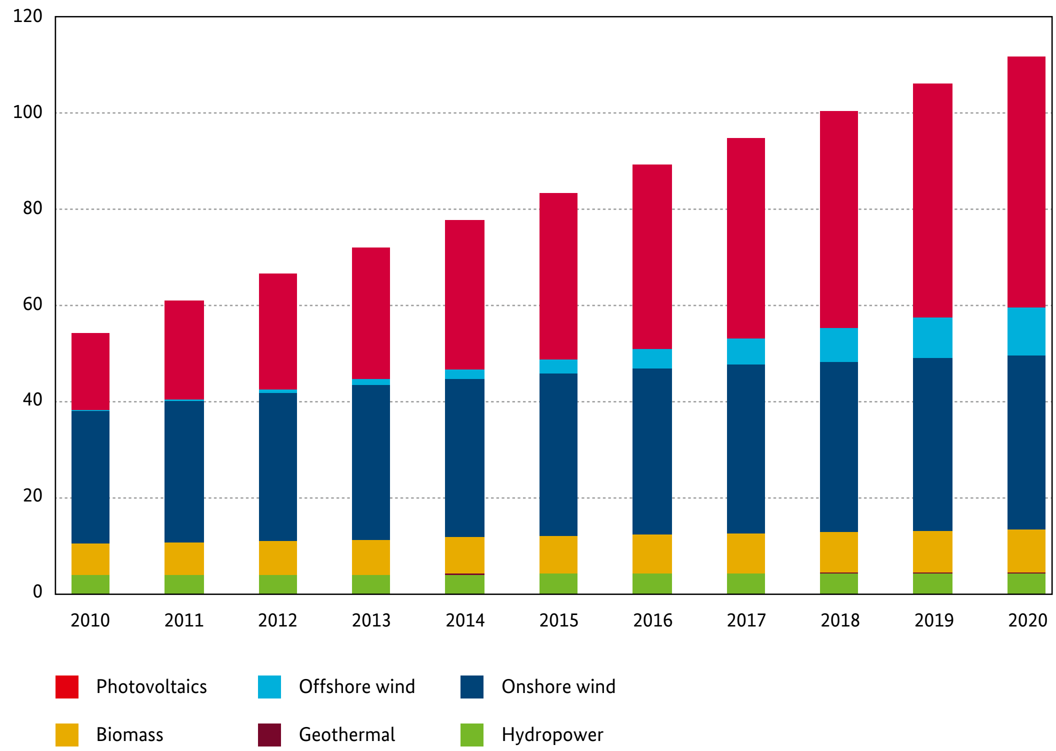
The transition to the new energy era demands a thorough overhaul of energy supply systems. The current energy supply system is limited in its capacity to meet the future demands of a modern, environmentally compatible energy supply system built on renewable energy sources. Furthermore, the time is right: aging grids and power plants would need to be upgraded in the coming years so this presents a perfect opportunity to revamp the current electricity system.

Wind energy and photovoltaic installations with a nominal power output of roughly 98 GW are expected to be installed in Germany in 2020 (National Renewable Energy Action Plan of 4 August 2010). Germany's demand for electricity currently varies throughout the year, but only within a range between 40 and 80 GW. Therefore, wind power and photovoltaic systems alone will be able to cover the country's entire electricity needs more and more frequently, and even produce a surplus (Fig. 4.4).

The future energy supply system must be designed to accommodate the growing share of intermittent energy from renewable sources. It is therefore essential to optimise how renewable electricity production and energy consumption are aligned. To this end, renewable energy production needs to be more demand-oriented, while demand itself must become more flexible through measures such as load management etc. The storage of renewable energy and the evolution of grid technologies designed to receive a large share of electricity from renewable sources will play a key role. Furthermore, renewables must also increasingly deliver system services which are largely provided by fossil-fueled power plants at present.

As decentralised renewable energy plants on the distribution grid continue to grow, our current energy network is shifting from a unidirectional energy system to a system with bidirectional traffic. Situations in which more energy is fed into the grid than is actually consumed will become all the more common. As a result, previous "distribution-only" networks will have to act

Fig. 4.4: Projected development of installed capacity of renewables in Germany



Source: National Renewable Energy Action Plan of 4 August 2010, p. 116f

occasionally as feed-in networks to supply energy to higher grid levels. Generally speaking, present-day distribution grids are not ready to cope with this task. Today's passive distribution networks must become flexible, active grids to continue to safeguard the quality of supply.

From a technical, economic and administrative perspective, the electricity production system of the future must be designed to accommodate a high proportion of renewables. Specifically, this requires the smart interaction between alternative electricity production and power consumption, with energy storage systems and modern grid technology factored into the equation. In view of the large share of electricity that will come from renewable sources, the electricity grid must evolve into a smart grid. Technological advances in this area are urgently needed.

Designating the "integration of renewable energy and alternative energy supply systems" a funding priority will make a key contribution to implementing the Federal Government's Energy Concept (see also section 1.1). As defined in the Energy Concept, the 6th Energy Research Programme also attaches priority to energy storage systems and grid technology, the integration of sources of renewable energy into the energy supply system, and the interaction of different energy technologies.

The optimisation of the energy supply system – and specifically the electricity supply system – is of prime strategic importance and a key objective of the Federal Government. The R&D issues associated with such an objective are complex and go beyond the remit of the individual ministries involved in the Energy Research Programme. With regard to the "Energy storage" and "Power grid technologies" energy themes, in particular, interministerial collaboration is the way forward in order to overcome the specific challenges facing researchers in these fields (see chapter 2). As three government ministries (Federal Ministry of Economics and Technology, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, and the Federal Ministry of Education and Research) all support research and development in these domains with different priority areas, such an approach drives synergy. In this way, these Ministries are actively helping to make way for a highly efficient energy supply system which is built primarily on renewable energy resources.

Research funding objectives

Against this backdrop, research funding that focuses on the “integration of renewable energy and alternative energy supply systems” aims to contribute to an innovative, sustainable energy system with the bulk of energy derived from renewable energy sources. To deliver on this goal, the integration of renewables must be optimised and the overall system must be aligned with the needs of a renewable energy system. Cost reduction efforts will continue to be of central importance.

Key strategic funding areas

Priority areas of research support geared toward the integration of renewables and alternative energy supply systems comprise renewable-energy CHP plants or virtual power plants; “smart” grids designed to accept a high amount of intermittent energy from renewable sources (suitable grid technologies, grid operation, load management); storage technologies to compensate for temporary fluctuations, and long-term storage solutions for seasonal variations in renewable energy; system services provided by renewables; and the enhancement of forecasting tools for suppliers of intermittent energy.

The following section will examine these priority funding areas in greater detail.

4.7.1 Renewable-energy CHP plants – virtual power plants

Combined-cycle or virtual power plants combine renewable energy production systems with storage modules and/or load management techniques to provide a way of supplying energy from renewables to match market demand. This also enables direct sales of electricity generated from renewable sources. Intermittent renewables can be linked with controllable production systems, energy storage modules and installations and equipment with flexible power consumption. Priority funding areas are:

- The development and optimisation of control solutions, information and communication structures and related standards
- The inclusion of topping-cycle CHP systems to improve the integration of renewable energy
- Load/production forecasts for combined-cycle power stations
- System services provided by combined-cycle power stations

4.7.2 Smart grids – load management

Using information and communication technology (ICT), a smart grid intelligently links electricity producers, consumers and grid equipment to optimise control of the entire system. The aim is to put a distributed system in place that compensates renewable variability. Smart grids give rise to new energy markets and new forms of energy services and products for the integration of renewable energy sources. This makes it possible for both private consumers and electricity producers (such as operators of photovoltaic systems) to play an active role in the energy markets. For this reason, funding priority is given to:

- The development of smart control equipment and meters to enable interaction between domestic consumption, domestic renewable energy production and the power grid
- The establishment of distributed smart subsystems designed to manage grid operation given high renewable penetration
- Innovative processes, instruments and solutions to further harness the untapped potential of load management to integrate renewable energy in both industry and the private sector

Issues regarding the integration of renewable energy resources into district heating and gas networks are also considered.

4.7.3 Grid technologies

The shift in the power production structure toward a renewable energy system calls for the evolution of the grid infrastructure and the development of a grid operation system that fits with the inherent characteristics of the renewable energy sources. For this reason, projects in the following fields are priority funding areas in application-related research and development:

- Modification of current grid resources, such as transformer stations in the distribution network, to have the flexibility to actively respond to variable flows of electricity, and thereby improve the quality of energy supply

- → Further development of grid connection regulations and grid operation to meet the needs of a renewable energy system
- → Development of new solutions for grid protection (adaptive protective systems) and grid security in an energy system with high levels of renewable energy
- → Better grid health monitoring and the development of the measuring technology needed to make optimum use of available grid capacity given high levels of renewable energy on the grid
- → The use of real-time data to operate distribution networks with high renewable penetration
- → Innovative electricity transmission technologies for connecting renewable energy systems (e. g. high voltage, direct current electric power transmission systems for off¬shore windparks)
- → Development of grid simulation models and planning instruments for a whole-of-system approach to planning grids that use renewable energy sources

In light of the central role grids play in the renewable energy system of the future, the participating government ministries have jointly formulated a "Power grids" funding initiative to incorporate the entire value-added chain (see chapter 2).

4.7.4 Storage technologies

Energy storage systems are a fundamental part of any renewable energy system. Given that intermittent renewable energy (wind, photovoltaics) will supply the bulk of energy in the future, Germany needs storage technologies that address different requirements, ranging from the compensation of temporary fluctuations to the seasonal (long-term) storage of variable renewable energy. Examples of priority funding areas for research, development and demonstration in this area are provided below. These projects can also be funded by the "Energy storage" interministerial funding initiative described in chapter 2:

- → Further development of storage technologies and adaptation to intermittent energy supply from renewable energy resources in the short and medium-term (e. g. redox flow batteries)
- → Development and adaptation of storage technologies to increase domestic consumption of PV electricity and reduce the load on the power grid (e. g. Li-ion batteries)
- → Long-term storage of renewable energy by converting intermittent energy supply to hydrogen or methane and then storing the gas in the gas grid, for example
- → Development of flexible electrolysers to respond quickly to transient load variations arising from intermittent energy from renewable energy resources
- → Coordination and linking of multiple small, distributed storage systems to create large virtual reservoirs
- → Provision of system services by storage systems in tandem with renewable energy sources
- → Reduction in investment costs and ramp-up times, and improvements in efficiency and service life/ life cycle
- → Use of the storage capacity of electric vehicles to manage load and feed energy back into the grid, and for balancing energy services to integrate renewable energy

4.7.5 System services

Currently, system services are primarily provided by fossil-fueled power plants. In an energy system built on alternative energy, these services must be provided by renewable energy plants and energy storage systems. While this is already possible to a certain extent today, these system services frequently remain unused. Renewable energy plants are switched off and fossil-fuel power plants are connected to the grid on the grounds of system security issues. Funding priority is given to research and development focussing on the following energy themes:

- → Development of a specific framework for system services provided by renewable energy and storage systems, e.g. development of concepts for frequency regulation in an energy system largely built on renewables

- Development of solutions and regulatory procedures to enable renewable energy systems to become active in the balancing energy market
- Further enhancement of system components, such as power inverters for grid feed-in, to provide system services
- Development of requirements and opportunities for system services provided by renewable energy plants, based on an energy system primarily derived from renewable sources of energy

4.7.6 Forecasting electricity production and consumption

Forecasting the supply of intermittent renewable energy is a key planning instrument both for grid operation and energy trading. The quality of the forecasts has a bearing on the need for control-energy capacity, for example, and thereby the costs of the energy system. In addition to production forecasts, load forecasts will become an increasingly important instrument in estimating resources for load management activities. Research is required to:

- Improve electricity production forecasts for wind and photovoltaic energy
- Extend the time scale for forecasts to e.g. 96 hours, week
- Improve regional forecasts, taking special weather conditions and regional phenomena into consideration
- Improve the forecasts of extreme events
- Develop a risk management system with warnings and uncertainties
- Forecasts on cable transmission capacity to improve grid capacity utilisation in order to minimise curtailment of electricity from renewable energy plants
- Load forecasts for estimating the resources available for load management (including electric vehicles) in order to promote the integration of renewable sources of energy

4.8 Cross-cutting research: conditions for greater renewable penetration

Appropriate political, social, environmental and economic conditions must be created and followed before we can deliver on the goals of expanding and developing the renewable energy base. To this end, the current energy supply system must be developed further, with a focus on transforming the energy supply system into a system built primarily on renewable energy sources, and on the market and system integration of renewables. This also involves identifying the economic and environmental framework for a high renewable content in an optimised energy mix, and ensuring a secure, economically viable and socially and ecologically compatible energy supply at all times. Appropriate studies can be sponsored as part of cross-cutting research programmes of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. The specific priority areas are regularly defined in separate calls for proposals geared toward the overall strategy of further expanding the renewable energy base.

4.9 Budgetary funds

Project funding provided by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (in thousand of €)

	Actual 2010	Planned 2011	Projected Data 1), 2) 2012	2013	2014
Renewable energy	120,202	128,866	148,866	158,366	158,366
Energy and Climate Fund	–	22,000	16,000	71,400	91,000
Total	**120,202**	**150,866**	**164,866**	**229,766**	**249,366**

1) Figures relating to the federal budget are subject to parliamentary approval.
2) Funding for the Energy and Climate fund is subject to change.

5. Research funding provided by the Federal Ministry of Food, Agriculture and Consumer Protection

5.1 Bioenergy – facts and figures

Background and current energy status

Bioenergy is already a key pillar in Germany's renewable energy power supply system [1].

According to data supplied by the Working Group on Renewable Energy (AGEE-Stat), 243.5 TWh of final energy in 2009 were derived from renewable energy sources, 70 percent of which originated from biomass. Accounting for a 43.2 percent share, heat produced from biomass still beat wind energy as the single most important source of heat from renewable energy. Biofuels contributed 13.9 percent to final energy production and 12.5 percent to electricity production. (Fig. 5.1)

Biofuels are the only renewable fuels currently available. Of the 33.8 TWh produced from biofuel, biodiesel accounted for 76.9 percent, ethanol for 20 percent and vegetable oil for 3.1 percent.

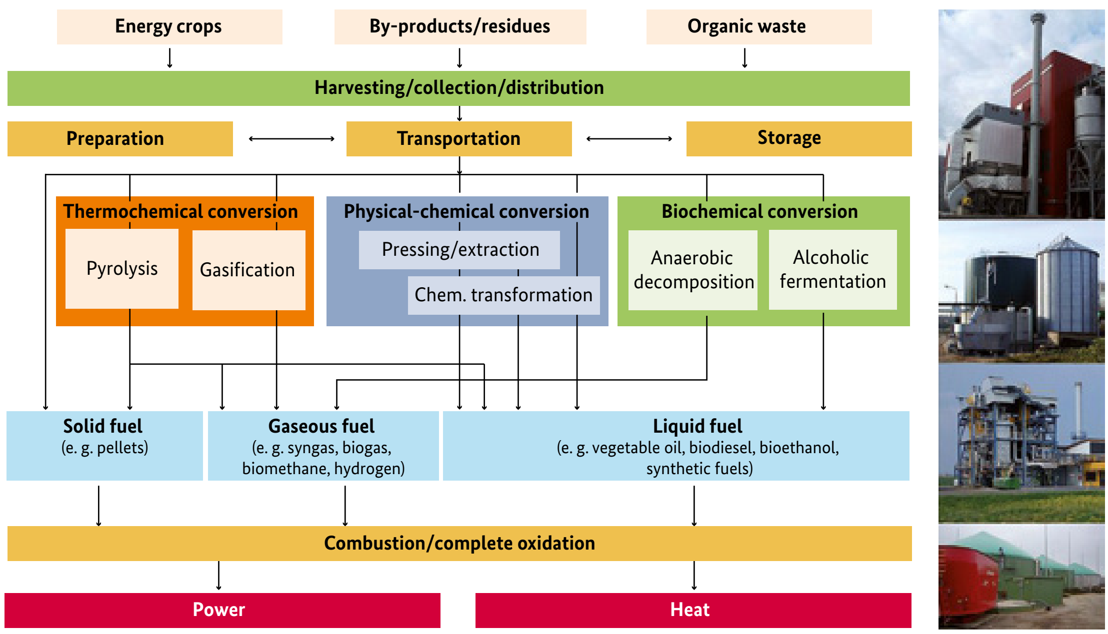
In 2009, the use of renewables prevented the equivalent of some 109 million tonnes of CO_2 emissions, with biomass contributing roughly 47 percent to this result.

The possibilities of generating energy from biomass are particularly wide and varied, as Fig. 5.1 demonstrates.

Bioenergy also plays a key role as an economic factor in the field of renewable energy. The value add from the operation of bioenergy plants in 2009 totalled €9.15 billion (total for all renewables: €17.1 billion), and investments of €12.6 billion were also made in the bioenergy field (total for all renewables: €37.5 billion). This was associated with roughly 110,000 jobs, up from 2004 when the number of individuals employed in the bioenergy industry was in the region of 57,000.

This trend also benefits local agriculture. The cultivation of energy crops grew from 1,701,500 ha in 2009 to 1,834,000 ha in 2010. Apart from the cultivation of rapeseed for biodiesel/vegetable oil on 940,000 ha of

Fig. 5.1: Possible sources of energy from biomass



Source: after German Biomass Research Centre, 2010 land, the cultivation of crops for biogas production over an area of 650,000 ha was a key contributing factor to this increase. Of Germany's 12 million ha of arable land, roughly 2.15 million ha were used for the cultivation of renewable resources in 2010.

The Federal Government's Energy Concept unveiled on 28 September 2010 presents new challenges for the use of bioenergy. With primary energy consumption simultaneously expected to almost halve by 2050 – down from today's 14,000 PJ to approx. 7,000 PJ – the contribution biomass makes to primary energy production is set to increase immensely, as the following graphic illustrates (Fig. 5.2).

Furthermore, 80 percent of the possible 2,200 PJ which bioenergy is expected to provide in 2050 will be sourced in Germany. In this connection, increasing the use of biofuel to produce up to 880 PJ – a six-fold increase on today's levels – also presents a particular challenge. The Federal Government's Energy Concept therefore clearly illustrates that research, development and demonstration activities in the provision and use of bioenergy will continue to assume an important role (Fig. 5.3, p. 86).

Institutional research funding

Research support has also been stepped up considerably since 2008 with the inception of the German Biomass Research Centre (DBFZ) in Leipzig, which was established to consolidate interdisciplinary application-related research, technology appraisal, and advice for policymakers into one institution. The DBFZ is therefore the chief German institution for research in the field of bioenergy.

Technological developments and funding structure

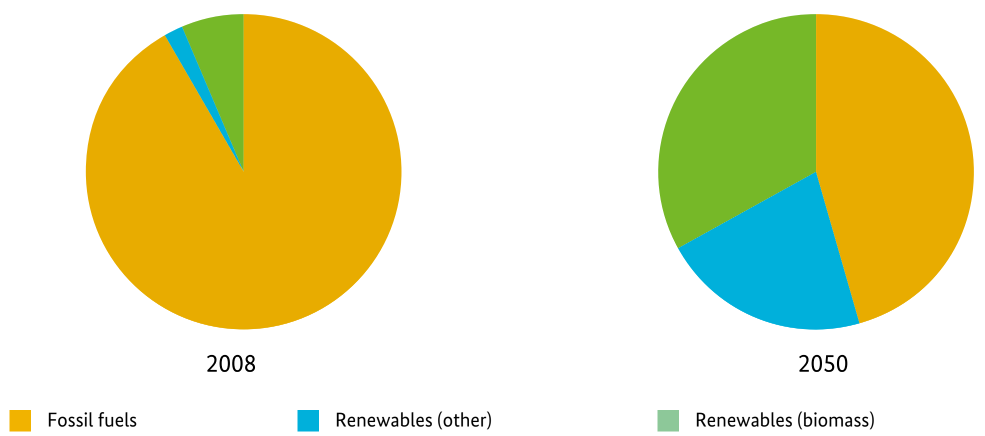
Since 1993, the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) has been supporting RD&D in energy recovery from renewable resources in Germany through the "Renewable Resources" [2] funding programme.

Potential projects must meet the following conditions to qualify for possible funding from the "Renewable Resources" funding programme:

- Contribute to a sustainable supply of raw materials and energy
- Protect the environment by conserving resources and reducing carbon emissions while also maintaining the natural ecosystem balance
- Secure and improve the competitiveness of Germany's agricultural and forestry sectors

Furthermore, funding can only consider renewable feedstocks, i.e. biomass specifically produced in Germany's agricultural and forestry industries for energy or non-energy use, as well as waste and by-products of agriculture and forestry, such as straw, grain waste or

Fig. 5.2: Contribution of different primary energy sources to primary energy consumption in 2008 and forecast for 2050



The graphic does not factor in the planned 50 % reduction in primary energy consumption

Source: prognos AG; energy scenario for an Energy Concept presented by the Federal Government 08/2010; 2050 = scenario II A manure. Industrial and municipal organic waste and residues cannot be considered.

The "Renewable Resources" funding programme is not exclusively limited to energy research. Energy is just one of many areas of this programme, which also supports the non-energy use of renewable resources, or public relations activities. Currently, some 40 percent of funding is allocated to projects focussing on the use of renewable resources for energy production, roughly 40 percent to the non-energy use of renewable resources, and roughly 20 percent to consumer awareness activities.

With the creation of the special "Energy and Climate Fund" [3], the Federal Government is making additional research funding available from 2011 to increase the penetration of renewable energy sources. Within the remit of the Federal Ministry of Food, Agriculture and Consumer Protection, additional funding is available for R&D on the use of renewable resources for energy production. Six additional priority funding areas could be introduced as a result:

- Plant breeding to adapt energy crops to climate change
- Smart solutions for the combined use of bioenergy and other sources of renewable energy
- Increased efficiency for distributed bioenergy solutions
- Development of conversion methods to use algae to produce renewable energy from renewable feedstock
- Biofuels
- Studies into the humus and nutrient value of organic residues from biomass conversion plants

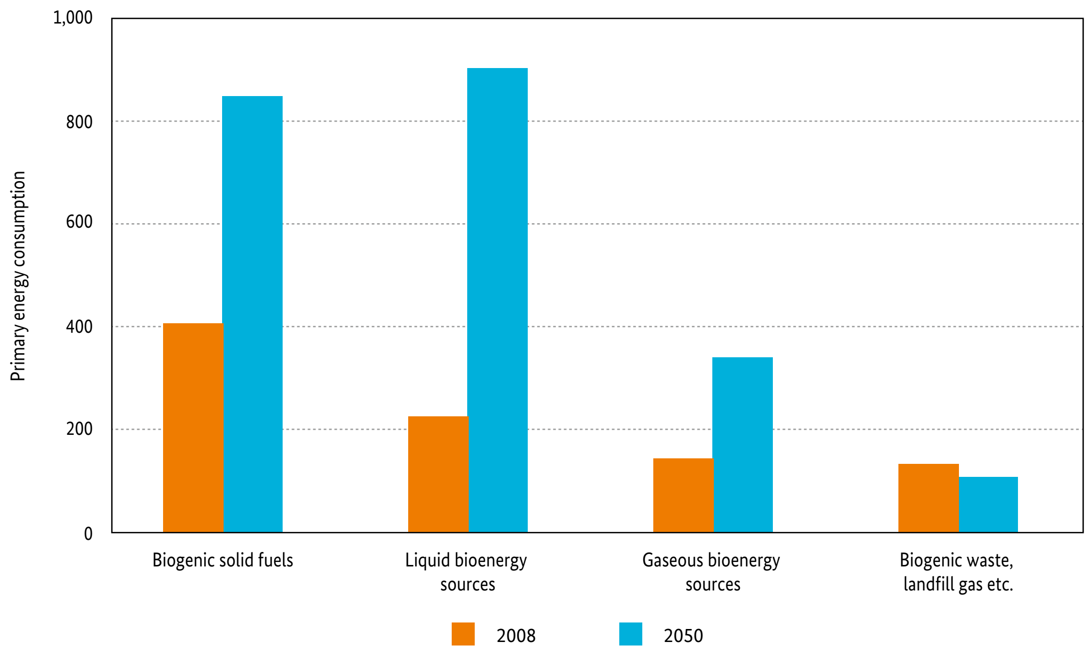
The funding programme is managed by Fachagentur Nachwachsende Rohstoffe e.V. (FNR), a project management organisation based in Gülzow. Further information on the structure of projects is available at www.fnr.de.

Application-oriented research support provided by the Federal Ministry of Food, Agriculture and Consumer Protection is coordinated closely with funding for basic research into bioenergy provided by the Federal Ministry of Education and Research.

Current state of research

Bioenergy is different from other fields of energy research given the variety of possible approaches to

Fig. 5.3: Contribution of different biomass energy sources to primary energy consumption in 2008 and 2050



Source: prognos AG; energy scenario for an Energy Concept presented by the Federal Government 08/2010; 2050 = scenario II A bioenergy production, the competition for land and competing product uses. In light of the heterogeneity of renewable feedstocks or waste and by-products of the agricultural and forestry industry, there is no "one-size fits all" solution to biomass usage. This is why the "Renewable Resources" research programme takes a "whole-of-system", incorporating the entire value added chain.

Cultivation and breeding – sustainability

As a cross-sectoral issue [2, 4] in the field of bioenergy, the cultivation and breeding of crops is of central importance to the future supply of feedstocks across all conversion routes. The increased use of bioenergy as formulated in the Federal Government's Energy Concept is contingent upon the sustainable and effective provision of renewable feedstocks from the agricultural and forestry sector which are not in competition with food production or other uses. The Federal Ministry of Food, Agriculture and Consumer Protection has been supporting this development for many years, such as in the form of the "EVA" multi-phase collaborative project on energy crop cultivation.

While sustainability has been an integral part of everyday agricultural and forestry practice in Germany for centuries, the environmentally and ecologically compatible production of biomass has become a central issue when it comes to public acceptance of biomass. This is due to the significant growth in the demand for biomass for energy needs and the resulting increase in imports of biomass and products such as palm oil. Furthermore, the broader public and nature conservationists are critical of the increased cultivation of certain types of energy crops, such as corn, witnessed in many regions.

The criteria for appraising and assessing sustainability must also be updated, however. The sustainability criteria introduced at the national and European level as part of the Directive on the Promotion of the Use of Energy from Renewable Sources and the Directive on the Promotion of the Use of Biofuels ignore many elements of good agricultural practice, such as crop rotation which was introduced to maintain the long-term fertility of the soil. For this reason, the requirements must be updated and any changes must be supported by research and development measures, such as measures to determine greenhouse gas emissions. Against this backdrop, the Federal Ministry of Food, Agriculture and Consumer Protection also supported the development of the ISCC certification system. Given the fundamental importance of cultivation and breed-

Fig. 5.4: Cultivation trials with the "cup plant" (perennial energy crop, grows quickly and can endure extremely dry conditions, Latin name: Silphium perfoliatum) as an alternative to classic renewable resources [5]

Graphic source: Fachagentur Nachwachsende Rohstoffe e. V.

ing for biomass production, and the sustainability of such activities, the Federal Ministry of Food, Agriculture and Consumer Protection assigns priority to energy crop production in the "Renewable Resources" funding programme (see section 5.2) (Fig. 5.4, p. 87).

Solid bioenergy sources

Solid biomass, which primarily comprises wood or wood products such as pellets, is chiefly used to produce heat for space heating or short-distance district heating. As already mentioned in the "Background and current energy status" section, space heating from solid biomass accounts for a large share of the energy produced from renewable sources.

With regard to heat generation, there is a considerable need for R&D particularly in small combustion installations that fall under the scope of the First Ordinance for the Implementation of the Federal Immission Control Act *(Erste Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes, (1. BImSchV)).* The recent amendment to this Ordinance introduced a series of more stringent emission thresholds. As a result, a sharp decline is expected in the use of biogenic fuels in installations that are affected by the Ordinance. Appropriate support measures must therefore be introduced to head off such a development. In particular, the use of alternatives to wood – i.e. other solid biomass sources, such as straw, cereal residues or mixed pellets – must be examined and elaborated further. Given the important role solid biomass currently plays in installations falling under the scope of the First Ordinance for the Implementation of the Federal Immission Control Act, further development in this area is a funding priority of the Federal Ministry of Food, Agriculture and Consumer Protection (see section 5.3).

For economic reasons, electricity production in combined heat and power (CHP) plants is concentrated on scrap wood and waste wood. While forest timber or agricultural biogenic fuels are rarely used in large installations with a thermal input above 1 MW, forest timber and alternative solid biomass sources can play a key role in smaller installations in the future. Wood can be used in association with the established steam-power process which enables state-of-the-art electricity generation.

Up to now, CHP systems that use solid biomass other than wood have failed on account of the combustion properties of alternative fuels, such as straw or energy grain. Furthermore the regulations of the German approval system are restrictive (e.g. emission thresholds), making it difficult to adopt technically sound solutions, such as those used in Denmark. There is a clear need for research and development in this area in order to force the pace on combustion technologies in a German framework.

In theory, thermochemical processes, such as gasification, could present another way for CHP plants to use solid biomass, also in conjunction with other processes, like pyrolysis for example. Despite numerous development approaches in the past two decades, only one process could be brought to market. This process was developed in Austria and first used in the plant at Güssing. A project building on this process is currently being implemented in Ulm in Germany with support from the Federal Ministry of Food, Agriculture and Consumer Protection. Every other attempted approach in Germany has failed to reach the market. Thermochemical gasification will remain an option for the use of solid biomass for energy production. However, given its long development history, new funding measures will have to be analysed and considered very carefully.

Other approaches to using solid biomass, such as pyrolysis or hydrothermal processes, are currently under development. Projects must be examined on a case-by-case basis to determine whether possible research and development needs can be covered by the "Renewable Resources" funding programme.

Gaseous energy sources [7]

The past decade has seen a massive increase in the quantity and performance of plants using gaseous fuels that are not derived from decomposition processes. Many companies have been set up, and the German biogas industry occupies a leading position worldwide. In addition to traditional CHP systems, the injection of upgraded biogas, known as biomethane, into the natural gas grid has become increasingly important in the past two years. Biomethane can therefore be used for stationary applications and also deployed as a fuel. In addition to traditional biogas plants, over 50 plants with gas-grid injection are now successfully in operation. Continued and appropriate research and development support is now essential to secure this development leap. Plant technology, process control systems and substantial cost savings in biogas processes must be optimised and delivered for new crops supplied by plant cultivation and breeding projects, which give due attention to agricultural biodiversity.

Process optimisation and process enhancement – ranging from substrate conditioning to fermentation processes and digestate treatment – are key areas for future research and development. The processes must be further refined with a view to maximising biogas yield while ensuring high gas quality, low methane loss and production sustainability (see section 5.4). As the injection of upgraded biogas into the gas grid is becoming increasingly important, upgrading processes must be further enhanced.

Overall, funding and support in the biogas sector is a good example of the interplay between entrepreneurial activities and public funding measures.

Liquid bioenergy sources [8, 9]

Apart from biomethane as a gas energy source, liquid bioenergy sources are the only marketable alternative to fossils fuels today. Policymakers have confirmed the continued use of biofuels in the Biofuel Quota Act *(Biokraftstoffquotengesetz)*. Biofuels are primarily used by blending fatty acid methyl esters (FAME) from vegetable oils, and ethanol from starchy and sugar-rich crops, with hydrocarbon-based petrodiesel. Hydrogenated or hydrotreated vegetable oils (HVO) are also blended with the fuels. Political conditions have led to a decline in the importance of vegetable oils. The production of conventional FAME, ethanol and HVOs is state of the art and the production methods are commercially proven. To qualify for public funding, research and development must focus on meeting dynamic sustainability requirements which must bring about a further significant reduction in greenhouse gas emissions in the coming five to seven years. There is a particular need for development in the field of unblended fuels as more stringent emission thresholds mean future engine generations must meet stricter technical requirements. While general research levels must be maintained in this area, it must be said that this application is increasingly restricted to niche markets. Therefore, market viability will have a bearing on whether proposed R&D projects will qualify for funding or not.

Measured against the scenarios presented in the Energy Concept of the Federal Government – suggesting, in some cases, a fourfold increase in the use of biofuel by 2050 – it is important that we broaden the resource base by using the entire crop or considering alternative sources (e.g. algae biomass), and that we develop new conversion routes. This could include generating ethanol from lignocellulosic biomass or the recovery of synthetic biofuels through thermochemical processes (e.g. Fischer-Tropsch fuels, biomethane via bio-synthetic natural gas (SNG), dimethyl ether etc.). The Federal Ministry of Food, Agriculture and Consumer Protection has demonstrated its clear commitment to research in this area by sponsoring the bioliq process developed by the Karlsruhe Institute of Technology (KIT).

As a result of increased emissions trading, additional sectors of the transport industry will look to biofuels as a solution, with the aviation sector already expressing interest in this area. The biodiesel demands of these sectors are vastly different from those of road-based transport systems. Research and development is needed in this field. The involvement of German businesses will be a key factor in deciding the form and scope of future funding measures.

Key strategic funding areas

Under the funding programme, a wide range of themes can qualify for funding – ranging from cross-sectoral issues such as plant cultivation, breeding or PR activities to specific issues concerning solid, liquid or gas energy sources. The individual priorities in the "Renewable Resource" funding programme and the Energy and Climate Fund are described in detail below as general R&D themes.

Thanks to the creation of the Energy and Climate Fund and the associated funding provided, it has been possible to develop horizontal R&D priority areas in the field of bioenergy:

- Smart solutions for the combined use of bioenergy and other renewable sources of energy (coordinated with the ministries responsible)
- Increase the efficiency of decentralised bioenergy production solutions

One particular objective of these priority areas is to make the energy use of renewable resources more efficient and to increase solution integration, while protecting the natural environment and biological diversity as much as possible.

In addition to providing details on the priority areas, the section below will also specify the funding priorities announced by the Federal Ministry of Food, Agriculture and Consumer Protection.

5.2 Sustainable biomass production

This research topic includes crop breeding and cultivation with a biomass logistics system, as well as mechanisms that safeguard sustainable production while protecting the natural environment. Key action areas include:

→ Adaptation of energy crops to climate change

→ Research into crop breeding to establish new crops and develop cultivation methods/crop rotation systems

→ Optimised cultivation methods with regard to crop yield, use of resources, water protection, biodiversity and sustainability [10]

→ The analysis, improvement and adaptation of measurement and evaluation methods to determine relevant emissions for energy crop cultivation

The Federal Ministry of Food, Agriculture and Consumer Protection has declared "energy crop production" the priority of the "Renewable Resources" funding programme in 2011. This will focus on agronomic, agricultural and logistic research activities, as well as research into breeding techniques and suitable measures to assess the contribution of new crops to increasing agricultural biodiversity in the German agricultural sector. This results in the following project themes:

→ The optimisation of energy crop production

→ New energy crops for biomass production in Germany

Thanks to the additional funding available from the Energy and Climate Fund, "crop breeding to adapt energy crops to climate change" has also been defined as a priority area, helping to step up R&D activities in this field.

Furthermore, the "development of conversion routes to use algae to produce renewable energy from renewable feedstock" has also been declared a priority on the basis of additional funding available through the Energy and Climate Fund. The aim is to combine renewable resources and algae to create new sustainable product lines.

In the interests of a closed substance cycle, it is also essential to feed waste material from biomass conversion back to agricultural and forestry land, wherever possible. To this end, the "analysis of the nutrient and humus value of organic waste from biomass conversion plants" constitutes a further focal area funded through the Energy and Climate Fund. Work in the area will concentrate specifically on digestate from biogas plants.

5.3 Solid bioenergy sources

Background and current energy status

Given the importance of biomass-derived heat in the context of renewable energy, the need for R&D in the field of solid bioenergy sources is dominated by recent changes to the legal framework, particularly the amendment to the First Ordinance for the Implementation of the Federal Immission Control Act.

This has prompted the Federal Ministry of Food, Agriculture and Consumer Protection to announce a specific funding priority in this field for 2011. This comprises application-oriented projects designed to conduct research into new and innovative methods, processes and strategies for utilising solid biofuels as an energy source. The following key themes have been defined:

→ Development of environmentally friendly, effective and efficient biofuels for heat generation as an alternative to wood

→ Environmental compatibility of biofuels in small combustion installations as defined under the First Ordinance for the Implementation of the Federal Immission Control Act

Given the pressing need for R&D to address the First Ordinance for the Implementation of the Federal Immission Control Act, research and development themes include:

→ Enhancing energy efficiency in the use of solid biofuels

→ Development, testing and appraisal of mixed fuels, with a particular focus on assessing the potential of certain types of biomass feedstock not currently used

- Development and testing of decentralised high-efficiency cogeneration or trigeneration processes

- Preliminary treatment of solid biomass feedstock, particularly by thermochemical or hydrothermal means, to produce syngas, for example

5.4 Gaseous bioenergy sources/biogas

The need for R&D in biogas is very practice-driven. Additional research is required both in fundamental biotechnological processes and in ways to reduce negative environmental impacts. Recognising this, the following have been identified as key areas for research and development in the biogas field:

- Gaining a better understanding of the biogas process

- Using additives (enzymes, minerals etc.) to increase biogas conversion efficiency

- Improving process control techniques by refining and enhancing instrumentation and control technology

- Reducing negative effects on the environment (through technical developments and innovations, and by introducing strategies for the efficient use of biogas as an energy source)

- Optimising technologies and biomethane supply chains in large and small output facilities

5.5 Liquid bioenergy sources/biofuels

Measured against the energy scenarios presented in the Federal Government's Energy Concept, there is a clear need to significantly increase the use of biogenic fuels in the future. As already mentioned, transport sectors other than road-based transport systems have also expressed interest in biofuel, a fact which must be factored into future R&D in this field:

- Development and testing of new, highly efficient production routes for the production of biofuels

- Development, testing and appraisal of fuel blends with variable biogenic content

- Assessment of the possibility of using biogenic fuels in areas other than road transport, such as shipping, air or rail

The Federal Ministry of Food, Agriculture and Consumer Protection has initiated the "Biofuel" funding initiative under the Energy and Climate Fund. This initiative is designed to promote:

- Innovative approaches to boost the efficiency and reduce greenhouse gas emissions of legacy biofuel plants

- Demonstration projects for innovative production processes

The "Biofuel" funding initiative is application-oriented.

5.6 Budgetary funds

Project funding provided by the Federal Ministry of Food, Agriculture and Consumer Protection (in thousand of €)					
	Actual	Planned	Projected Data [1), 2)]		
	2010	2011	2012	2013	2014
Bioenergy	23,168	25,000	25,000	25,000	25,000
Energy and Climate Fund	–	9,000	6,500	29,300	37,000
Total	**23,168**	**34,000**	**31,500**	**54,300**	**62,000**

1) Figures relating to the federal budget are subject to parliamentary approval.
2) Funding for the Energy and Climate fund is subject to change.

Institutional funding for the German Biomass Research Centre (DBFZ) constitutes another focal area of research funding into the use of biomass for energy purposes, with roughly €5 million allocated to the centre every year.

References:

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[3] Fachagentur Nachwachsende Rohstoffe e. V. (2011): *(German Agency for Renewable Resources)* Funding Priority of the Energy and Climate Fund. Available for download at: http://www.nachwachsenderohstoffe.de

[4] Agentur für Erneuerbare Energien e.V. (2009): *(German Agency for Renewable Energy)* The Full Picture of Renewable Energy. Available for download at: http://www.unendlich-viel-energie.de

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[10] Fachagentur Nachwachsende Rohstoffe e. V. (2010): Energy Crops Cultivation Systems Adapted to Suit Local Conditions. Available for download at: http://www.fnr-server.de

6. Research funding provided by the Federal Ministry of Education and Research

6.1 New research agenda

Germany is ramping up the development and expansion of renewable energy. This transition to a clean energy economy requires political and social change at the deepest levels. The scale of this challenge demands a broad consensus in society on the goals set out and the strategy for goal delivery. This calls for both social innovation and technological ingenuity.

Science and research are central to this process. Without scientific expertise, a new energy era is simply inconceivable. What we need now are both short-term solutions and long-term technological and social alternatives to meet the new objectives of energy policy. As the country's energy roadmap through to 2050, the Federal Government's Energy Concept also provides a reliable framework for guiding basic research.

We owe it to future generations to stay the course and develop a sustainable energy economy. This will demand continuity and perseverance, creativity and diversity. For this reason, the Federal Government is encouraging and promoting research for a new, long-term energy perspective. We must reduce our dependency on fossil fuels and continue to lend scientific support to phasing out nuclear power and reengineering our energy supply system toward renewable sources.

By implementing specific funding policy measures, the Federal Ministry of Education and Research will deliver basic knowledge for application-oriented energy research. In particular, the Federal Government's long support of research in the energy sector and the funding provided by the Federal Ministry of Education and Research to research institutions have created the infrastructure and scientific basis needed to ensure that we can set about creating a sustainable energy supply system in Germany in line with the Energy Concept and have the power to respond to unanticipated developments.

The Federal Ministry of Education and Research specifically promotes basic development, conscious of the fact that basic research and applied research are two sides of the one coin and are closely meshed. Successful innovation support must consider every link in the innovation chain and make allowances for the increasingly multidisciplinary and interdisciplinary nature of energy research. Basic research deals with topics such as electrochemistry, solid-state physics, light-matter interactions, simulations and material properties, and develops new methods and instruments for describing processes and analysing quality.

Effectively interlinking research fields that are relevant to the energy industry is also of particular importance. These include material research, nanotechnology, laser technology, microsystem technology and mathematical models, and can make a key contribution to advancing basic research. For this reason, the research activities of the Federal Ministry of Education and Research in generic technologies are closely linked to the research initiatives of the Energy Research Programme.

Socio-scientific research approaches strengthen basic research

The Federal Ministry of Education and Research incorporates research approaches from the fields of social science and humanities into the Energy Research Programme. This is because technology-aligned research alone fails to accurately factor in human-technology interaction and does not adequately consider the "acceptance factor" when new technologies are implemented. This approach supports the application-related research activities of the ministries.

Our ability to link technology issues with economic and social concerns will be central to the success of implementing new technologies in the energy sector. This is why future research funding measures must regard economic and sociological aspects more and more. For this reason, the Federal Ministry of Education and Research will address methods and procedures that are important for answering acceptance issues, rendering the introduction and distribution of new energy technologies more transparent, and identifying utilisation and demand patterns. Research funding from the Federal Ministry of Education and Research will be carried out in parallel with the analysis of political, sociological, ecological and economic conditions governing cross-sectoral research of the other ministries.

Alternative solutions and new options for the future of energy

Germany's decision to abandon nuclear power clearly underlines how important it is for energy research to provide a broad range of options to ensure a secure supply of energy even if framework conditions change.

Therefore it is essential to take precautions and make sure alternative solutions and strategies are available in time.

Restructuring the energy supply system in Germany will raise many currently unknown or unforeseeable issues that can only be resolved in a predictable time frame on a sound knowledge base.

For this reason, the Federal Ministry of Education and Research will establish an "energy technology radar" as part of the Energy Research Programme to facilitate early identification of progress in fundamental research and to create links to application-related research.

Furthermore, energy researchers will be given the chance to explore new ideas and unconventional approaches, since many of today's extremely successful innovations were the brainchild of scientists who moved away from the mainstream and thought outside the box. With its "Energy: Powerhouse of Ideas" initiative, the Federal Ministry of Education and Research has created a flexible research funding instrument which aims to identify and act on new ideas in energy research at an early stage, and act as a sounding board for ideas that have not yet been given due consideration in a conventional setup.

A systemic approach

Through targeted research funding, the Federal Ministry of Education and Research will deliver cutting-edge knowledge to help reengineer the energy system. Furthermore, it will help identify future research needs so Germany can deliver on the goals of the Energy Concept in the specified time frame. In doing so, due attention must be given to the complex technical and scientific environment, as well as to political, social, economic and cultural interlinkages.

The Federal Ministry of Education and Research will support the development of methods and procedures that allow continuous system analysis. Scenario development is a particularly important element of system analysis as it enables supportive and continuous research that helps pinpoint sources of error and shortcomings at an early stage. The Federal Ministry of Education and Research closely coordinates all work in this field with the other ministries.

Knowledge and technology transfer drive progress

The Federal Ministry of Education and Research will actively seek dialogue with stakeholders in the innovation process to ensure that basic development takes the needs of the energy sector into account early on. At the same time, the aim is also to ensure that research results make their way into industrial development as swiftly as possible in close collaboration with the other ministries. Instead of leaving scientific findings to "gather dust", their potential must be tapped immediately and results must be actively incorporated into the innovation process as early as possible.

More power for research funding

Basic research at the Federal Ministry of Education and Research comprises both project funding and central elements of institutional funding.

The Federal Government is committed to linking institutional funding to project funding even more closely than before, and aligns it with the objectives of the Energy Concept. The Federal Ministry of Education and Research will encourage and promote this approach for basic research. To this end, there is a need to refocus programme-oriented support of the Helmholtz Association of German Research Centres (HGF) in the energy field by formulating specific requirements of research policy which must be agreed by the ministries involved.

Fostering young research talent: laying the future foundations of cutting-edge research

Fostering and promoting young research talent is a key objective of the Federal Ministry of Education and Research. The continued training and education of specialists and experts is central to Germany's future as a location for business and industry.

With the Pact for Research and Innovation and the Initiative for Excellence, the Federal Ministry of Education and Research has paved the way to deliver outstanding support to junior scientists.

The research institutions supported already play a key role in training up the next generation of scientists in the field of energy research. One excellent example is the “KIT School of Energy,” which gives students, doctoral candidates and professionals the opportunity to identify, understand and solve the problems of a sustainable and viable global energy supply.

Linking universities and schools of applied science with research institutes and other stakeholders in the energy environment plays a central role. Special support instruments, such as research schools, junior research groups or special programmes (e. g. “research at schools of applied science”), are also implemented here.

The Federal Ministry of Education and Research also fosters young talent in the field of nuclear safety research, and in doing so makes a major contribution to ensuring key skills are available in Germany and worldwide to guarantee the safe operation and decommissioning of nuclear plants and to appraise technical developments.

A programme that learns

As with the entire Energy Research Programme, the funding initiatives of the Federal Ministry of Education and Research are intentionally designed as an open research programme that learns as it goes along (see chapter 1).

This approach gives us the flexibility to update the research agenda as necessary on a continuous basis and add new agenda topics. If the focus of the programme is changed or refined, the Federal Ministry of Education and Research will systematically seek dialogue with academia, the business sector and society in the form of regular agenda processes on basic research issues.

Creating linkages to other energy-related initiatives of the Federal Ministry of Education and Research

In its own specific research programmes and framework schemes, The Federal Ministry of Education and Research also addresses energy themes that are outside the remit of the 6th Energy Research Programme of the Federal Government, the most important being:

- Sustainable mobility strategies with a focus on battery research, energy management in electric vehicles and initial and further training
- The “Renewable Resources” and “Biomass” action areas in the “National Research Strategy - Bioeconomy 2030”
- Socio-ecological research, approaches to using CO_2 as a resource, and resource efficiency as part of the “Research for Sustainable Development” framework programme
- ICT, materials and production research
- The Geotechnology Programme

6.2 Need for action

Germany’s plans to switch to a sustainable energy supply by 2050 raises scientific, technological, economic, social and political questions and issues. As such, energy research must take a holistic approach within a whole-of-community framework and be incorporated into the set of objectives of common European energy policy.

Within its specific area of responsibility, the Federal Ministry of Education and Research is directing its research support towards the following defined action areas:

Integration of renewables into the current energy system

The Federal Government has set itself the ambitious goal of increasing the share of renewables in electricity generation to 80 percent by 2050, a goal which demands the comprehensive restructuring of the entire energy system and the power supply grids in particular.

Before Germany can enter a new energy era, the electricity grid must be engineered to accept injections of energy from decentralised supply points and to handle variable power capacity.

Only some of the technologies needed to deliver on this goal are currently available. Others are yet to be developed. If the renewable content in the energy mix increases as planned but grid development lags behind, this could have serious ramifications for the security of supply over the medium to long term. Therefore, we must strengthen basic research in energy storage and ramp up the development of suitable infrastructures (see also chapter 2).

Intensive research will produce technologies that enable the following:

- Guaranteed security of supply by accepting and storing excess energy generated by intermittent energy sources (wind and sun) and by making the stored electricity available when demand for electricity exceeds current production levels

- Cost savings in power plants. To meet load peaks, power plants will provide energy stored from times of excess energy production (strong winds, low demand) instead of generating new energy.

Implementation of basic knowledge in technological solutions

German universities and research institutions achieve many promising research results, but not all find their way into commercial applications. The reasons for this are many and varied: sometimes the institutes lack the know-how to market the solution. Furthermore, analyses of economic and social implications are often not available. Such analyses include the risks of implementing new technologies in the value chain. Therefore, the Federal Ministry of Education and Research provides incentives to continuously appraise and organise basic results in the context of the energy system and to coordinate results with users. This also involves incorporating technology transfer skills into basic research.

Provision of system analysis resources

There are many question marks surrounding the reorganisation of the energy supply system. Up until now, not enough fundamental system knowledge has been available to appraise the technical, social, political, cultural and economic interaction of the transition process with regard to future research and technology needs. Channelled through the Federal Government's planned central information system, the results of these systematic analyses will give the business community and policymakers the basis for solid decision-making. For Germany and the European community to overcome the challenges presented in reforming the energy supply system, we must pool all the expertise available, leverage knowledge and experience, and jointly assess possible solutions while taking all the relevant system aspects into consideration. Within its area of responsibility, the Federal Ministry of Education and Research will do its part to deliver on this goal.

Coordinated and concerted research funding

In following through on its own priority funding areas under the 6th Energy Research Programme, the Federal Ministry of Education and Research is increasingly focussed on close-knit, interministerial and – wherever possible – concerted research funding in as many funding areas as possible.

6.3 Basic research in energy efficiency

Expanding renewable energy sources is the preferred course of action to address climate change and depleting fossil fuel reserves. Moreover, to meet growing energy demands, energy must be used more efficiently to drive down energy consumption without compromising on quality of life. Measures run the gamut from modern, renewable and fossil fuel-based power plants to low-energy engines, household appliances and industrial processes, to energy retrofits. Many technologies are already available and can help phase out nuclear energy. Other avenues must be explored for the future.

In the field of research, new potential for boosting efficiency must be identified and utilisation strategies developed to tap the full potential of energy efficiency. The efficient use of electrical energy has priority over the short term. Research funding is geared toward maximising energy efficiency improvements in both industry and the building and transport sectors. Energy research policy goes hand in hand with smart resource policies. Energy research aimed at improving energy efficiency demands close interlinkages between basic research and applied research. Within its area of responsibility, the Federal Ministry of Education and Research is actively involved in projects both within and outside the scope of the Energy Research Programme (see also chapter 3.1). Key topics are as follows:

- There is still ample potential for energy savings in industry. Research aims to analyse the entire process chain and develop innovative logistics and production strategies based on its findings. The specific use of key technologies – such as new or improved materials and processes or electric motors – also holds considerable efficiency-enhancing potential which must be tapped (e. g. energy-efficient lightweight designs). Innovative materials offer great potential to boost the efficiency of industrial processes along the entire value chain, while also reducing the use of resources.

Basic research will make a significant contribution to energy and resource efficiency in this way.

- HVAC, lighting, warm water and IT systems are some of the biggest energy hogs in buildings, and their energy consumption needs to be reduced. Research accepts this challenge head-on and has set itself the goal of developing new energy supply systems along with the fundamental development of new technologies, components and materials (e.g. in the field of LEDs and organic LEDs). Socio-ecological research also plays an important role here. The aim must be to develop smart incentives to ensure that enhanced efficiency does not encourage consumers to use more energy (rebound effect), and to examine the effect of regulatory and consumer awareness measures.

- Currently, fossil fuels are at the heart of the transport sector. The "Mobility and Fuel Strategy" launched by the Federal Government aims to identify the medium- and long-term potential of fossil fuels and alternative fuel sources, as well as innovative drive train technologies for the transport sector. Committed to conserving valuable resources and reducing CO_2 emissions, research and development focuses on electric mobility (battery and fuel cell technology), alternative drive train and vehicle designs, and ways to optimise the overall transport system. Technological innovation aside, changes in consumer behaviour can also bring about considerable savings in electrical energy.

- Energy efficiency and resource efficiency are closely linked. Energy-intensive industries must be given the tools to make their production processes more energy efficient, while also developing, manufacturing and selling products that are competitive on the world market. Research is needed into the development of energy-efficient production technology and process engineering, as well as into the mechanical engineering and systems technology needed for this new technology. With regard to chemical processes, research into suitable catalysts is usually the key to achieving considerable energy savings.

6.3.1 Towards a carbon-neutral, energy efficient city adapted to climatic conditions

The "carbon-neutral, energy-efficient and climate-smart city" defined in Germany's High-Tech Strategy is an exemplary forward-looking project that paves the way towards a carbon-neutral society. Cities, towns and municipalities play a central role in reforming the energy supply system. Acting as both the provider and consumer, they are the nucleus and engine behind the development of decentralised structures.

This priority area promotes the development and validation of strategies aimed to enable municipalities, urban areas and communities to be carbon neutral by 2020, with the target of creating at least 30 carbon-neutral municipalities in Germany.

The results of basic research will make a key contribution to the following areas: integration of energy technologies and energy efficiency technologies, planning and balancing instruments, market incentives for new services and new financing models, such as models for retrofitting buildings and checking approval procedures.

To unlock the synergies of basic research and application-oriented research in related funding areas, the Federal Government is planning to launch the "Solar-powered buildings – Energy Efficient Cities" interministerial initiative which is described in chapter 2.

6.3.2 Climate protection: a smart approach to carbon management

A modern energy research policy considers every technological option. The aim is to identify approaches that reconcile public opinion, research interests and business opportunities. A smart approach to managing carbon dioxide is one such area.

Our long-term objective is to create a carbon-neutral energy supply system, with four specific areas making key contributions to accomplishing this goal:

(1) New carbon prevention strategies

As we expand renewable energy sources, fewer fossil fuels are needed to meet our energy needs and less CO_2 is released to the atmosphere. In mobile application, non-carbon sources of energy (such as hydrogen), or methane recovered from renewable electricity, have the potential to replace fossil fuels. The carbon-neutral provisioning of such energy sources is a decisive factor.

(2) Closed carbon cycles

Carbon fuels can only be utilised in a carbon-neutral way if CO_2 is the only source used to produce such fuels. This can apply to bioenergy, for example. Through the process of photosynthesis, plants convert carbon dioxide into biomass using the energy of sunlight. If this biomass, or fuel derived from the biomass, is used to produce energy, any carbon released is climate neutral.

(3) Trend-setting uses

The carbon cycle is not solely restricted to the energy sector. A large amount of fossil-derived raw material is used as feedstock in the chemical industry. The value-added potential of CO_2 requires further investigation so that carbon can be used as a chemical building block to produce raw materials for industry, for example. Interlinking energy supply and material reutilisation offers enormous potential. Therefore Germany's local brown coal can act as a raw material once it is no longer used as a source of energy. This requires appropriate measures to prepare for alternative coal technologies.

(4) Storage

It is important to discuss ways of dramatically cutting carbon emissions of fossil-fuel power stations and energy-intensive industrial plants. Carbon capture and storage (CCS) is one possible option. Following promising work on the CCS test site in Ketzin combined with the results of off-site research (e.g. research into the chemical reaction of carbon with the surrounding rock), research must now be continued in pilot and demonstration sites so that robust, high-quality information concerning the underground processes, the long-term safety of the storage system, and general feasibility is available for large-scale projects. These results will form the backbone of any decisions to use this technology in the future.

6.3.3 Gearing cross-sectoral activities toward priority fields of application

Basic research in generic technologies involves new materials and substances, nanotechnology, information and communication technology and environmental engineering. The results of research in these fields will provide key impetus to the following areas of energy research:

- **Buildings:** New insulation materials, thin, robust and transparent materials for using photovoltaic technology on facades and windows, microsystem technology for integrating self-powered microsystems
- **Electricity grids:** Information and communication technology to create smart grids (e.g. adapting electricity consumption to supply)
- **Photovoltaics:** Nanotechnology for new interface structures to trap light as efficiently as possible; use of optic technologies to implement nanostructures, production technology
- **Wind energy:** New materials for wind turbines, information and communication technology for controlling offshore wind farms
- **Thermal storage modules:** New materials as the basis for new technologies (e.g. high-temperature materials), heat transfer media
- **Chemical storage modules:** New materials and processes for splitting water (which are suitable for intermittent operation)

6.4 Basic research on renewable energy

Considerable interdisciplinary basic research is required if we are to reach the climate goals set out by the Federal Government. Research activities have a broad base to give decision-makers as many options as possible when it comes to defining energy policy. Support provided by the Federal Ministry of Education and Research in the field of renewable energy sources complements the application-oriented research support given by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

Basic research:

- Delivers the knowledge and technological basis to find solutions to enter the new energy era
- Develops additional alternative solutions to counter unforeseen developments and trends
- Provides ideas to further refine or substitute commercialised technologies, processes and procedures

- Improves the fundamental understanding of energy-transfer processes at the molecular level as such processes form the basis to practically all kinds of energy technology. Basic research in these fields helps to optimise existing processes and discover and develop completely new technologies.

6.4.1 New technologies and solutions for grid development

The development and expansion of the energy grids, and particularly the electricity grids, creates the framework for further increasing the renewable content in the energy mix. Efforts must be made to resolve issues concerning the transmission, distribution and storage of energy in an energy grid with decentralised and sometimes fluctuating energy input. Future challenges facing this sector involve reducing the amount of energy lost in energy transmission and conversion processes, and ensuring competition, the security of supply and energy supply quality. Basic research is encouraged in many areas, including the development of grid solutions with little energy loss that deliver flexible responses to fluctuations and disturbances.

Smart grids align intermittent sources of renewable energy and normal ups and downs in demand. To make such grids a reality, additional basic research efforts must focus on optimising demand side management and leveraging information and communication technology. The demand for energy must be controlled in such a way that individuals are not restricted or limited in their energy consumption habits. A new-generation refrigerator, for example, will preferably use power when there is a lot of energy on the grid (e.g. when winds are high).

Support for basic research is primarily provided in the framework of the interministerial “Power grids” research initiative (see chapter 2). Funding priorities comprise components, grid design, security, safety and social aspects:

Components

- New conductor material, innovative core materials, innovative insulation methods
- Development and testing of new wireless transmission technology
- Development and testing of new high-temperature superconductor materials offering excellent current capacity rating, enhanced performance and cost reduction

Grid design

- Further development of analytical methods for grid expansion requirements, use of dynamic models, incorporation of geographic information systems, innovative modelling processes
- Grid design for intermittent energy input focussing on energy efficiency and grid stability; holistic modelling of the technical operation of the smart grid

Safety, security and social aspects

- Accompanying scientific research into the social impact of increased grid expansion
- Development of mitigation strategies for using rare resources in grids and components
- To complement application-related research, basic research can also contribute to the following areas:
- Making transmission capacity more dynamic, such as operation at the physical limit, high-temperature conductors and monitoring of overhead transmission lines
- Reducing energy lost in transportation (power transmission lines) and transformation (power electronics)

6.4.2 Storage systems for more renewable electricity

Energy storage systems make it possible to decouple electricity production and electricity utilisation. Energy that cannot be used is stored and fed back into the grid when demand is high (load peaks), making it possible to guarantee the security of supply while reducing the number and size of power plants.

The development of innovative storage technologies and strategies is therefore given top priority, and R&D efforts must explore and tap all possible options and combinations. Currently these include electric, thermal, mechanical and chemical storage technologies.

The core objective of basic research is to expand and improve our fundamental understanding of storage processes.

The development and implementation of new concepts and innovations is promoted in all fields of technology with the aim of boosting storage efficiency, cutting costs and providing suitable storage solutions for every application. Currently, chemical storage methods (such as methane or hydrogen), for example, appear to be a very promising solution for seasonal storage.

Topics addressed include the following:

→ Progress in the field of electrochemistry will result in more efficient conversion processes (storage and electricity generation) for electrical and chemical storage modules. The examination and analysis of reactions at interfaces is fundamental to this goal. Any findings can also go toward developing a more flexible process control system.

→ A detailed understanding of thermochemical mechanisms and the development of thermally stable electrodes is central to developing fast-charging safe and secure electrical storage modules.

→ New materials can play a key role in improving numerous applications. For example, phase change materials promise higher storage density rates in thermal storage systems, and the use of organic materials in electrolytes promises higher cell voltage and energy density in redox flow batteries.

→ Another priority area is the development of simulation methods for using storage systems in the electricity grid. System analysis must be performed on the interaction of electricity and gas grids while factoring in storage systems that convert the form of energy.

Given the strategic importance of energy storage to a future energy system that is based on renewable energy, an interministerial funding initiative has also been put in place to address this issue (see chapter 2).

6.4.3 Photovoltaics: electricity from solar energy

Basic research comprises projects in the field of silicon wafer and thin-layer technology and in organic photovoltaics. The primary objective of this research is to boost the system's efficiency (third-generation solar cells) and operating life (e.g. encapsulation of organic solar cells) and to develop cost-cutting processes over the entire value chain.

The fundamental scientific challenges lie in understanding light-matter interactions and the conversion of solar energy to electrical energy.

The focus is on the following areas:

→ Optimisation of light trapping and photon management

→ Optimisation of absorption using highly structured absorbers and nanostructures (third-generation solar cells)

→ Development of modern cell designs, such as the development of multijunction photovoltaic cells which optimise how solar energy can be exploited

→ Understanding degradation mechanisms and development of mitigation strategies

→ A combination of simulations and physical analyses

This knowledge delivers the basis for future enhancements and further developments. New materials, enhanced photon management and optimised production processes will help drive down cost, boost efficiency and ultimately bring about grid parity, injecting new vigour into the photovoltaics market. The landscape will not change as a result of these developments but individuals will benefit increasingly from photovoltaic technology. Every modern photovoltaic module will produce more electricity on the same footprint, helping to spur on the transition to green energy. Organic photovoltaics will help scientists break into new fields of application. Flexible, lightweight and semi-transparent solar cells will open up new possibilities for use in building facades, windows and mobile applications.

6.4.4 Using biological resources for electricity production

In the field of renewables, particular importance is attached to bioenergy since the production of electricity can be specifically controlled and regulated using bioenergy as the energy source. Less energy storage is required with bioenergy than with intermittent energy sources, such as solar energy or wind. The quantitative potential of bioenergy must be analysed systematically. Such analysis must include an examination of the effect imported biomass could have on the energy balance sheet.

Bioenergy research ranges from biomass production and the use of biomass as an industrial material and an energy source, to the production of biofuels and research into systemic aspects such as the food vs. fuel debate, the overuse of land and bioeconomics. Basic research focuses on examining, modelling and optimising energy conversion processes with the aim of gaining a thorough understanding of the fundamental processes involved in the production of biomass (cell material), biofuels (such as methane/hydrogen) and physical compounds (chemical compounds for industrial processes), and aligning these processes with one another. The results will contribute to optimising the entire process and provide the ideal framework for tapping the potential to reduce carbon emissions.

Other priority areas of basic research include:

- Screening of microorganisms to develop new substrates
- Examining the effect of the substrate on metabolism and production methods. The impact on emissions and the energy balance sheet should also be analysed.
- Understanding the development of microbiological relationships under different conditions to deliver the basis for process optimisation
- Developing innovative methods for recycling phosphorous and nitrogen compounds

Basic research is fostered with due attention also given to the effects of scale and systemic aspects. This includes research into possible applications with regard to pressures on the environment and the impact on food supplies.

6.4.5 Harnessing the untapped potential of wind power

Even today, wind power generates the largest share of electricity production from all alternative sources. In accelerating the shift to a clean energy economy, it is important to specifically promote basic research that could soon have practical relevance, with a focus on fundamental material development, theoretical models and techniques for remote diagnostics and repair. This should contribute to reducing maintenance, increasing reliability, boosting efficiency and cutting costs. Research funding activities of the Federal Ministry of Education and Research and of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety are closely meshed.

In the onshore and offshore domain, there is huge scope for development which can be tapped over the short and medium term. To harness new potential on the long term, we foster innovative ideas which are still in their infancy, such as airborne wind farms.

Given the important role wind power is expected to play in our future energy mix, basic research is also tasked with developing ideas for future wind turbine designs.

The following priority funding areas have been identified:

- Wind physics: turbulence research (large-scale, mesoscale and small-scale wind turbulence)
- Material:
  - Alternative solutions for wind power plant components to prevent dependence on scarce resources (nacelles, rotors, support and foundation structures and peripherals)
  - Enhanced materials (e.g. laminate, resin, metal composites)
- Grid integration: develop new models for integrating wind-derived electricity into the grid (intermittent output with many extremes)

6.4.6 Solar thermal technology, photosynthesis and hydroelectric power

The aim of basic research is to deliver alternative technologies that can support the transition to a clean energy economy and allow us to respond to unanticipated developments in the future. Some of the research areas include:

Thermal solar power utilisation such as "concentrated solar power" (CSP)

Solar energy is converted into thermal energy (heat) which can then be used to produce electricity. In solar towers, flat mirrors track the sun and concentrate the solar energy on the highest point of a tower. This results in extremely high temperatures of over 1,000 °C in a heat-transfer oil which is ultimately used to produce steam and generate electricity in a turbine.

Generally speaking, research priority lies in methods to cut costs and boost efficiency. In the basic research domain, funding focuses primarily on research into material and the development of new solutions. For example, interconnecting to a second power source has the potential to prevent a drop in efficiency in poor weather conditions (or cloudy locations).

Photosynthetic energy production

Photosynthesis is the foundation of life on the planet. Plants use solar energy to produce sugars, forming being the basis for growth. In this process, plants release oxygen as a waste product, allowing us to breathe. Researchers work to understand photosynthesis in close detail and use this knowledge to deliver energy solutions.

A core task is to understand the fundamental processes involved in water splitting. Another objective is to gain a thorough understanding of the proteins involved (primarily photosystem II proteins) to enable industrial usage over the long term. For example, energy can be produced by applying biomimetic approaches to the production of hydrogen or electricity in a kind of "biological solar cell".

Hydropower

Currently, virtually all the energy storage capacity available is in the form of pumped storage power stations. If a lot of energy is produced during periods of intense sunshine or strong winds, these systems store the energy and make it available again in times of higher demand. In the future it will also be possible to use hydropower in other technological approaches. For example, slow-rotation rotors could continuously convert flow energy, and the use of tidal power and wave power will increase as technology matures. Furthermore, power stations built at river estuaries could use energy from the difference in salinity between the fresh water and sea water. Basic research can help to tap the potential of underground pumped storage systems (e.g. disused mines).

6.5 Knowledge-based system analysis

Continued fundamental system analysis, technology tracking and transformation research make it possible to map the current situation and future developments and trends in the energy system. Research provides the framework and knowledge base to understand changes in the interaction of technological, economic, social and regulatory factors in the energy system and be able to deliver adequate responses. In projecting the outlook for a secure energy supply, it is essential to factor in both sociocultural conditions and technological developments. The Federal Ministry of Education and Research will contribute to accomplishing this goal within the scope of its responsibilities.

System analysis and transformation research approaches will lend ongoing support to the technological overhaul of the energy supply system and should reflect the growing system complexity that results from the use of renewable energy sources.

The following goals have been identified:

- → Identify the technological and systemic challenges associated with transforming our energy system early on, develop possible solutions, identify areas where there is a specific need for basic and anticipatory research and determine the feasibility of the technologies
- → Pinpoint the potential and need for science and business to become more interconnected, identify the need for scientific networks focussing on specific topics and coordinate efforts with the ministries that support research to deliver an efficient network structure
- → Develop scenarios and projections that demonstrate the impact which a higher penetration of renewable energy sources has on living conditions and the economy

In its commitment to continuous system analysis, the Federal Ministry of Education and Research – in addition to the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and the Federal Ministry of Economics and Technology – will put an energy technology radar in place to identify areas where fundamental research will be needed in the future. The aim is to identify fundamental gaps in technology, and identify and assess new technological alternatives.

6.6 Energy research and society

If Germany is to become a smart energy economy, it needs flexible strategies that can adapt to short-term changes in the global economic, social, climatic and technological framework.

The permanent transformation process that is needed will focus more on the entire energy spectrum – from production to transportation – and bring about significant changes for the public with regard to living and working conditions, consumer patterns and production methods.

Our long-term plan to restructure our energy system can only succeed with the support of the public.

Scientists throughout Germany are working on technologies for a sustainable energy supply and on a response to the challenge of climate change.

New projects and new technologies often face opposition from the public. Funding provided by the Federal Ministry of Education and Research in this field aims to identify the reasons and factors for this, and develop methods and tools to enable transparent, trust-building communication with the community to address technology issues. An examination of the role cultural factors and traditional lifestyles play in society's appraisal of new or established energy technologies constitutes a central aspect of research support.

Scientific expertise should be leveraged to develop methods and approaches that aim to involve the public in decision-making processes centred on the future of energy in Germany and that can answer central questions which the public may have concerning science, research and technology. By the same token, appropriate issues, questions and knowledge gaps should be incorporated into the planning and structure of funding initiatives at an early stage.

Such goals require ideas and strategies that deliver appropriate dialogue and communication platforms. The instrument of "public dialogue studies" will be tested and refined to this end. These studies are unique in that technological questions are answered in a way that takes regional conditions and the knowledge gap of the participating interest groups into consideration, while also drawing on independent knowledge from experts in the field.

6.7 Nuclear safety and disposal research and radiation research

The events in Japan in March 2011 have not done anything to alter the safety of Germany's nuclear power plants. However, the incident has prompted a reassessment of the acceptable risk in large sectors of our society and led to greater support for Germany to ramp up efforts to abandon nuclear power.

Research into nuclear safety is ongoing. With its nuclear safety and disposal research programme, the Federal Ministry of Education and Research supports the training and education of junior scientists. This helps ensure that Germany will have the necessary experts and sufficient knowledge in the future to:

→ Be able to assess and guarantee the safety of the operation of German nuclear power stations until nuclear energy is fully phased out, and adapt strategies to the latest findings and technological developments

→ Exert influence in defining international safety standards and shaping regulatory systems to be able to voice Germany's safety concerns if new nuclear power stations and other nuclear systems are erected outside our borders

→ Develop final repositories that guarantee the long-term safety of nuclear waste. Germany must maintain a strong nuclear skills base to manage this agenda. New solutions must be developed for geological disposal including waste retrieval and surface storage.

Efforts on the part of the Federal Ministry of Education and Research to foster young talent in reactor safety and disposal research are closely linked to project funding provided by the Federal Ministry of Economics and Technology - the Ministry responsible for this field. In light of Germany's decision to abandon nuclear energy, it is all the more important that support for young scientists is not solely limited to national partnerships and alliances.

Research into reactor safety broadens the scientific foundation for appraising the safe operation of nuclear reactors, with a focus on using physical and mathematical models and developing innovative diagnostics to gauge the condition of reactors.

Disposal research concentrates on developing solutions and technologies for treating and disposing of a variety of radioactive waste. As the preferred option in Germany is to store waste in deep geological repositories, research must go towards ensuring that radioactive waste, once deposited, remains stationary. Research will also touch upon processes for the effective separation of radionuclides with longer half-lives from high-level radioactive waste. This also applies when dismantling nuclear plants.

As another component of nuclear safety research, radiation research ensures the systematic and continuous support for young talent through scientific work in collaborative projects dealing with biological, biochemical, medical and radiological issues. This guarantees a high scientific standard over the long term and ensures that future needs for highly skilled workers in this field can be met.

6.8 Fusion research

Nuclear fusion mimics the way the sun produces energy. When two light hydrogen isotopes, deuterium and tritium, fuse they release energy and produce helium as a by-product. If scientists manage to fully control the nuclear fusion process and advance it to practical applications, the advantages would be manifold: there is a virtually unlimited supply of fuel, the process is practically climate-neutral, less radioactive waste is produced and nuclear fusion does not have any of the long-lived radioactive waste problems associated with conventional nuclear power plants. Nuclear fusion is an option for the long-term supply of global energy which extends beyond the time frame of the government's Energy Concept.

Fusion research does not form part of the Energy Concept unveiled by the Federal Government since research into this field will extend beyond 2050. However, responsible research support also involves tracking long-term social, economic and technological developments. Against this backdrop, exploration into nuclear fusion is promoted. As soon as the scientific and technical challenges have been overcome, nuclear fusion could make a key contribution to supplying base load energy in the future. This is why Germany is collaborating with European partners in developing the ITER international research reactor which aims to demonstrate the feasibility of producing energy from fusion reactions with a burning fusion plasma in the 500 MW range.

To enable the technical implementation of nuclear fusion, two approaches are pursued for the magnetic containment of fusion plasma, namely the tokamak and the stellarator principle. ITER is based on the tokamak principle. The construction of the world's largest and most advanced stellarator experiment – Wendelstein 7X – in Greifswald specifically aims to demonstrate the feasibility of applying this type of system in a power station. In contrast to tokamaks, the different magnetic containment approach of stellarators means that they are suitable for continuous operation from the outset. To date, however, stellerators have not yet been explored in great detail.

6.9 Institutional energy research

The Federal Ministry of Education and Research is in charge of considerable parts of institutional energy research. The Pact for Research and Innovation gives the organisations of the jointly funded research institutions the financial planning security and the necessary leeway to push ahead with dynamic developments despite increasing costs. Institutional funding helps create a unique working environment for scientists at the participating research institutions in Germany. Only with such an approach is it possible to continuously address fundamental and long-term energy issues, which form the basis of a sustainable energy supply system.

6.9.1 Institutional funding within the Energy Research Programme

The Helmholtz Association of German Research Centres (HGF) is at the forefront of institutional energy research and part of the Energy Research Programme (see also chapter 3.2.4). Institutional funding granted to the HGF by the Federal Ministry of Education and Research alone totals roughly €250 million per year in the energy field, with the Federal Ministry of Economics and Technology providing annual funding in the region of €20 million to the German Aerospace Centre (DLR), which is part of the HGF.

Helmholtz Association of German Research Centres (HGF)

In the field of energy research, scientists at Helmholtz research centres work to address the central challenges posed by the energy supply system:

- Secure the long-term supply of sustainable energy
- Develop economically and ecologically viable solutions
- Curb energy consumption, reduce Germany's dependency on imports and explore new storage technologies and ways to mitigate climate change over the short and medium term
- Work towards the long-term goal of completely replacing limited sources of energy with sustainable and climate-neutral energy solutions

Individual research programmes are defined. The programmes currently relevant to the field of energy include: Renewable Energy; Efficient Energy Conversion and Use; Technology, Innovation and Society; Nuclear Fusion; Nuclear Safety Research.

6.9.2 Additional institutional funding

Apart from the Helmholtz Association of German Research Centres, the Federal Ministry of Education and Research also lends support to other institutions that conduct energy research which, however, is outside the scope of the Energy Research Programme. The most important institutions include the Fraunhofer-Society, the Max Planck Society for the Advancement of Science and the Leibniz Association.

Fraunhofer Society (FhG)

The Fraunhofer Society has the following priority areas in the energy domain:

- Sustainability, security and efficiency of the energy supply system
- Energy conversion
- Energy and resource efficiency
- Electric mobility

With over 1500 staff working on these energy themes, the "Fraunhofer Energy Alliance" makes a key contribution to research in this field. Renewable energy, efficiency technology, buildings and components, smart power grids and storage and microenergy technology are the Alliance's current business areas. Furthermore, specific initiatives are also in place, focussing on areas such as resource efficiency (including the "Maintenance, Repair and Overhaul" innovation cluster).

Max-Planck Society (MPG)

The following are the core activities of the MPG:

- Harnessing the untapped potential of current energy sources
- Developing new sources of energy
- Increasing energy efficiency
- Making better use of the planet's resources
- Understanding the carbon cycle and the impact of carbon on the climate

To deliver on these goals, the MPG organises research into energy-related fields under the umbrella of its "Research Perspectives 2010+" model. This includes research into a sustainable energy supply system, complex technical systems, carbon cycle in the earth system, catalysis research, nanoscience and nanotechnology as well as light & matter.

Leibniz Association (WGL)

In the Leibniz Association, renowned institutions work on solutions to energy and climate issues, with activities primarily concentrated on "energy and resource efficiency" and "material development".

Particular attention is also given to the development of sustainability strategies and macroeconomic impact analyses, research into the impact of climate change and the development of catalysts.

The Federal Government expects that energy research with institutional funding will contribute to future efforts to adapt and overhaul the German energy infrastructure. Research resources at centres receiving institutional funding are directed towards addressing current research gaps, with close collaboration between the research institutions, the Federal Government and the Länder.

Transparent research

To maximise transparency, the Federal Ministry of Education and Research will work with the other ministries to develop an "energy research roadmap". The current research situation will be systematically appraised on the basis of such parameters as stakeholders and points of contact; research resources and funding; focal topics and degree of interlinkage with other partners in academia and business. The link between universities and Helmholtz institutions is an example of one aspect which is examined.

Directing research resources

Using the results of system analyses, the Federal Ministry of Education and Research will uncover additional research gaps and incorporate these areas into institutional research funding. Structural strengths and potential of energy research, the opportunities and need for interlinkages in academia and business, and the need for scientific networks focussing on specific topics will be identified.

Links must be forged between basic research and application to ramp up innovation processes and expedite breakthroughs in the energy sector. Trend-setting frontier research and rapid advances in the commercialisation of ideas are more important than ever before. The aim is to focus the activities of the research environment on priorities areas, pool resources and provide impetus that will create the fabric for the entire research process.

The Federal Ministry of Education and Research will play a central role in defining key requirements of research policy as part of programme-oriented funding for the Helmholtz Association of German Research Centres in the field of energy. Under the framework of programme-oriented funding, research objectives are defined for the Helmholtz Association in 5-year cycles. The requirements and objectives are aligned with the Federal Government's priority areas as defined in the Energy Research Programme.

The Federal Ministry of Education and Research will align project funding and institutional funding in energy-related fields more closely than before. To this end, we will develop new forms of partnership in energy research in order to pool existing resources, step up the transfer of the results of basic research to practical applications and enjoy a new quality of collaboration between state, public and private institutions as well as centres receiving institutional funding. Flexible organisation and management structures and time-limited partnership programmes will be the hallmark of this new funding approach. With the goal of intensified and highly integrated project support on a multidisciplinary and transdisciplinary basis, it will be important to create interlinkages between the best skillsets that are needed to deliver specific solutions to the current challenges facing the energy sector. Initially research will focus on the "No Regret" priority areas, including efficiency and storage technology. The research themes should specifically contribute to reducing carbon emissions, increasing the penetration of renewable-derived electricity generation and/or boosting energy productivity.

The Federal Ministry of Education and Research will enter ongoing, strategic programme dialogue with the scientific community. Research themes will be addressed in a coherent and coordinated manner through regular communication with stakeholders in energy research and research institutions receiving institutional funding.

The Federal Ministry of Education and Research supports the European Energy Research Alliance of leading energy research organisations in ten European countries. Together, the participating organisations have an annual budget of over €1.3 billion for energy research. Germany is represented by research institutions and universities. The initiative contributes to achieving the objectives of the European Strategic Energy Technology Plan (SET Plan).

6.10 Budgetary funds

Project funding provided by the Federal Ministry of Education and Research (in thousand of €)					
	Actual	Planned	Projected Data 1), 2)		
	2010	2011	2012	2013	2014
Energy efficiency	12,094	15,300	15,800	16,300	12,300
Renewable energy	16,291	18,700	18,200	17,700	18,623
Nuclear safety and final disposal research	9,055	10,000	10,000	10,000	10,000
Fusion research	8,341	11,000	14,000	14,000	11,000
Energy and Climate Fund	–	15,000	11,500	47,900	61,000
Total	**45,781**	**70,000**	**69,500**	**105,900**	**112,923**

1) Figures relating to the federal budget are subject to parliamentary approval.
2) Funding for the Energy and Climate Fund is subject to change.

Institutional funding provided by the Federal Ministry of Education and Research: Helmholtz Association (in thousand of €)					
	Actual	Planned	Projected Data 1),		
	2010	2011	2012	2013	2014
Energy efficiency conversion and usage	46,125	41,080	41,804	42,696	43,479
Renewable energy	37,739	42,431	43,272	44,290	45,332
Nuclear safety research	29,508	29,741	30,236	30,850	31,478
Nuclear fusion	122,690	137,148	138,655	140,611	142,599
Technology, innovation, society	7,283	7,745	7,793	7,872	7,950
Other measures[2)]	-	5,196	23,677	34,262	19,527
Total	**243,345**	**263,341**	**285,437**	**300,581**	**290,365**

1) Figures relating to the federal budget are subject to parliamentary approval.
2) Measures comprise energy-related research work and research resources outside the energy research field, such as portfolio topics,special activities and contributions from other HGF programmes. These measures are to be assigned equally (50 %) to both the "Efficient energy conversion and usage" and "Renewable energy" areas.

7. Guidelines for project funding

Project funding is directed at businesses, research institutes and universities. It is granted in the form of subsidies for research projects that cannot be realised on the market or for projects that intend to demonstrate the first practical application of new or improved energy technologies. Project funding is an instrument for supporting high-risk projects of national interest with a defined topic and time frame. Project funding is only granted if the market is not able to provide new technological developments within the foreseeable future.

Project funding is frequently provided in the form of collaborative research, in which universities and research institutes join forces with commercial enterprises at the precompetitive stage. The aim is to enhance existing energy technologies or develop new energy technologies by an interdisciplinary division of labour to deal with complex problems that can only be resolved over the long term.

7.1 Preconditions

These guidelines intend to provide an initial overview of the framework conditions for funding. Detailed funding conditions are published in the departmental guidelines for funding and calls for proposals, which ensure that funds are used in the public interest in line with legal requirements.

The topics that qualify for funding are described in the 6th Energy Research Programme, entitled "Research for an environmentally sound, reliable and affordable energy supply". However, not all the topics listed can always be supported extensively. Nevertheless, the programme provides the framework, outlines the essentials of funding policy and is the basis for making funding decisions. Applicants are not automatically entitled to receive a grant. A decision is made by the grant-awarding agency on the basis of due discretion and within the framework of available budget funds.

For applicants it is important to note that several ministries share responsibility for project-oriented funding of R&D in the energy sector (see section 1.4).

Only the responsible ministries and the project management organisations tasked with implementing the research programme can decide on a case-by-case basis whether the topic at the heart of a project proposal qualifies for funding. The project management organisations examine the innovation content of every project proposal submitted, as well as the expertise and the creditworthiness of the applicant. Moreover, they also assess the possible contribution of the project to the funding objectives of the Energy Research Programme. If the project sufficiently meets these criteria, funding can be considered. The final funding decision lies with the responsible ministry.

Applications may be made by companies with production operations in Germany (particularly SMEs), universities as well as non-university research centres based in Germany and other institutions or legal entities. The project generally has to be implemented and the results exploited in Germany. Furthermore, applicants have to make a financial contribution to the research project.

7.2 Interministerial funding initiatives

The Energy Concept unveiled by the Federal Government envisages the development and implementation of joint research initiatives in key fields or in areas under the responsibility of several ministries (see also chapter 2). The first phase involves the implementation of funding initiatives that focus on "Energy Storage", "Electricity Grids" and "Solar Buildings – Energy Efficient Cities". Other priority areas for interministerial collaboration are also possible. Joint research initiatives deal with a broad range of topics, are extremely complex and address issues that require close collaboration between basic research, applied research and technological developments to deliver a successful outcome.

For this reason, a central programme management system is planned to support the specific implementation of joint initiatives. The programme management system has a central point of contact, which is designed to answer initial funding queries and to collect all project proposals. The project proposals are assigned to the participating ministries or specific financing instruments based on the topics the projects intend to address. The formal applications for funding are then processed in the second project phase by the project organisation units assigned to the individual ministries. This procedure simplifies the application and helps to avoid the risk of double funding at an early stage.

7.3 Financial modalities for project funding

Funding will be provided in the form of grants. The Federal Budget Regulations (BHO) together with the general administrative agreements on the Federal Budget Regulations, which regulate the conditions and procedures, form the legal basis for funding. Furthermore, European law also applies through the Community Framework to national research and development grants. Grants are awarded in the form of partial financing for pro rata funding, matched funding or fixed amount funding, or – in exceptional cases – also for complete funding of a project.

For applicants from public institutions, the project expenditure is the basis for calculating the amount of funding provided. In the case of industry, the project costs including the overheads form the basis for funding.

The rates for funding must not exceed the maximum levels specified in the Community Framework for state grants towards research, development and innovation in the European Union. For example, in the case of application-oriented projects, as generally performed by industrial enterprises, this means that up to 50 percent of their costs can be financed. Universities can receive funding of up to 100 percent. Respecting the appropriate and economic use of public funds, the technological risk and the national interest attributed to the project determine any decisions on the level of funding.

7.4 Project implementation

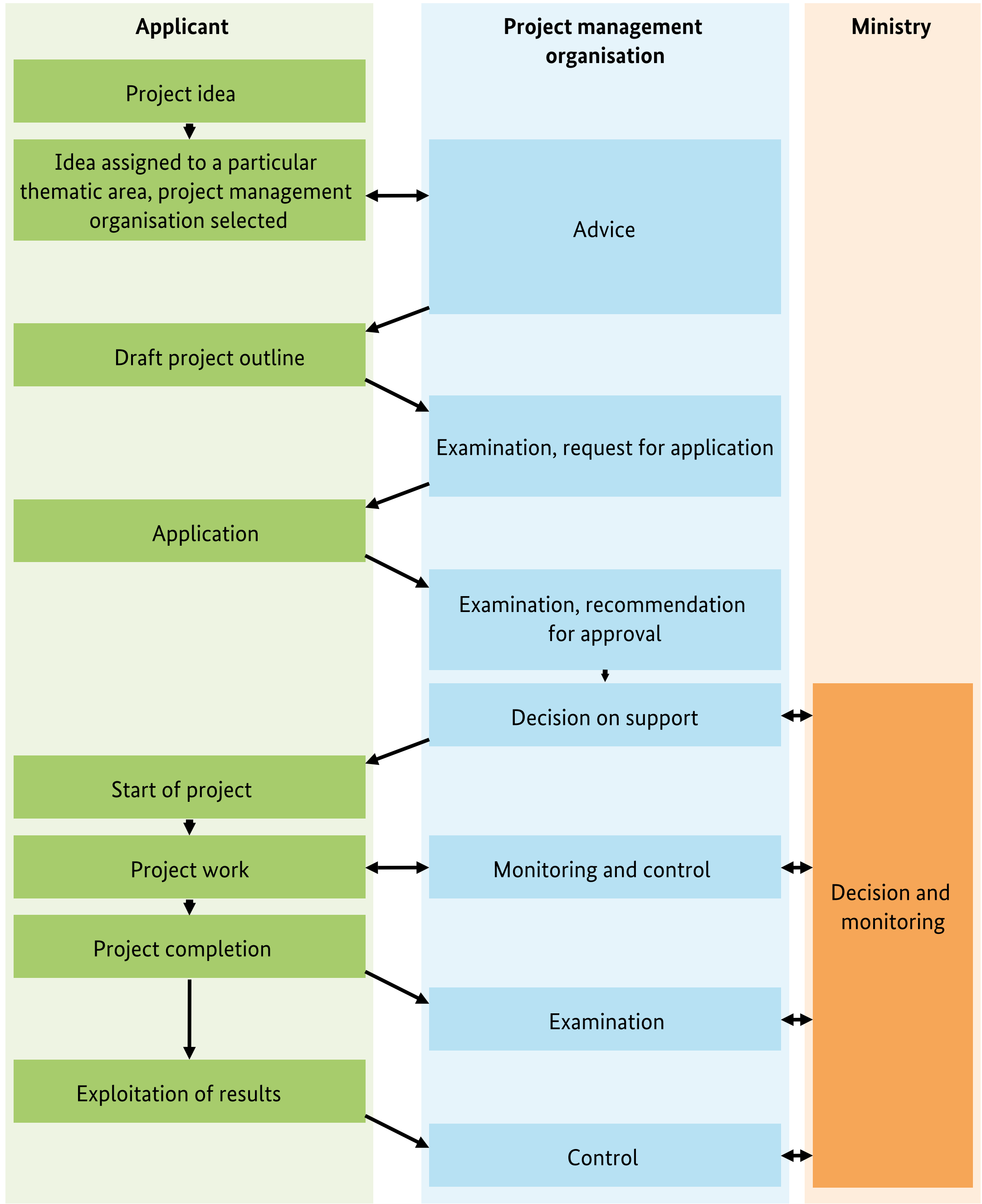
The Federal Government is committed to providing detailed and professional advice to applicants on the possible funding options of the Energy Research Programme. The project management organisations tasked with realising and implementing this Research Programme on behalf of the responsible ministries are the contact points for such information (see Annex for an overview of the project management organisations and for details on other sources of information, section 7.6).

The project management organisations provide scientific and administrative support and guidance once the applicant contacts the organisation. This support continues through the subsequent stages involving the application procedure, application appraisal, funding decision, fund disbursement, efficiency control and final accounting up to the final utilisation and exploitation of the project results. Fig. 7.1 (p. 109) illustrates the course of a successful project from the proposal stage through to the final exploitation of results.

7.5 Utilisation of results

For a project to be successful, the project results must be utilised in the best possible way. Therefore, funding guidelines require applicants to submit a utilisation plan, detailing how they believe the project results can be subsequently used. The principal investigator has to commit fully to delivering according to this utilisation plan. In return, he is entitled to utilise exclusively the results obtained. However, in the case of research projects where commercial use is expected, the principal investigator must ensure that the results are protected by patent as, in the interests of project funding, it is particularly important to file a patent for new patentable knowledge. Small and medium-sized enterprises and public research institutions can apply for funding of the costs involved. Furthermore, there is a general obligation to publish results in the form of conference proceedings and/or contributions to the scientific literature.

Fig. 7.1: The course of a successful project



7.6 List of project management organisations

Subject to change over the course of the programme as programme management is generally put out to tender.

Energy technologies including basic research

Projektträger Jülich (PtJ), Geschäftsbereich ERG
Forschungszentrum Jülich GmbH
52425 Jülich
Tel.: +49 (0)2461 61-4624, Fax: +49 (0)2461 61-2880
PTJ-ERG@fz-juelich.de, www.ptj.de

Renewables

Projektträger Jülich (PtJ), Geschäftsbereich EEN
Forschungszentrum Jülich GmbH
52425 Jülich
Tel.: +49 (0)2461 61-3172, Fax: +49 (0)2461 61-2840
PTJ-EEN@fz-juelich.de, www.ptj.de

Nuclear safety research

PT Reaktorsicherheit, Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) mbH
Postfach 10 15 64, 50455 Köln
Tel.: +49 (0)221 2068-720, Fax:+49 (0)221 2068-629
reinhard.zipper@grs.de, www.grs.de

Nuclear repository research, nuclear safety research and radiation research

Projektträger des BMBF und BMWi für Wassertechnologie und Entsorgung (PTKA-WTE),
Karlsruher Institut für Technologie (KIT)
Postfach 3640, 76021 Karlsruhe
Tel.: +49 (0)721 608-25790, Fax: +49 (0)721 608-925790
www.ptka.kit.edu

Bioenergy

Fachagentur Nachwachsende Rohstoffe e. V.
Hofplatz 1, 18276 Gülzow
Tel.: +49 (0)3843 6930-0, Fax: +49 (0)3843 6930-102
info@fnr.de, www.fnr.de

8. Annex

8.1 Other sources of information

Federal "Research and Innovation" Funding and Advisory Service

Projektträger Jülich (PtJ)
Forschungszentrum Jülich GmbH
Zimmerstraße 26–27, 10969 Berlin
Fax: +49 (0)30 201 99-4 70

Research and innovation funding hotline
0800 2623-008 (free)

Business support service
0800 2623-009 (free)

beratung@foerderinfo.bund.de
www.foerderinfo.bund.de

NOW GmbH (organisation for hydrogen and fuel cell technology)
Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie
Fasanenstrasse 5, 10623 Berlin
Tel.: +49 (0)30 3116116-00
Fax: +49 (0)30 3116116-99
kontakt@now-gmbh.de
www.now-gmbh.de

8.2 Conversion factors

Target unit / Starting unit	PJ	Million t TCE	Million t COE	TWh
Petajoule (PJ)	1	0.034	0.024	0.278
Million t of coal equivalent (TCE)	29.308	1	0.7	8.14
Million t of crude oil equivalent (COE)	41.869	1.429	1	11.63
Terawatt hour (TWh)	3.6	0.123	0.0861	1

8.3 List of abbreviations

AC	Alternate Current
AGEE-Stat	Working Group on Renewable Energy
APU	Auxiliary Power Unit
BAM	Federal Institute for Materials Research and Testing
BGR	Federal Institute for Geosciences and Natural Resources
BHO	Federal Budget Regulations
BIPV	Building Integrated Photovoltaics
BImSchV	Ordinance for the Implementation of the Federal Immission Control Act
BMBF	Federal Ministry of Education and Research
BMELV	Federal Ministry of Food, Agriculture and Consumer Protection
BMF	Federal Ministry of Finance
BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BMVBS	Federal Ministry of Transport, Building and Urban Affairs
BMWi	Federal Ministry of Economics and Technology
CAES	Compressed Air Energy Storage
CCS	Carbon Capture and Storage
CdTe	Cadmium Telluride
CEM	Clean Energy Ministerial
CEP	Clean Energy Partnership
CERT	Committee on Energy Research and Technology
CHP	Combined Heat and Power Plant
CIS	Chalcopyrite Thin-Film Cells
CO_2	Carbon Dioxide
COE	Crude Oil Equivalent
COORETEC	CO_2 Reduction Technologies
CSLF	Carbon Sequestration Leadership Forum
CSP	Concentrated Solar Power
D	Germany
DBFZ	German Biomass Research Centre
DC	Direct Current
DII	Desertec Industrial Initiative
DLR	German Aerospace Centre
DSTTP	German Solar Thermal Power Technology Platform
ECBCS	Energy Conservation in Buildings and Community Systems
ECES	Energy Conservation through Energy Storage
EduaR&D	Energy Data and Analysis R&D
EEG	Renewable Energy Resources Act
EEGI	European Electricity Grid Initiative
EERA	European Energy Research Alliance
EEWärmeG	Act on the Promotion of Renewable Energies in the Heat Sector
EFZN	Energy Research Centre of Lower Saxony
EIBI	European Industrial Bioenergy Initiative
EJ	Exajoule
EnEV	Energy Saving Ordinance
EnOB	Energy-Optimised Building
EPBD	European Building Directive
ESNII	European Sustainable Nuclear Industrial Initiative
ETSAP	Energy Technology Systems Analysis Programme
EU	European Union
EURATOM	European Atomic Energy Community
EV	Electric Vehicle
FACTS	Flexible Alternating Current Transmission Systems
FAME	Fatty Acid Methyl Ethers
FCH JU	Fuel Cell and Hydrogen Joint Undertaking
FhG	Fraunhofer Society
FNR	Fachagentur Nachwachsende Rohstoffe e. V. (project management organisation)
GaAsP	Gallium Arsenid Phosphide
GaInP	Gallium Indium Phosphide
Gen	Generation
GRS	Gesellschaft für Anlagen- und Reaktorsicherheit (Society for Plant and Reactor Safety)
GT	Gas Turbine
GW	Gigawatt
H_2	Hydrogen
HDR	Hot Dry Rock
HGF	Helmholtz Association of German Research Centres
HT	High Temperature
HVAC	Heating Ventilation Air Conditioning
HVDC	High Voltage Direct Current
HVO	Hydrotreated Vegetable Oil

IAEA	International Atomic Energy Agency
IBP	Institute for Building Physics (Fraunhofer Society for the Advancement of Applied Research e. V.)
ICT	Information and Communication Technology
IEA	International Energy Agency
IGD-TP	Implementing Geological Disposal of Radioactive Waste Technology Platform
IMAB	Institute for Electrical Machines, Traction and Drives
IPHE	International Partnership for Hydrogen and Fuel Cells in the Economy
IRENA	International Renewable Energy Agency
ISCC	International Sustainability and Carbon Certification
ISGAN	International Smart Grid Action Network
ITER	International Thermonuclear Experimental Reactor
KEK	Kompetenz Kerntechnik (Maintaining Competence in Nuclear Engineering)
KIT	Karlsruhe Institute of Technology
kW	Kilowatt
LED	Light-Emitting Diode
Li	Lithium
LowEx	Low Exergy
MCFC	Molten Carbonate Fuel Cell
MEA	Membrane Electrode Assembly
MENA	Middle East and North Africa
MPG	Max Planck Society
MW	Megawatt
NaS	Sodium Sulphur Battery
NEA	Nuclear Energy Agency
NEP	National Development Plan Hydrogen and Fuel Cell Technology
NiCD	Nickel-Cadmium Battery
NiMH	Nickel-Metal Hydride Battery
NIP	National Innovation Programme Hydrogen and Fuel Cells
NOW	National Organisation for Hydrogen and Fuel Cells
OECD	Organisation for Economic Co-operation and Development
ORC	Organic Rankine Cycle
PAFC	Phosphoric Acid Fuel Cell
PCM	Phase Change Material
PCS	Phase Change Slurries
PEM	Proton Exchange Membrane
PHEV	Plug-In Hybrids
PJ	Petajoule
POF	Programme-Oriented Funding
PT	Project Management Organisation
PtJ	Jülich Project Management Organisation
	PTKA-WTE Project Management Organisation of BMBF and BMWi for Hydrogen Technology and Disposal
PV	Photovoltaics
P&T	Partitioning and Transmutation
Q	Quarter
RAVE	Research at Apha Ventus
RS	Reactor Safety
RD&D	Research, Development and Demonstration
R&D	Research and Development
SEII	Solar Europe Industry Initiative
	Strategic Energy Technologies Information System
SET-Plan	Strategic Energy Technology Plan
SH&C	Solar Heating and Cooling
SME	Small- and Medium-Sized Enterprise
SMES	Superconducting Magnetic Energy Storage Systems
SNG	Synthetic Natural Gas
TCE	Tonne of Coal Equivalent
TW	Terawatt
VPE	Crosslinked Polyethylene
WEC	Wind Energy Converter
WGL	Leibniz Association
WSVO	Ordinance on Thermal Insulation