Energy R&D in Germany

Paul Runci
2004
Energy R&D in Germany

Population: 83,251,851 (July 2002 est.)
GDP: $2.174 trillion (2001 est., PPP)

National R&D Effort 2000: $52.6 billion
- Public Sector: 32%
- Private Sector: 67.6%
- Private Non-Profit: 0.3%

Gross Domestic Expenditure on R&D as a Percentage of GDP 2000: 2.48%

Federal Energy R&D expenditure 2001: $417.2 million

Private Sector Energy R&D expenditure: $194.4 million

Chapter Overview
- National Science and Technology Effort and Funding Goals
- National Energy Policy and Energy Overview
- Energy R&D Programs
National Science and Technology Effort and Funding Goals

Germany’s public and private sector support for research and development reached its highest level to date in 2000 at $52.5 billion, as Figure 1 shows. Since the latter half of the 1990s, R&D expenditures have recovered from a period of declining investment, attributable in part to the expenses associated with German reunification. Between 1994 and 2000, support for R&D increased by almost 16%; steady increases in private sector R&D funding over this period have more than offset a continuing decline in overall government R&D funding. In 2000, Germany’s R&D expenditures were equal to approximately 2.48% of gross domestic product (GDP). The public and private sectors contributed $35.6 billion and $16.7 billion to the total, respectively. The non-profit sector accounted for the remainder of about $219 million.2

Figure 1. R&D Funding by Sector

In 2001, the German government instituted a new R&D investment program, known as ZiP (Zukunftsinvestitions-Programm), that aims to direct more resources to those technology programs and projects that hold particular promise for the future and that may serve to strengthen Germany’s overall position as a leader in science and innovation. Thus, even as overall federal R&D support declines, priority research areas have seen budget increases. Among the R&D areas that have benefited from the ZiP program are:
biotechnology, information and communications technology, and environmental science. Specific energy technology areas, including fuel cell research and geothermal research, have also received renewed emphasis, despite the fact that the overall energy R&D budget has fallen steadily since the mid-1980s. The general trend in public sector funding has been influenced in large part by the high costs of reunification. In the 1990s, structural reforms in the public research infrastructure and related legal framework that had been called for by many research managers and politicians for several years were delayed by the shift in funding priorities following the collapse of communism, and by the sluggishness of the German economy in the early 1990s. Since taking office in September 1998, Germany’s Red-Green coalition government has stated its intention to substantially increase budgetary appropriations for research grants in an effort to bolster Germany’s international standing as a leader in science and technological innovation. The government is seeking to reconfigure the public R&D infrastructure to enhance researcher autonomy and rely more on competition, cost-sharing with industry, and the use of international benchmarks as metrics for the performance of research programs.4

As Figure 2 shows, defense research and technology receive more federal government funding than any other research area in the federal budget, even though defense R&D support has declined by some 45% in real terms since 1989. Germany’s defense
research program covers not only technology development but also military medicine and psychology and other non-technical studies by the Bundeswehr (Federal Armed Forces). Defense R&D is governed by the principal that Bundeswehr research projects should be limited to specific defense applications; while the results of civilian research are to be applied as broadly as possible, spinoff of defense research results is consciously minimized by the government’s approach to the structure and sponsorship of defense R&D.5

Germany’s space research program has received consistent support from the federal government. Funding for the program has remained essentially flat, near the current (2002) level of $809 million. In May 2001, the federal government approved the German Space Programme, which provides industry and research institutions a reliable political framework for independent planning and action on space-related research activities. It places all space-related program under a unified strategic umbrella to ensure the most efficient use of public funds. One of the key overriding aims of the German Space Programme is to serve as a tool for greater global environmental sustainability. Recognizing that the Earth is an ecologically closed system, space research seeks to enhance understanding of Earth systems and generate information that may be used to support the development of sustainability policy. To this end, the German government supports three major space research programs: the National Space Programme, the European Space Agency’s (ESA) research program, and the German Aerospace Center’s space activities. Approximately 70% of federal funding for space research is directed to European programs within ESA. Under the German Space Programme, Germany bears the largest share of operational and usage costs (7%) associated with the International Space Station.6

Environmental research is also a major component of Germany’s R&D portfolio. In 2002, government support for environmental R&D was $517 million, placing it among the largest of the federal research programs. Germany’s environmental research program has the primary goal of supporting the long-term goal of creating more sustainable societies. Research carried out under the federal environmental research program falls into three major areas: social-ecological research and regional sustainability; economic sustainability and integrated environmental technology; and global change research. The social-ecological research program covers a wide range of activities including soil conservation, remediation, and revitalization research, water research, and social science research on a many aspects of human interactions with natural systems. The economic sustainability program includes twelve initiatives aimed at providing incentives for innovations in business, policy, and society generally to reduce pollution increase resource efficiency, and create new markets for sustainable technologies and products. The program supports measures in the metallurgy, textiles, and extractive industries to develop management tools for a sustainable economy. Finally, the global change program focuses on the causes and effects of global changes in the environment and in society, aiming to improve the predictability of short-term changes, prepare reliable scenarios for long-term developments, and identify pathways for sustainable development. Among the funding priorities within the global change program are atmospheric research, biosphere research, and the climate research program (DEKLIM).7
Information technology is a priority research area and one to which the government has devoted increasing amounts of resources in recent years. Since 1997 alone, government support has grown by approximately 40% to its 2002 level of $729 million. The information technology program is very broad-based, encompassing computer science, internet technologies, micro-system technology, and production engineering. A key overarching goal of the program is to improve significantly the performance of computer equipment and networks, for example by further miniaturization and integration, use of optical technologies and application of new information processing principles. In addition, the program aims to facilitate the development of new information technologies to enhance quality of life, safety, security, and mobility in an increasingly networked world.

Biotechnology is one of Germany’s strongest research areas and one that is a high priority for the German government. Federal biotechnology research sponsorship has grown by more than 50% over the past decade, to the 2002 level of $327 million. The primary purpose of the government sponsored program is to support innovation in the biosciences and genetic engineering, especially areas overlapping research in other disciplines. Biotechnology is regarded as a key to Germany’s future health and economic competitiveness. The biotechnology program funds a major National Genome Research Network and genome research program, and supports the reorganization of industrial processes to make them more sustainable through the use of biotechnology and related methods. The National Genome Research Network funds research in five key areas of diseases disorders: cardiovascular disorders; cancers; nervous system disorders; environmentally-related illnesses; and infections. The program also investigates ethical, legal, and social aspects of genome research.8

Health research in Germany, as in many other industrialized countries, is a high priority funding area that has enjoyed consistent funding increases since the mid-1980s. The government’s health research portfolio comprises four main programmatic elements. “Effective prevention and treatment of disease” is a broad program that includes research on lifestyle, nutrition, and environmental health, as well as nervous system and mental health, and cancer research. “Research for the health care system” addresses a variety of public health and policy issues including the quality and cost-effectiveness of the health care system, epidemiological research, and study and analysis of groups in the population representing high health risks. “Health care research” is primarily a medical technology R&D partnership between the German government and health technology industry. Finally, “strengthening the research landscape through structural optimization/innovation” supports interdisciplinary centers for clinical research, provides assistance to research institutions in the eastern German states, and provides support to coordination centers for clinical studies, clinical pharmacology, and medical ethics.9
Energy Overview and Energy Policy

In 2000, Germany consumed 15.1 quadrillion BTUs, making it the world’s fourth largest energy consumer. On a daily basis, Germany consumed approximately 2.8 million barrels of oil, 98% of which was imported, making Germany the world’s third largest oil importer. Germany also is a large user of natural gas, of which it consumed 3.3 trillion cubic feet (tcf) in 2000, 75% of which is imported. Gas use is expected to rise significantly over the coming decades, as the German government aims to use gas broadly to replace both nuclear and coal-fired power plants. Coal, which today fuels more than 50% of Germany’s electric power production, is the nation’s only major domestic fuel source, although heavy subsidies are necessary to maintain the viability of the domestic coal industry. Domestic coal reserves are approximately 74 billion tons, of which 36% is hard coal (anthracite and bituminous) and 64% is soft coal (lignite and sub-

Table 1. Germany’s Energy Policy Goals

<table>
<thead>
<tr>
<th>Strategies</th>
<th>Supply Security</th>
<th>Economic Growth</th>
<th>Environmental Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Strengthen and develop domestic resources</td>
<td>• Ensure affordable energy supply to industry and</td>
<td>• Replace high-emissions energy sources with</td>
</tr>
<tr>
<td></td>
<td>• Increase import diversification</td>
<td>residential consumers</td>
<td>low-emissions sources (especially renewables)</td>
</tr>
<tr>
<td></td>
<td>• Increase energy efficiency</td>
<td>• Maintain competitiveness of Germany as</td>
<td>to meet climate protection goals</td>
</tr>
<tr>
<td></td>
<td>• Ensure security of transmission lines</td>
<td>locale for energy production</td>
<td>• Increase energy efficiency</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Provide opportunities for German energy</td>
<td>• Internalize environmental externalities in cost</td>
</tr>
<tr>
<td></td>
<td></td>
<td>firms in foreign markets</td>
<td>calculations</td>
</tr>
</tbody>
</table>

bituminous). After coal, nuclear power contributes the largest share to Germany’s electric power production, accounting for almost 30% of actual power generation. The German government has also made a strong commitment to the accelerated deployment of renewable energy technologies (primarily offshore wind turbines and solar panels) as part of its overall effort to reduce greenhouse gas emissions and to offset the retirement of nuclear power plants. According to Germany’s Ministry of the Environment, as much as 60% of the country’s nuclear power could potentially be replaced with wind power by 2030.

Since 1998, when the Red-Green coalition government entered office, Germany’s energy policy has sought to balance three main objectives: environmental protection, energy supply security, and economic growth. Since the government regards these three goals as competing with one another inherently, it views the role of energy policy as intervening tool that can contribute to each of the three main energy policy objectives, it too figures prominently as a goal of German energy policy. In fact, overall energy use in Germany
has been declining in recent years and the government has made the continued decline in energy consumption an important element of its energy policy.\textsuperscript{13}

Germany has taken a leading role among industrialized countries in its efforts to reduce domestic greenhouse gas emissions and ensure climate protection. In late 1997, the German government announced plans to reduce domestic greenhouse gas emissions to 40\% below 1990 levels; this target far exceeded required commitments under the Kyoto Protocol. Since then, however, the government has indicated that it may be necessary to revise those goals in the light of the potential economic and energy supply security implications of such sharp emissions reductions. For example, achieving such ambitious climate protection goals could prompt the accelerated removal of domestic coal resources from the fuel mix, necessitating higher gas imports. Such a policy, in turn, could undermine an important facet of Germany’s energy supply security by effectively shutting down the domestic coal industry. Similarly, while the government remains committed to aggressive climate protection, it maintains that it can only do so if overall economic development is not weakened as a result. Germany’s energy policy since 1998, has had to recognize explicitly the real trade-offs and challenges that policymakers face in seeking to create a more sustainable energy economy. Germany’s greenhouse gas emissions today are approximately 17\% below 1990 levels.\textsuperscript{14}

The German government now recognizes three major energy issues that present particular policy challenges:

\textit{Liberalization and Integration of European Energy Markets.} The liberalization and integration of EU electricity and gas markets is a key component of overall European integration. Several EU statutes govern the integration of energy networks throughout Europe and provide a legal framework and an imperative for integration. For example, EU Council Directives concerning common rules for the internal market in electricity and gas necessitate the gradual opening of EU member states’ domestic energy markets to competition and to foreign firms’ participation. Nonetheless, the integration process is occurring unevenly and with varying degrees of enthusiasm on the parts of member states. In preparation for full integration, Germany began liberalizing its electricity market—Europe’s largest—in 1998; its electricity market is now the most competitive in Europe. German firms are increasingly active in foreign markets, while foreign investment in Germany’s power market has also grown steadily.\textsuperscript{15} Liberalization is proceeding via agreements among major market participants and is not overseen by any government regulatory agency. Thus far, liberalization has resulted in lower consumer prices, decreased employment in the industry, and significant consolidation.

Major issues remain to be resolved, including the question of third party access to electric power transmission networks. A 1998 agreement, the \textit{Verbandervereinbarung}, placed control of the transmission network largely in the hands of six firms and generated significant controversy among industry participants. A subsequent agreement, concluded the following year, aimed to resolve outstanding issues, but stirred additional controversy and even attracted the attention of EU competition authorities. Major issues raised with
respect to the agreement include a lack of price transparency in the transmission market and the division of the German power market into two distinct trading zones.\textsuperscript{16}

Since EU Directives mandate the opening of member states’ energy markets to foreign investment and competition, the German government has been vocal in criticizing several EU member states that have not adopted liberalization measures. German courts have now granted power companies the right to block electricity imports from countries that deny or limit market access to foreign firms.

Liberalization and integration of energy markets also raise related challenges in the prospect of higher levels of energy import dependence. Germany currently imports all of its oil and more than 80\% of its natural gas supply, and that level of dependence is expected to rise significantly as gas supplants coal and nuclear power for electricity generation. Liberalization and market integration are likely to reduce energy prices further, making it more difficult for domestic energy producers to compete and ultimately heightening Germany’s overall risk exposure resulting oil, gas, and power imports. A growing challenge for German policy makers will be that of balancing rising energy imports with the goal of sustaining the domestic coal industry.\textsuperscript{17}

\textit{Climate Protection}. In the coalition agreement of 1998, Germany’s Social Democratic Party and Green Parties established as an overall goal the pursuit of sustainable development: “development that is economically efficient, socially equitable, and ecologically acceptable.”\textsuperscript{18} In conjunction with this goal, Germany has demonstrated a strong commitment to an energy policy that protects the Earth’s climate by reducing the nation’s emissions of greenhouse gases and other contributions to climate change.\textsuperscript{19} As part of the European Union’s commitment under the Kyoto Protocol, Germany agreed to a 21\% reduction in greenhouse gas emissions from 1990 levels within the period 2008-2012. Its domestic emissions reduction goals go even further, aiming for a 25\% emissions cut by 2005, relative to 1990 levels. German industry also entered into a voluntary agreement with the federal government that aims for a 28\% reduction in industrial greenhouse gas emissions by 2005 and a 35\% reduction from 1990 levels by 2012. To this end, the energy industry committed itself in November 2000 to an annual CO\textsubscript{2} reduction of 45 million tones; at least 51\% of these reductions are to be achieved through the government-sponsored deployment and upgrading of combined heat and power stations.\textsuperscript{20} More recently, in June 2001, the leading German associations of the German energy industry, the Federation of German Industries, the German Ministry of Economics and Technology and the Ministry of the Environment initialed a supplementary agreement to reduce CO\textsubscript{2} emissions and promote cogeneration. Under this agreement, industry has committed itself to the expansion of cogeneration and renewable energy sources to achieve an additional CO\textsubscript{2} reduction of at least 20 million tones by 2010.\textsuperscript{21}

An important goal of German energy and climate policy is the reduction of overall energy use through the continued improvement of energy efficiency and the development and deployment of new energy technologies, including cogeneration, fuel cells, and renewable energy technologies, all of which are receiving significant federal government
support. Wind power especially, as Germany’s most abundant renewable energy resource, is making steady inroads into Germany’s primary energy supply. Germany now has approximately 700 MW of wind capacity installed and is home to the world’s largest wind farm, with a production capacity of 105 MW. In 1999, wind power already accounted for 2.8% of total electric power production; through aggressive promotion programs including loan guarantees to investors, the government intends to increase wind power share to 12.5% by 2010, mainly through the development of offshore wind parks.22

In an effort to maintain the momentum behind recent reductions in the country’s greenhouse gas emissions, Germany’s Renewable Energy Law provides exemptions from “eco-taxes” and other incentives for private investment in wind, solar, and other renewable energy systems. This law, in conjunction with other federal government programs, such as the 100,000 Solar Roof Program, has played important roles in spurring the accelerated development of renewable energy technologies, which, in turn, has helped Germany to attain a leading position in the world market for renewable energy technologies. EU-level policies, such as the 2001 guidelines for the promotion of renewable energy for electric power production, have also prompted all EU member states to adopt ambitious goals for the expansion of renewables in the power production fuel mix.23 The German government views climate change as both a moral imperative and as an important marketing opportunity for German technology vendors. German firms are currently world leaders in the market for wind turbines, solar photovoltaic panels, and other renewable energy technologies.

Replacing Nuclear Power in the Fuel Mix. In June 2001, the federal government and the operators of nuclear power plants signed an agreement that serves as the basis for the orderly and complete phaseout of nuclear power in Germany, potentially by 2021. Under the agreement, each nuclear facility is granted a fixed lifetime allotment of power production, and every plant has a maximum lifespan of 32 years.24 Since nuclear power accounts for 30% of Germany’s electricity generation capacity, replacing it clearly presents major challenges. The government proposes to accomplish this goal in part through the accelerated deployment of renewable energy technologies, including wind turbines and geothermal power stations, through cogeneration, and through intensified efforts to improve the energy efficiency of the economy, from energy production to end use.25 Moreover, government scenarios of Germany’s energy future anticipate that overall primary energy use will continue to decline to 2020 and beyond. Declining overall energy use, in conjunction with the expanded use of natural gas and renewable energy technologies are expected to facilitate the replacement of nuclear power without a corresponding rise in greenhouse gas emissions.26

During the phase out of nuclear power, a key policy goal will be the maintenance of Germany’s high level of nuclear safety in both reactor operation and waste management. Thus, the federal government will continue to make significant investments in nuclear research on reactor safety and waste storage. In 2002, the federal government invested approximately $125 million in nuclear fission research, 31% of the total federal energy R&D budget.27
Private Energy Research & Development

The public sector has consistently been Germany’s primary sponsor of energy R&D. As Figure 3 shows, public and private investment in energy R&D have both declined over the past decade, although investments in both sectors have stabilized recently.

Figure 3. Public and Private Energy R&D Expenditures, 1991-2001

Few data are available regarding the specific direction of private R&D funds. However, it is clear that German industry is actively engaged in several R&D areas that hold great commercial potential. For example, Daimler Chrysler Corporation, through its NECAR program, is currently developing a mass-market fuel cell vehicle. In collaboration with other energy technology firms including Canada’s Ballard Power and U.S.-based SatCon Technology Corporation, Daimler Chrysler is developing both hybrid electric fuel cell vehicles and dedicated fuel cell vehicles, which are expected to be available by 2004.28 German auto makers, including Volkswagen, Audi, and Daimler Chrysler, are also collaborating in the development of transportation fuels from biomass, including biodiesel.29
Germany’s Federal Energy Research and Technology Development Program

Germany’s energy R&D program is housed in two federal government agencies, the Federal Ministry of Economics and Technology (BMWi) and the Federal Ministry of Education and Research (BMBF). BMWi’s energy R&D portfolio includes research in the fossil fuel, renewables, and nuclear fission areas, while BMBF administers the government’s fusion and nuclear decommissioning research programs and provides core funding for the Helmholtz Society of German Research Centers, a consortium of 15 user facilities and major research centers. The Juelich Research Center (FZ-Juelich), one of Germany’s Helmholtz Centers, manages the federal energy research program for both BMWi and BMBF. FZ-Juelich, which is one of 15 major research facilities that collectively form the Helmholz Society of German Research Centers, is also a major performer of energy R&D in Germany.

As Figure 4 shows, Germany’s federal energy R&D program has declined sharply and steadily since the early 1980s, when the last of the major world energy crises occurred. After peaking in 1981 at approximately $1.65 billion, government investment in energy R&D was $407.7 million in 2002.

Figure 4. Federal Government Investment in Energy R&D 1981-2002

Until the early 1990s, the nuclear fission research program accounted for the majority of Germany’s energy R&D activity and, thus, its subsequent decline accounts for the majority of the reduction in Germany’s energy R&D program. Waning public acceptance of nuclear energy and questions surrounding reactor safety and waste management led to a corresponding decline in public R&D support beginning in the 1990s. Funds that had
previously been used for fission research were not re-directed to other energy R&D program areas, but were shifted to other budget areas altogether. Since its peak in 1982, fission R&D has declined by 91% in real terms.

Similarly, funding for fossil energy R&D has experienced a continual decline since the early 1980s, although from a much lower peak level than the fission R&D program. Between 1981 and 2002, fossil energy R&D fell by 98% in real terms. Since the 1980s, the emphasis of government-sponsored R&D has clearly shifted from fossil energy research to energy efficiency and the accelerated development and deployment of renewable energy technologies. The fact that Germany has very few indigenous fossil resources—aside from significant hard and brown coal reserves—plays a role in the government’s decision to focus its remaining R&D resources in this manner. Consistent with German energy policy’s focus on climate change and greenhouse gas emissions, the government energy R&D program now aims in the first line to reduce overall energy demand and replace of fossil technologies with renewable energy sources.

Renewable energy and rational energy use have gained considerable favor on the parts of both the German government and the public and now serve as the centerpiece of German energy policy. Yet, direct federal sponsorship energy R&D in these areas has fluctuated widely over the past twenty years and has declined in seven of the past nine years. From a peak of $223 million in 1991, renewable energy/rational use R&D has fallen by 27% to its current level of $164.7 million. Nonetheless, through the enactment of legislation such as the Renewable Energies Act, “eco-taxes,” and other policy incentives, the German government has succeeded in continually achieving higher levels of energy efficiency and broader deployment of renewable energy technology, especially for electric power production. Moreover, the German government has partnered with private firms in several cost-shared research projects aimed to assist German firms in attaining a prominent position in the world market for solar and wind power technologies.30

In the domain of non-nuclear energy, emphases are in the following three areas:

- Reduction of energy demand
- Improvement of energy efficiency
- Augmentation of renewable energy source

Under the 2001-2003 investment program emphasis is being placed on the following technology areas: fuel cells, geothermal devices for power and heat production, offshore wind parks, energy optimization of older buildings and innovative propulsion technologies. Also, since nuclear safety will remain a high priority for the remainder of the plants’ service lives, development of reactor safety technologies, methods, and instruments is ongoing. Geologic disposal of nuclear wastes also remains an important research area.
Coal and Other Fossil Fuels

Support for fossil energy R&D in Germany has declined precipitously over the past decade. While the German government continues to provide some funding, mainly for coal combustion/combustion efficiency and power plant technology research, the federal fossil program has declined by approximately 80% since 1990 and appears poised to continue along the same trend line.

Figure 5. Fossil Energy R&D 1990-2002

Existing fossil energy R&D program areas include:

Energy Conversion Efficiency

The improvement of combustion processes and components is a central element of Germany’s fossil energy research program. The improvement of conversion efficiency is central to the federal energy research program in the light of expectations that electricity demand is likely to continue to grow and, thus, end use efficiency programs alone are unlikely to reduce emissions of greenhouse gases and other pollutants. The development of more efficient gas and steam turbines for combined cycle power plants, and cleaner coal use through higher temperature combustion are core elements of the federal energy R&D program. Through the five-year “Komet 650” program, which began in 1998, the government aims to boost average power plant efficiency from its current level of 34% to 50% by raising the steam temperature in power plant boilers to 650 degrees Celsius.
Achieving this target would also reduce power plant carbon dioxide emissions by 34% on average from current levels.  

Creating the "CO2-Poor" Power Plant FY 2002 $3.84 million

The fossil energy program also aims to cut power plant emissions through the development of advanced materials that facilitate operation of power plants at higher temperatures and pressures. A main focus of research in this area is the further development of combined cycle gas turbines to reach operating efficiencies in excess of 60% by 2005.  

Other Fossil Research FY 2002 $1.6 million

Additional fossil research, performed primarily by the Juelich Research Center, focuses on the continued improvement of fluidized bed coal combustion for the long-term future and investigation of hot gas scrubbing methods and their potential use in conjunction with gas turbines and high-pressure combustion technologies.
Renewable Energy and Rational Energy Use FY 2002 $195.54 million

The German government’s renewable energy program has fared best of all energy R&D programs in Germany, although the direction of funding within the program has been far from consistent over the past decade, as Figure 6 shows. The program has the long-term goal of increasing the economic viability of renewable energy sources and aggressively deploying renewable technologies. The program also aims to improve overall energy efficiency and energy productivity throughout the economy. Although government funding for renewables and energy efficiency R&D has fluctuated over the past decade, this area has received a commitment that is stronger and more consistent than those in any other energy R&D area. In this regard, the relatively high levels of government funding for renewables and efficiency research underscore the its centrality to Germany’s energy policy and to its vision of a future that is less energy- and carbon-intensive.

Figure 6. Renewable Energy and Rational Use R&D, 1990-2001

In a few, high priority R&D program areas described below (photovoltaics, wind energy, residential solar energy), the federal research expenditures have included funding for technology demonstrations and commercialization programs, although the resources devoted to such activities have declined in recent years.

Major areas of research include:
Photovoltaics  

FY 2002 25.62 million

The government-sponsored photovoltaic research program focuses on the continued reduction of manufacturing costs for solar cells and modules, and on measures to reduce high costs associated with assembly, installation, and controls. In addition, the government sponsors a variety of experimental solar technology deployment and integration programs. Among these are programs for new housing developments, for example in the town of Hettstadt bei Wuerzburg, where state-of-the-art solar roofs and passive solar features are combined to create community-wide renewable energy systems. Other programs explore the integration of solar photovoltaic technologies with passive solar building methods in commercial and industrial buildings.

Wind Energy  

FY 2002  $18.48 million

Wind energy research concentrates on the development of high-megawatt wind installations, especially for offshore deployment. In 2002, three offshore wind power research platforms are being constructed with federal government support to measure a number of technical parameters (e.g., wind speed, wave height, ocean currents, environmental impacts) that have important bearings on wind turbine design and deployment. In 2002, the federal government is investing $15.5 million in the construction, deployment, and operation of these offshore research platforms.

Geothermal Energy  

FY 2002 $7.67 million

Geothermal (hydrothermal) research currently is evaluating the geological and economic conditions for the use of geothermal springs for energy production. There are two major research areas within the geothermal energy program: hot dry rock and hydrothermal geothermal energy. Funding for the geothermal research program includes resources for a multinational, large-scale hot dry rock demonstration facility (in Soultz, France) that aims to improve the prospects for industrial applications of geothermal energy; overall improvement of the commercial potential of geothermal technologies and, particularly, development of more corrosion-resistant materials.

Biomass Energy  

FY 2002 budget data unavailable

Biomass research falls under the auspices of the Federal Ministry of Agriculture, Consumer Safety, and Nutrition. Research concentrates on three program areas: development of high-efficiency boilers for the combustion of wood- and straw-pellets for heat and power production; production and use of biogas from agricultural and municipal wastes; and biofuels (including biodiesel) for heat and transportation applications.
Electrochemical Processes and Hydrogen FY 2002 $47.38 million

The electrochemical processes and hydrogen research program, which encompasses fuel cell research, is one of the highest priority research areas in the German government’s energy R&D portfolio. Government sponsorship of fuel cell research concentrates on the development of technologies that would facilitate the cost-effective production and reliable use of fuel cells. Germany’s fuel cell research program focuses on four fuel cell designs for transportation and stationary applications: proton exchange membrane (PEM) fuel cells; molten carbonate fuel cells (MCFC); solid oxide ceramic fuel cells (SOFC); and direct methanol fuel cells (DMFC). Federally sponsored transportation fuel cell research has three main objectives. First, it aims broadly to expand the technology options available to alleviate the overall environmental burdens associated with energy use. Secondly, it aims more specifically at the creation of a zero-emissions vehicle, and finally, it seeks to demonstrate the potential of the fuel cell as a true alternative to the internal combustion engine and as a means to energy independence. Through the ZIP program, the German government is currently sponsoring a wide variety of fuel cell projects in an effort to reduce fuel cell production costs, assess alternative fuel cell designs and applications, and train a cadre of qualified professionals in Germany. Table 2 below details current federal investments in fuel cell projects.

Table 2. Current Federal Investments in Fuel Cell Research Projects

<table>
<thead>
<tr>
<th>No.</th>
<th>Grant Recipient</th>
<th>Research Area</th>
<th>Funding Level 2002 ($ million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3</td>
<td>EFC, Schunk, Freudenberg</td>
<td>Development of manufacturing technology for residential PEM fuel cells</td>
<td>11.5</td>
</tr>
<tr>
<td>4</td>
<td>RWE Plus AG</td>
<td>System integration, field testing of residential PEM fuel cells</td>
<td>2.72</td>
</tr>
<tr>
<td>5</td>
<td>HEW</td>
<td>Integration of residential PEM fuel cells in energy systems</td>
<td>1.41</td>
</tr>
<tr>
<td>6-9</td>
<td>KET, DBI, S&amp;R GmbH, Technische Universitaet Freiburg</td>
<td>Field testing of 12 kW PEM fuel cell</td>
<td>1.04</td>
</tr>
<tr>
<td>10-14</td>
<td>DVGW, Ruhrgas, GWI, Technische Hochschule Karlsruhe, DBI</td>
<td>Development of common European standards for residential fuel cell applications</td>
<td>1.93</td>
</tr>
<tr>
<td>15</td>
<td>Energieversorgung Weser Ems</td>
<td>Field testing of residential PEM fuel cells</td>
<td>1.88</td>
</tr>
<tr>
<td>16</td>
<td>Ballard Power</td>
<td>Field testing of fuel cells for electric power generation</td>
<td>1.36</td>
</tr>
<tr>
<td>17-18</td>
<td>FZ-Juelich, FEV Motorentechnik</td>
<td>Establishment of safety standards for fuel cells in combined heat and power applications</td>
<td>0.17</td>
</tr>
<tr>
<td>19-21</td>
<td>RWE AG, VSE, IPF</td>
<td>Field testing of MCFC in greenhouses, clinics, and laundry facilities</td>
<td>6.06</td>
</tr>
<tr>
<td>22</td>
<td>Pfalzwerke AG</td>
<td>Fuel cell for Gruenstadt emergency clinic</td>
<td>2.35</td>
</tr>
<tr>
<td>23</td>
<td>DeTe Immobilien Deutsche Telekom</td>
<td>Fuel cell for transmission facility</td>
<td>2.62</td>
</tr>
<tr>
<td>24</td>
<td>EnBW</td>
<td>Testing of MCFC in process heating application</td>
<td>1.78</td>
</tr>
<tr>
<td>25</td>
<td>Stadtwerke Hannover</td>
<td>Field Testing of SOFC</td>
<td>3.19</td>
</tr>
<tr>
<td>26</td>
<td>E.ON AG</td>
<td>MCFC for industrial combined heat and power application</td>
<td>1.83</td>
</tr>
<tr>
<td>27</td>
<td>ALSTOM Power</td>
<td>Integration of fuel cell in steam power plant</td>
<td>1.51</td>
</tr>
<tr>
<td>28-30</td>
<td>BVG Berlin, Stadler, Proton Motor FC GmbH</td>
<td>Development of fuel cell-powered double-decker buses</td>
<td>5.17</td>
</tr>
<tr>
<td>31</td>
<td>Stadt Barth</td>
<td>Fuel cell-powered small bus; hydrogen infrastructure</td>
<td>1.36</td>
</tr>
<tr>
<td>32</td>
<td>STILL GmbH</td>
<td>Fuel cell fork lift</td>
<td>0.99</td>
</tr>
<tr>
<td>33</td>
<td>TRUMA GmbH</td>
<td>Fluidized gas reformer for fuel cell application</td>
<td>0.62</td>
</tr>
<tr>
<td>34</td>
<td>MTU AeroEngines</td>
<td>Integrated fuel cell-gas turbine concept (APU)</td>
<td>0.2</td>
</tr>
<tr>
<td>35-37</td>
<td>Stuttgarter Strassenbahn AG, Hamburger Hochbahn AG, HEW AG</td>
<td>Testing of fuel cell buses and hydrogen fuel supply</td>
<td>3.34</td>
</tr>
<tr>
<td>38</td>
<td>MTU Friedrichshafen</td>
<td>MCFC production methods</td>
<td>1.36</td>
</tr>
<tr>
<td>39</td>
<td>ZSW Stuttgart</td>
<td>PEM testing instruments</td>
<td>3.14</td>
</tr>
<tr>
<td>40-44</td>
<td>ZSW, FZ-Juelich, HPI Hannover, TUV-Rheinland, OWI</td>
<td>Development of training centers</td>
<td>2.77</td>
</tr>
</tbody>
</table>

**Stationary Fuel Cells for District Heating**

**Mobile Fuel Cell Applications**

**Technical Training and Skill Development for Fuel Cell Technologies**

**Energy Efficiency**

FY 2002 $18.3 million (estimated)

The German government provides support for a wide range of energy efficiency programs including:
• The Rational Energy Use Program, which focuses on heat production for buildings and district-heating technologies ($2.9 million).
• Energy Optimization of Building Materials, which focuses on the retrofitting of existing residential buildings with energy efficiency technologies and the development of new software and components for incorporation in buildings demonstration projects ($8.65 million).
• Energy Efficient Industry, which focuses on industrial processes, particularly on electronic separation of metals, draining and drying, and refrigeration engineering ($6.69 million).
As Figure 7 shows, Germany’s nuclear R&D program reflects the nation’s intention to end its use of nuclear power and its ongoing need for a long-term storage site for radioactive waste. While the government had previously sponsored major programs in the areas of breeder reactor research and high temperature reactor research, funding for all reactor design activities has been cancelled altogether. Several reactors will be decommissioned in upcoming years, beginning with a series of pilot- and experimental reactors, while the newest commercial reactors have a potential remaining service life of around 20 years.

Nuclear safety remains a high priority for all reactors in service and will continue to reflect advances in related technologies. Consequently, the government continues to sponsor a nuclear safety research program, albeit at a reduced level. Government agencies as well as foundations and research institutions are all engaged in intensive reactor safety and waste disposal R&D independent of private industry participation. Waste disposal now constitutes the largest element of the remaining fission research budget. An important objective of this research is to maintain Germany’s high level of competence and capability in the reactor safety technology area.
Germany’s nuclear energy program also includes a strong non-proliferation component. Technologies developed through the government-sponsored fissile materials safeguards program are placed at the disposal of the International Atomic Energy Organization and Euratom for use in weapons inspection programs.

**Nuclear Decommissioning**

**FY 2002 $4.7 million**

Germany’s nuclear decommissioning program currently focuses on the dismantling of twelve experimental and pilot reactors that have now reached the end of their service lives. Several of these sites, including experimental reactors in Niederaichbach and Grosswelzheim have now been fully decommissioned and returned to “green field” condition. Several other experimental reactors have long been out of service and now await full decommissioning, although funding for decommissioning R&D has been sharply reduced in recent years, as Figure 8 shows.

**Figure 8. Nuclear Decommissioning R&D, 1989-2001**
Nuclear Fusion Research  

The goal of fusion research is to show that large-scale power production is possible through a controlled fusion reaction in a fusion reactor. Germany’s fusion research program is concentrated in three centers: the Max Planck Institute for Plasma Physics, the Karlsruhe Research Center, and the Juelich Research Center. Germany’s fusion research is a component of the broader European fusion program, carried out under the auspices of Euratom, which provides partial funding. Figure 9 shows German federal government support for fusion research from 1989-2001.

Figure 9. Fusion R&D, 1990-2001

At the center of the research is the study of the physics of plasma combustion for fusion and the development of materials for the containment, heating, and preservation of plasma. The largest ongoing fusion project in Germany is the new, large stellator experiment Wendelstein 7-X, which runs through 2006. The stellator, like the Tokamak, is a variant for magnetic plasma containment.

---


See, for example, http://www.daimlerchrysler.com/index_e.htm?/news/top/2000/t00406_e.htm

