

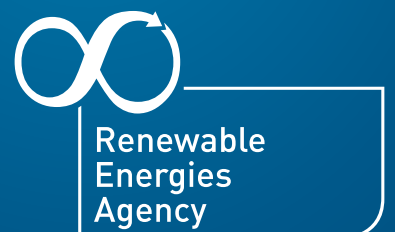
# Renews Special

## Issue 41 / September 2010

Background information  
from the German Renewable Energies Agency

### **A Success Story: Twenty Years of Support for Electricity from Renewable Energies in Germany**

[www.renewables-in-germany.com](http://www.renewables-in-germany.com)



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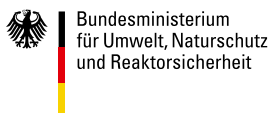
This Renews Special is a short version of an extensive research report titled Erneuerbare Energien in Deutschland – eine Biographie des Innovationsgeschehens, which is available free of charge from the web page of the library of the Berlin University of Technology:

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## Contents

• <b>Preface</b>	<b>5</b>
• <b>Summary</b>	<b>6</b>
• <b>Renewable energies in their socio-political context</b>	<b>7</b>
• <b>Energy Policy Milestones, 1990-2009</b>	<b>9</b>
– The Electricity Feed-In Act (StrEG)	9
– The Renewable Energy Sources Act (EEG)	10
– The EEG revision, 2004	11
– The EEG revision, 2008	11
– Other policy milestones	12
– Climate protection and a sustainable energy supply	14
– An engine for business and the labour market	14
– Perspectives	15
• <b>The Innovation Dynamics of Renewable Energies</b>	<b>17</b>
– Actors of innovation	17
– Various dynamics of technical innovation	17
• <b>Hydroelectric power</b>	<b>18</b>
– The pioneer and expansion (1850-1930) and the maturity phases (1930-1990)	18
– Revival through legally mandated feed-in tariffs(1991-1999)	20
– Modernization under ecological stipulations (since 2000)	21
• <b>Wind Energy</b>	<b>23</b>
– Pioneers conquer the field (1975-1986)	23
– The fresh start (1986-1991)	24
– The first wind power support programmes	25
– Technical developments in the launching phase	25
– Initial planning specifications	25
– The breakthrough (1991-1995)	26
– Spanner in the works (1995-1997)	27
– Dynamic growth (1997-2002)	27
– Stable development onshore and planning for offshore (since 2002)	29
– Offshore wind energy	30
– Perspectives	32
• <b>Photovoltaics</b>	<b>33</b>
– Industry and research as pioneers (1970-1985)	33
– Industry withdraws, R&D stays (1986-1991)	34
– More than 1,000 roofs with photovoltaic systems (1991-1994)	35
– Uncertainty and slowdown (1994-1998)	36
– The breakthrough: The EEG and the 100,000 roofs program (1999-2003)	37
– Dynamic development (2004-2010)	38
– Perspectives	40

• <b>Biogas</b>	<b>41</b>
– The origin of biogas use	41
– Research and pioneer phase (1970-1990)	42
– The fresh start with the StrEG (1991-1999)	43
– Major expansion under the EEG (2000-2004)	45
– Dynamic growth (2004-2006)	46
– The market collapse due to the rise in substrate prices (2007-2008)	48
– Revival and perspectives (since 2008)	48
• <b>Geothermal energy</b>	<b>51</b>
– Research and development phase (1985-2003)	51
– Entry into electricity generation (since 2004)	53
– Technical and economic challenges	54
– Legal framework	55
– Perspectives	55
• <b>Perspectives</b>	<b>56</b>
– Climate and energy policy goals	56
– Challenges to the grid and the power plant park	56
• <b>Bibliography</b>	<b>58</b>
• <b>Photo Credits</b>	<b>58</b>

## Preface

Dear Reader,

As we look back at twenty years of the development of renewable energies in Germany, we can see an impressive success story. Who would have expected, at the beginning of the nineties, that within only 20 years renewable energies would be providing 16% of our electricity. This is five times as much as in 1990. At that time, hydroelectric power was the only significant renewable source element in the electricity production picture. The potential for renewable energies was generally seen to be low.

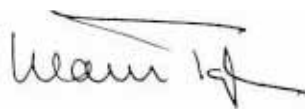
In 1990, the Bundestag laid the key foundation stone for the successful launching of a broad range of renewable energies in Germany by adopting the Electricity Feed-In Act (StrEG). The motivation for this was the ever greater realization in broad segments of the public and among policy-makers, and even – increasingly – in the business community that the energy supply would have to become more independent of imports of fossil fuels. Especially in the area of the wind energy, the Electricity Feed-In Act enabled rapid development, and electricity generation from the wind rose enormously. Legally mandated support paved the way for technical innovations, which made it possible to reduce the costs of wind energy faster than expected. Many future-oriented jobs were created.

In order to transfer these successes to other areas of renewable energies, the Electricity Feed-In Act was replaced by the Renewable Energy Sources Act in 2000. Since then, this law has proved to be the most important and most successful instrument for the launching of renewable energies in the area of electricity. It has become one of the big export success stories of German environmental policy. It is important to continue this successful development, so as to achieve a complete switch to a regenerative energy supply as soon as possible.

This support for renewable energies was and is integrated into national and international climate protection policy. Efficiency technologies and renewable energies are the keys for a secure and climate-friendly energy supply. Renewable energies can provide affordable energy over the long term, and guarantee supply security on a global scale. Germany bears a global responsibility to provide climate-friendly technologies and solutions – and the German economy, too, will profit greatly. Future-oriented, environmentally benign technologies create important jobs. The world will soon have 9 billion people, and will depend economically and ecologically on a secure energy supply beyond fossil fuels.

This paper takes a look back at the rich 20 year history of development – at the successes and also at the conflicts of that period.

I wish you informative reading.



Prof. Dr. Klaus Töpfer



## Summary

This publication from the series *Renews Special* traces the historical development of electricity generation from renewable energies in Germany. It is the summary of an extensive research project at the Berlin University of Technology titled "Renewable Energies in Germany: The biography of a phenomenon of innovation".

This analysis describes the societal background for the reorganization of the power supply system and the most important political and legal measures taken to set the course for the development of renewable energies, and provides a summary of the technological innovations achieved to date. One major focus is on the origin of the German feed-in regulations. This is particularly interesting, since it came largely from a parliamentary initiative with broad support from all the party groups in the Bundestag – rather than from the government. In terms of the technological processes of innovation, the report confines itself to the area of electricity generation, particularly to those technologies, which have undergone substantial further development over the past 20 years. Another background paper from the *Renews Special* series, no. 37, contains more information on technical innovations.<sup>1</sup>

The Electricity Feed-In Act (StrEG) was an initial effective step towards the broad launch of renewable energies in 1991. It forced companies in the not yet liberalised electricity market to provide access to the grid for power generated by hydroelectricity plants, wind turbines, solar energy and biogas plants, and pay legally defined prices for it. The Renewable Energy Act (EEG) took over from the StrEG in April 2000. It stipulated cost-covering remuneration, to make economic operation possible for all renewable systems of electricity generation. This remuneration was adjusted to the particular technologies of each system, and proved to be even more successful than the StrEG. It resulted in extremely dynamic growth in electricity generation from renewable energy sources. The successes of the EEG are described in a separate background paper in the *Renews Special* series, no. 27, which can be obtained in German on the Internet under [www.unendlich-viel-energie.de](http://www.unendlich-viel-energie.de).

Although neither the StrEG nor the EEG explicitly stipulated funding for research, they sparked considerable innovation in the renewable energy industry. Long-term investment security made the creation of in-house research and development departments possible for many companies, enabling important technological progress, which has made renewable electricity generation more efficient and more cost-effective. The revisions to the EEG passed in the years thereafter have taken this progress into account.



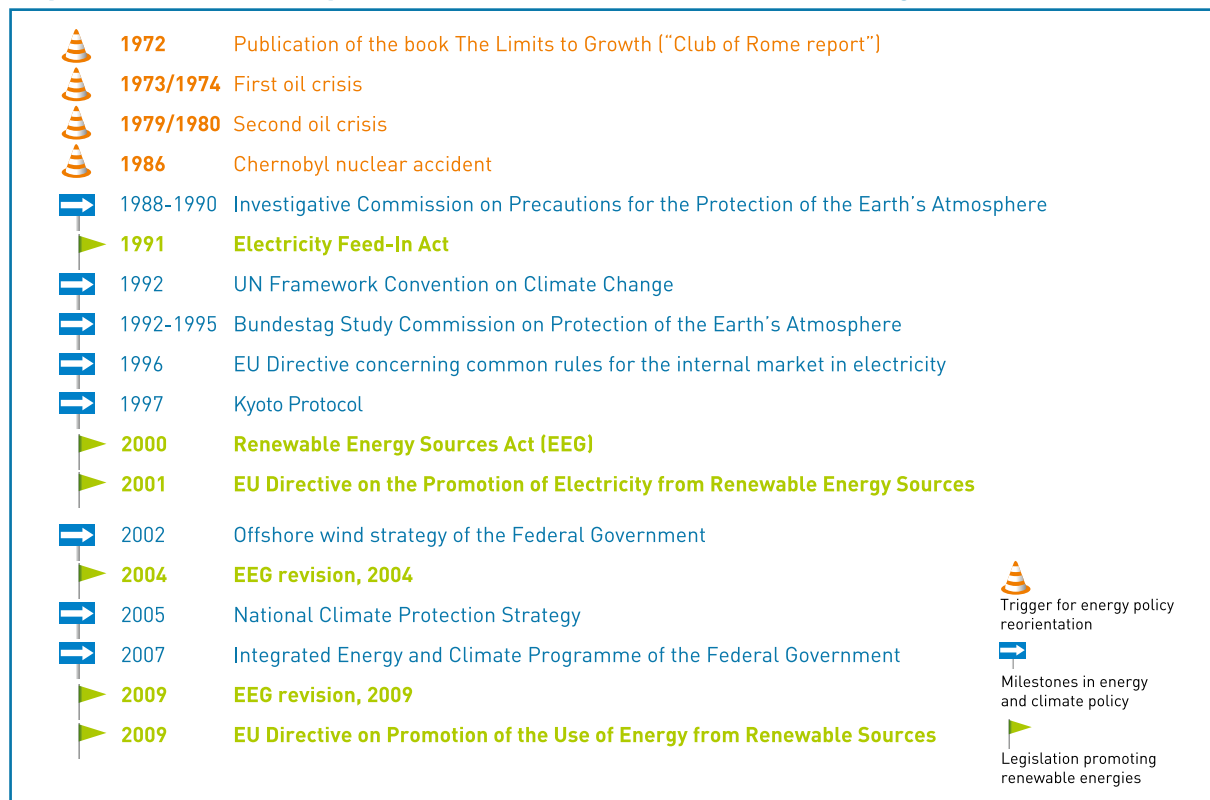
Renewable energies in the Morbach energy landscape provide regional power and heat supply.

<sup>1</sup> Literal translation of the German title; the English translation of the book is titled *Renewable Energies in Germany's Electricity Market*, by the present authors, Springer Verlag (2010).

## Renewable Energies in their Socio-Political Context

A number of events over the past 30 years have shaped the framework for innovation in the energy sector, and especially for the development of renewable energies. The supply and price crises, the public conflict around nuclear power, environmental problems and the threat of climatic change have played a key role, drawing strong public attention to the risks surrounding the conventional energy supply and increasing the pressure for action by governments. The crises have activated a widespread social and political reorientation in the energy area, which has made support for renewable energies an important policy issue.

### Important events and political milestones for renewable energies



As early as the 1960s, environmental awareness was growing in society and among political leaders. A major expression of this consciousness was the 1972 report of the Club of Rome titled *The Limits to Growth*, which attracted great public attention. During the 1970s, the oil price crises made it clear that alternatives to fossil fuels were urgently needed. To ensure the energy supply, the government also promoted nuclear power during this period. The reactor accident of Chernobyl in 1986 sensitized the public to the risks of this technology, and sparked the growth of the anti-nuclear power movement. This, together with the increased strengthening of the environmental movement, formed the socio-political background for energy policy changes during the 1980s. The model of sustainable development, first formulated in the so-called Brundtland Report,<sup>2</sup> also substantially influenced the international debate over development and environmental issues and goals. The report was a trigger for the environmental conference held five years later in Rio de Janeiro.

2) Report of the World Commission on Environment and Development *Our Common Future*, chaired by former Norwegian Prime Minister Gro Harlem Brundtland, 1987.



Dr. Hermann Scheer, 1980 – 2010 Member of the German Bundestag (Social Democratic Party/SPD); President of Eurosolar; Chairman of the World Council for Renewable Energy (WCRE). † 2010

**“Only renewable energies can fulfil the promise made by nuclear energy: a permanent, secure, independent, zero-emissions and peace-assuring energy supply.”**

In the late 1980s, the German Meteorological Society and the German Physical Society published a call, which drew attention to anthropogenic climatic change. Not only the scientific community, but the media and many political leaders too began to address the issue of global warming. Increasingly, reports of the warming of the earth’s atmosphere, the melting of the glaciers and the expected rise of the sea level began to emerge. They led to an intense discussion about the causes and impacts of climate change.

Climate protection became an issue on the German political agenda essentially as a result of the Bundestag Study Commission Precaution for the Protection of the Earth’s Atmosphere (1988-1990). The developments at the national level were carried out in interaction with the international climate protection process: the international climate conferences, the adoption of the UN Framework Convention on Climate Change in 1992 and the institutionalization of climate protection in the EU and at the international level were parts of this process. The greenhouse gas carbon dioxide (CO<sub>2</sub>) was identified as the most important cause of climate change. With the goal of reducing CO<sub>2</sub> emissions, renewable energies moved into the foreground as a central element for climate protection.



## Energy Policy Milestones, 1990-2009

Policy measures and decisions played a central role in the innovation of the German electricity sector and initiated substantial steps in the direction of an energy turn-around. The key was to create a stable financial and legal framework for the initial phase of the development of renewable energies. A major first success in launching the process of innovation of renewable energies was the Electricity Feed-In Act (StrEG) of 1991, which for the first time established a legal right to grid access and sale of electricity, as well as minimum remuneration for the electricity fed-in.

In the mid-'90s, the EU issued specifications for liberalising electricity markets. The resulting modification of the German Energy Industry Law confirmed the access of renewable energies to the electricity market. In 2000, the Renewable Energy Sources Act (EEG) replaced the revised StrEG. It far surpassed the effects of its predecessor legislation in scope, and became the central success factor for the development of renewable energies in Germany.

### The Electricity Feed-In Act (StrEG)

The starting shot for the successful development of renewable energies in Germany came at the end of 1990. Less than two months before the first national elections for a reunified German parliamentary in 1990, a group of members of the Bundestag from all party groups took the initiative for an Electricity Feed-In Act. Some of the representatives who showed particular commitment in favour of the law were Dr. Wolfgang Daniels of the Greens, Dr. Hermann Scheer of the SPD, and Bernd Schmidbauer and Matthias Engelsberger of the CDU/CSU (the conservatives). Within the Federal Government, Minister of the Environment Prof. Dr. Klaus Töpfer supported the bill. The Bundestag passed the StrEG unanimously on December 7, 1990. This was seen as indication of that renewable energies had become established as an important policy area.



Prof. Dr. Klaus Töpfer, Federal Minister for the Environment, Nature Conservation and Nuclear Safety, 1987-'94; Founding Director of the Institute for Advanced Sustainability Studies (IASS) in Potsdam.

**“The Electricity Feed-In Act was the starting point for the successful introduction of renewable energies to the markets.”**

The law, which came into force on January 1, 1991, proved to be a decisive impulse for the launching of renewable energies. Thanks to the StrEG, the electricity market, which was under the management and supply monopoly of the then seven large power companies, was opened for the producers of power from renewable energies. Basically, it regulated access to the power grid, and stipulated the purchase of electricity from renewable energy sources at legally fixed prices. This was a considerable improvement over previous regulations, such as remunerations negotiated case by case under the Associations Agreement.<sup>3</sup> Initially, primarily hydroelectric power and wind power operators profited from the regulations. Wind energy in fact received a real development push.



Dr. Wolfgang Daniels, Member of the Bundestag (Greens) (1987-'90), co-initiator of the Electricity Feed-In Act.

**“The Electricity Feed-In Act was passed because even in the CDU/CSU parliamentary group, some representatives wanted to do something for renewable energies. Nobody could foresee at that time that this law would some day be copied in 40 countries.”**

<sup>3</sup>) The Associations Agreement between the Federation of German Industry, the Federation of the Industrial Energy and Power Industry and the Federation of German Electricity Stations regulated the access conditions to the grid.

At first, the established energy industry saw no great importance in the StrEG, but this would soon change. With the revision of 1994 looming, the power providers made a great effort to have the law repealed. As its effects became ever more palpable, resistance grew commensurately, particularly in the years 1995 through 1997. The core of opposition emerged among those power companies associated in the Federation of German Electricity Industry (VDEW).

The resistance proved unsuccessful however, thanks to the broad political support of many members of the Bundestag. Starting in 1994, the then Federal Minister of the Environment, Dr. Angela Merkel, supported renewable energies, and another important conservative member of the Bundestag, Dr. Peter Ramsauer, also continued to support the StrEG. Ultimately, two revisions, in 1994 and in 1998, adapted the law to the developments that had taken place during the 1990s.

The second revision in 1998 was a compromise with the power companies, since it provided for a cap on the burden placed upon the grid operators by the mandatory purchase of renewable energy. Nonetheless, a lawsuit resulted, which was particularly unsettling to the yet young wind industry. Although the Competition Senate of the Federal Court of Justice had already ruled in 1996 that the StrEG of 1990 was constitutional, some power companies doubted that this was still true after the revision of 1998. The suit lodged by Preussen-Elektra and its subsidiary, Schleswig, before the Kiel District Court went all the way to the European Court of Justice, which in March 2001 ruled that the German law was compatible with EU legislation, and did not constitute an illegal state subsidy under the EC Treaty. In 2003 the Federal Court of Justice finally confirmed that the StrEG of 1998 and also the Renewable Energy Sources Act of 2000 were constitutional, thus putting an end to several years of uncertainty.

### The Renewable Energy Sources Act (EEG)

Under the StrEG, the remuneration for renewable energies was oriented towards the respective price of electricity. The law assumed continuously rising prices. However, when the price of electricity dropped as a result of the liberalization of the late 1990s, the remuneration no longer sufficed to encourage investment. Moreover, the fixed remuneration levels proved to be insufficient to provide a push for the development of technologies other than wind power. This endangered the German and European goals of doubling the share of renewable energies in the power mix by 2010, and of launching their introduction on a broad scale. Thus, the new ruling coalition of Social Democrats (SPD) and Alliance 90/ The Greens (the party's new name after merging with the former East German dissident group Alliance 90), in power since 1998, thus planned a new feed-in and remuneration system for renewable energies as of January 1, 2000.



Dr. Wolfhart Dürrschmidt, Chief of the Division for General and Fundamental Aspects of Renewable Energies at the Federal Ministry of the Environment.

**“With renewable energies, we can secure Europe’s and the world’s energy supply completely if their development and improvements in energy efficiency are greatly pushed forward. They play a key role not only for effective climate protection, but also for domestic and foreign security, sustainable social and economic development, and the preservation of our natural resources.”**

The Federal Ministry of the Environment started to prepare for the replacement of the StrEG with a Renewable Energy Sources Act (EEG). The Bundestag seized the initiative once again, and introduced a bill, with Green members the driving force. They were supported by SPD members Dr. Hermann Scheer and Dietmar Schütz, fighting for the companies of the still young wind and solar industries.



Dietmar Schütz, 1987 to 2001 Member of the German Bundestag, energy policy spokesperson of the SPD. Since 2008 president of the German Renewable Energy Federation (BEE).

**“The Renewable Energy Sources Act was a strongly parliamentary initiative. There was a majority in the SPD group for the law – even despite the position of the then-responsible Ministry of Economics, who said no at every turn. For most members, the EEG’s contributions to climate protection and job creation were key.”**

After intense and heated debates, the Bundestag adopted the EEG in February 2000; it came into force on April 1, 2000. Its 20-year remuneration guarantee and its cost-covering rates tailored to the various power technologies reduced the risks to investors greatly. Willingness to invest in renewable projects grew as a result, as did the demand for renewable power systems.



Hans Josef Fell, Member of the German Bundestag (Alliance 90/the Greens) since 1998; vice president of Eurosolar since 2005.

**“The EEG was a purely parliamentary legislation! Since it came from within the Bundestag, we members were able to pass it independent of lobby influence. The EEG is the most successful climate protection measure, much more, for example, than emissions trading.”**

### **The EEG revision, 2004**

After the re-election of the “red-green” government in 2002, the responsibility for renewable energies shifted from the Ministry of Economics to the Ministry of the Environment, which could thus now take the lead in developing the EEG further. It drafted a report on the initial experience with the legislation, on the basis of which it was amended in 2004.

The new version of the EEG differentiated the regulations for the various regenerative power technologies still more strongly. It thus grew greatly in scope and complexity. Supporters however see its success precisely in this differentiated and targeted support, since it provided improved incentives for innovation, ensured cost reductions and minimized windfall gains. While the opposition CDU/CSU and FDP (liberals) viewed the EEG draft positively, the business associations, the conventional energy industry and the Ministry of Economics attacked it intensely. The power companies wanted to limit support for renewable energies. Despite these intense attacks, the new EEG was finally adopted, thanks to its political support above party lines in the Bundestag and the support of innovative segments of business. It came into force on August 1, 2004.

### **The EEG revision, 2008**

The further development of the EEG in 2007 was part of the Federal Government’s integrated climate and energy programme. After consultation between various ministries, the Cabinet adopted a new version in December 2007. Within the government, there was a consensus for continued development of renewable energies and technological advances in the area of electricity into the future. The governing coalition, which now consisted of the conservative CDU/CSU and the SPD, reached an agreement on controversial points in May 2008. The new version of the EEG was passed by the Bundestag in June 2008 and came into force on January 1, 2009.



Jürgen Trittin, 1998 to 2005 Federal Minister for Environment, Nature Conservation and Nuclear Safety. Co-chair of the Bundestag parliamentary group of Alliance 90/ the Greens since 2009.

**“The Renewable Energy Sources Act is the simplest, cheapest and most efficient way to move the development of renewable energies in the area of electricity forward. It promotes new technologies, creates jobs and links climate protection with economic development.”**

In the 2009 version of the EEG, the goal for the target to be attained by 2020 was raised to at least 30% of the power supply. That share is to rise thereafter as well, although the legislation does not specify any further targets. Based on the EEG experience report of 2007, the Bundestag increased the feed-in tariffs in the 2009 EEG in almost all sectors, particularly for offshore wind power, geothermal energy and some biomass segments. The feed-in tariffs for solar power were however reduced considerably, since the annual cost reductions realized to date had considerably exceeded the 5% expectations.



Johannes Lackmann, 1999 to 2008 President of the German Renewable Energy Federation (BEE); 2009-2010 managing director of VDI Zentrum Ressourceneffizienz GmbH in Berlin.

**“The Renewable Energy Sources Act has become a lighthouse of courageous legislation, nationally and internationally. The fact that significant parts of this successful legislation were created by the Bundestag members themselves should certainly encourage them to now and then make direct use of their legislative powers. In the area of renewable energies and climate and technology policy, there is still plenty of room for creative action.”**

### Other policy milestones

Other important impulses for the process of innovation of renewable energies were provided by the Federal Government’s Offshore Strategy and Sustainability Strategy (2002), as well as its Climate Protection Programme (2005) and its Integrated Energy and Climate Programme (2007). A variety of legislative adjustments flanked the promotion of the renewable energies, including the project planning and spatial development legislation, the immission protection legislation, and the water and waste disposal legislation; they decisively affected the expansion process of renewable energies.

The support of research and development also move forward the process of innovation of renewable energies in the area of electricity generation. During the 1990s, the Federal Ministry of Education and Research (BMBF) was responsible for this area, but provided relatively little funding for renewable energies. Moreover, the BMBF could not officially take measures to launch renewable energy technologies on the market. Nonetheless, its “100 MW wind” and “250 MW wind” programmes led to the realization of wind power systems that went beyond support for research and development.

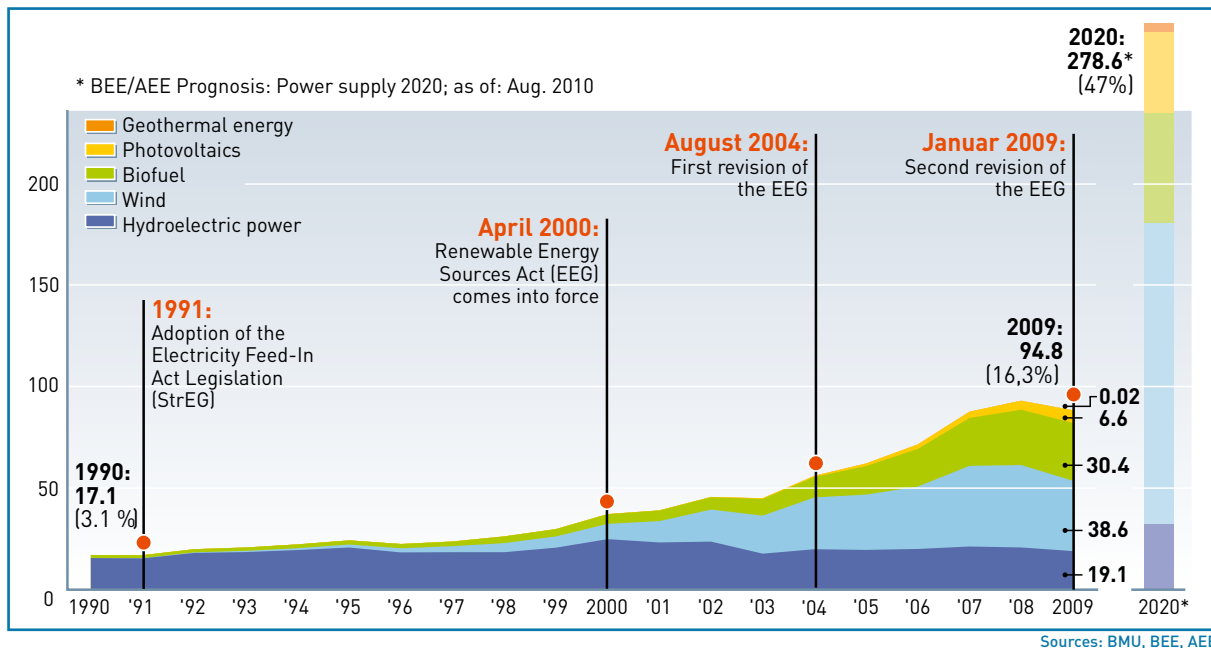
Until 2002, market entry of renewable energies was the responsibility of the Federal Ministry of Economics (BMWi), which had already control of application-oriented research and development since 1998. However, the BMWi undertook no initiatives for market incentive programmes in the electricity sector. The gap between research and development support and the launch of the market entry of renewable energies therefore continued. In the autumn of 2002, the Federal Ministry of the Environment was finally given responsibility both for research and development and for launching the market entry of renewable energies. Only now was an overall strategy for the promotion of renewable energies

developed and implemented. It embraced support for research, market introductory programmes, and the improvement of other legal and economic framework conditions.

The support instrument of feed-in remuneration, together with priority of purchase and payment, has proved to be a central factor driving the dynamic development of renewable energies in the power sector. The share of electricity generation from wind, solar, biofuels, hydroelectric power and geothermal energy in Germany has increased from 3% in 1990 to 16% in 2009. Renewable energies are thus a central pillar of Germany's energy supply.

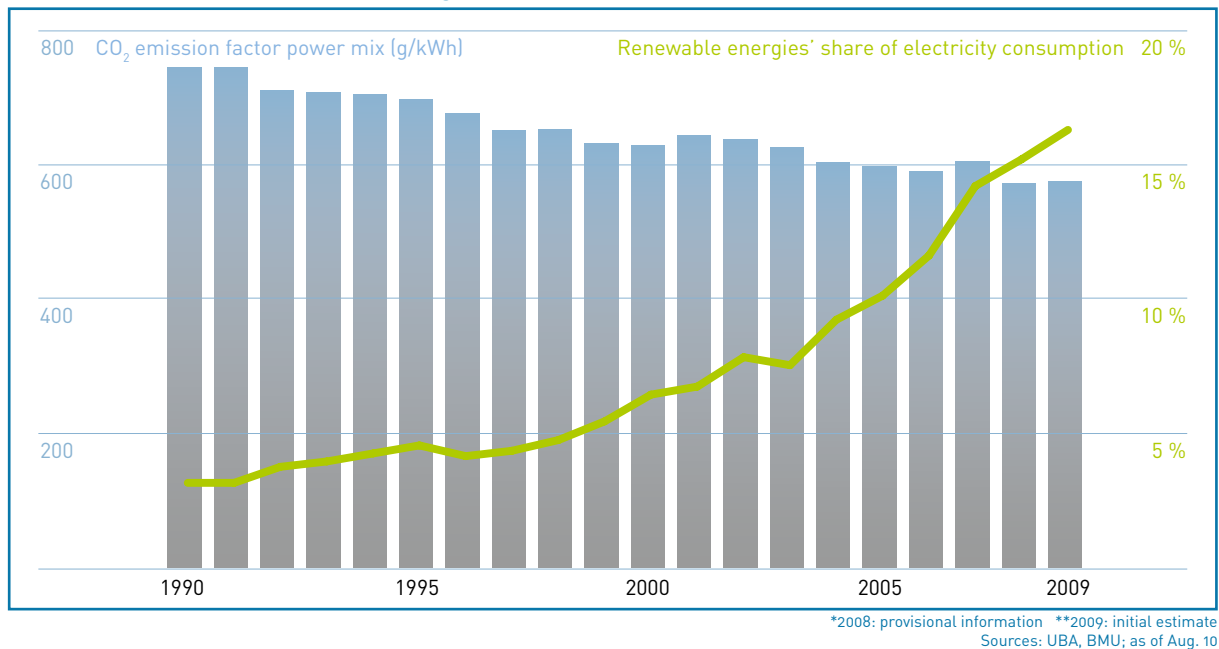
### Electricity generation from renewable energies in Germany 1990-2009

Terawatt-hours (in parentheses: share of overall electricity consumption in percent)



Worldwide, 47 countries including China, Brazil and South Korea, have used the German EEG as a model for their own support instruments. Of the 27 EU member states, 16 support renewable energies by feed-in tariffs. Clearly, the EEG has been convincing.

## Specific carbon dioxide emissions through electricity generation in Germany, and shares of renewable energies



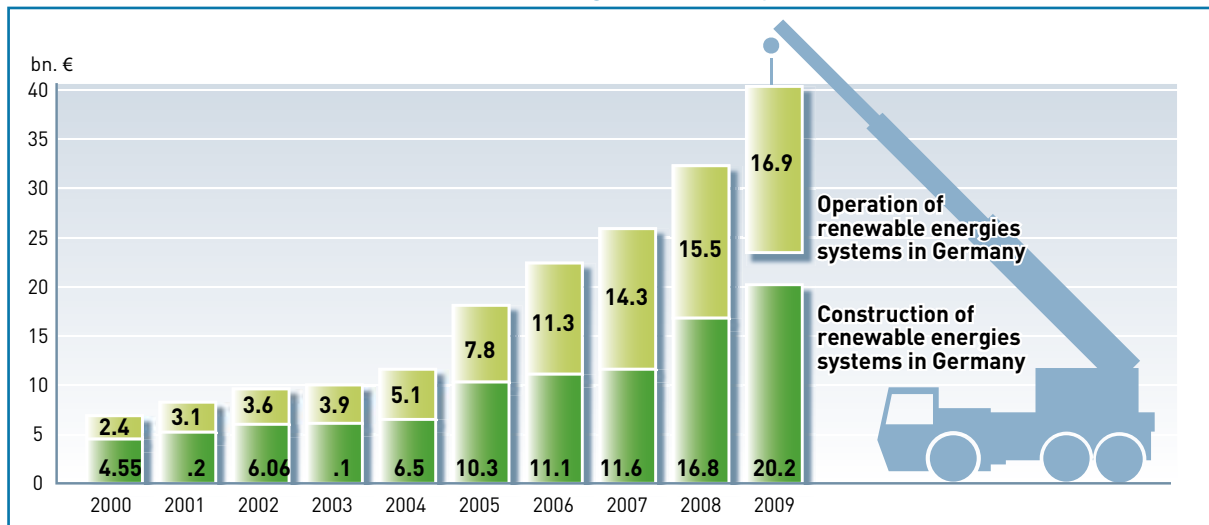
Together with energy savings and efficiency, the development of renewable energies is the central pillar for climate protection in Germany. The electricity sector has the highest greenhouse gas emissions of any segment of the economy; hence, it is here that it is most vital that the future course be set correctly. The restructuring of the power supply system towards renewable energies is technically and economically feasible, and also necessary for comprehensive climate protection; here, the EEG plays a key role. The continued commitment of Germany can contribute to strengthening the worldwide drive for climate protection that is so urgently needed.

Today, renewable power essentially replaces electricity generation fired by coal, a fuel that has a particularly high output of CO<sub>2</sub>. Thus, renewable power in 2009 avoided the emission of some 72 million tons of CO<sub>2</sub>, 55 million tons of which involved power output remunerated under the EEG. That matches the CO<sub>2</sub> emissions of approx. 14 coal-fired power plants, and shows that renewable energies are indispensable for climate protection.

### An engine for business and the labour market

The restructuring of the energy supply is a challenge to the German economy, and has sparked innovative technological advances. Renewable energies have now attained great economic importance, carried forward by a rapid process of innovation, as current sales and employment figures demonstrate impressively. The promotion of renewable energies has caused a major industry to emerge, with some €37 billion in turnover in Germany in 2009. By far the greatest share of investment in renewable energies in 2009 went to electricity.

## Turnover of the German renewable energies industry, 2000 - 2009



BMU/AGEE-Stat, industry-specific details; status 12/2010

The support provided by the EEG pays off in terms of both economic and labour market policy. Over the past ten years, the number of employees in the entire renewable energies industry has quadrupled. The industry employed almost 340,000 people at the end of 2009, and the need for qualified employees is increasing, even in times of economic crisis. This business-boosting engine runs so well primarily because the EEG has provided such a solid legal framework for it.

The growth potential is gigantic in view of globally increasing demand. In future too, the German renewable energies industry will be able to profit still more from the technological lead and the competitive edge it has gained in the international market.

### Perspectives



Prof. Dr. Frithjof Staiß, Managing Director of the Baden-Württemberg Centre for Solar Energy and Hydrogen Research (ZSW).

**“We will have a more varied energy mix in future, including the entire range of renewable energies. The use of solar power has the greatest worldwide potential, primarily since it is available everywhere.”**

Renewable energies have become an important component of the German energy mix. Globally too, they have grown out of their market niche, and have entered the expansion phase. The potentials of renewable energies are enough to assure security of electricity supply, if their continued development is accompanied, too, by energy savings and efficiency strategies. Moreover, Germany's high level of dependence on expensive energy imports can be reduced by the use of local renewable energy sources, and by increased energy efficiency.



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Dr. Joachim Nitsch, 1976 to 2005: Head of the Systems Analysis and Technology Assessment Division at the Institute for Technical Thermodynamics of the German Aerospace Center (DLR)

**“Renewable energies and efficiency belong together, and must be considered and conceived together. This has now been understood and is gradually being implemented. The future belongs to renewable energies.”**

---

However, on the way to a secure, environmental and climate appropriate energy supply structure with renewable energies as the basis for electricity generation, we will need more targeted policy regulation. This is particularly true with regard to the competitiveness of renewable energies and the expansion of the power grid and storage system as the prerequisite for permanent security of supply.



## The Innovation Dynamics of Renewable Energies

The development of renewable energies in Germany has seen growth rates and innovative processes implemented which were once not considered possible. This chapter deals with the actors of innovation, and the technological progress they have achieved.

### Actors of innovation

The engagement of civil society for an “energy turn-around” was an important force in the development of renewable energies in Germany. Motivated by the search for alternatives to fossil fuels and nuclear power, and for independence from energy imports, new ideas emerged within this scene, which was often organized in citizens’ action groups. Members of the environmental movement pioneered the development and the first application of wind power technology. Photovoltaic development was also substantially pushed by private investment and the concerted action of lobbies. In the area of biogas and also of wind energy, it was particularly farmers committed to environmental protection that initiated the application of technologies, and advanced them through a process of learning by doing. A key factor in the breakthrough of renewable energies was the fact that individual businesspeople managed, both in wind and photovoltaics and in biogas, to use new technologies professionally and build marketable structures.

They were able to rely on the acceptance and assistance of large segments of the population. The social acceptance for renewable energy has generally been high to this day, according to the surveys of public opinion. With respect to the construction of actual systems, this acceptance generally depends on the extent of real or feared negative effects on the ecosystem, the landscape and humans. Moreover, the need for space and the integration into the regional land use structure are also important factors, along with visual perception, and possible noise or odour burdens.

### Various dynamics of technological innovation

Despite many parallels, each of the technologies for electricity generation based on renewable energies has characteristics of its own. For example, each is different with regard to the technological state of the art and the dynamics of development of innovation. While hydroelectric power matured years ago, wind energy and biogas were still in their pioneering phase 20 or 30 years ago. Photovoltaics was at the very beginning of its development, with a great need for research, and the same was true for geothermal energy for electricity generation.

In addition to the different technological points of departure, the development dynamics depends largely on the respective cycles of production or renewal. For photovoltaics and wind energy, the dynamics is quite high, due to the relatively short reinvestment cycles of approx. 15 to 20 years; for hydroelectric power, these cycles are considerably longer – 30 to 50 years. Technical innovations can thus be implemented only at long time intervals.

There are also differences in the demands upon know-how and on the necessary manufacturing technologies. In the case of wind energy, technological expertise and manufacturing systems already existed in turbines, machinery and aircraft construction. A quicker expansion of production was possible here than in the case of photovoltaics, where production processes could only to a limited degree build upon semiconductor technology. The substantial innovations over the past twenty years in hydroelectric power, wind energy, photovoltaics, biogas and geothermal energy are described in the following:

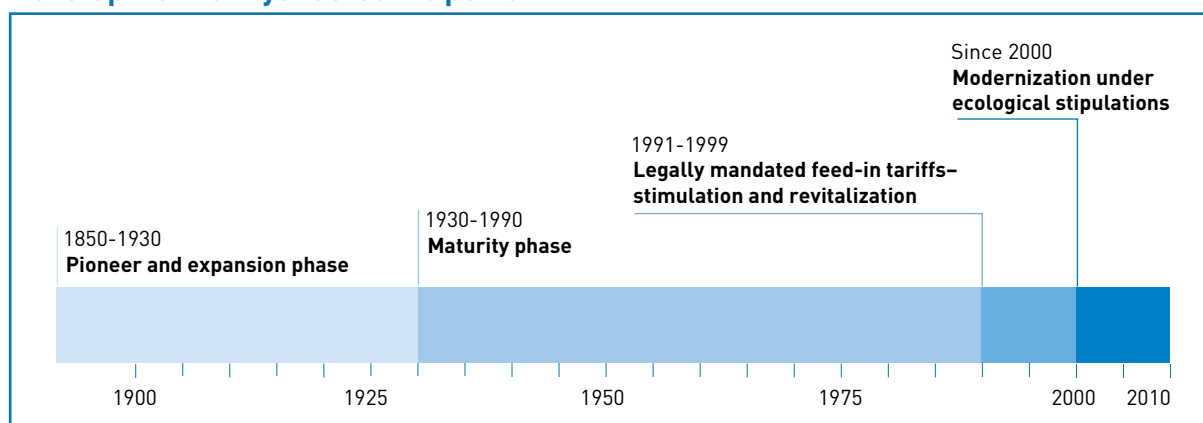
## Hydroelectric power

Hydroelectric power was already used for electricity generation long before so-called “alternative” forms of energy had even been dreamed of. As early as the mid-19th century, it made the electrification of rural areas possible and was an energy supplier for the industrial revolution. Due to the impressive engineering performance it required, and its contribution to industrial progress, hydroelectric power had a positive image. However, its quick spread soon made its limits apparent. The availability of economically viable sites was already limited by the mid-twentieth century.

During the 1980s and '90s, the protection of streams further limited site potentials. Changes in water levels, the drainage behaviour of rivers, and the loss of passage for migrating fish were unwanted side effects of hydroelectric power. Thus the positive image it had enjoyed during the electrification and industrialization era was lost, and it faced the challenge of developing strategies for more environmental compatibility.

The history of hydroelectric power shows the pattern of the different phases of development, from the invention of the technology through its optimization up to its integration into the existing energy supply structure. The low number of different development phases corresponds to the relatively low level of innovation dynamics in this sector.

### Development of hydroelectric power



#### The pioneer and expansion (1850-1930) and maturity phases (1930-1990)

The major technical solutions for the transformation of the energy of flowing water into electrical power were made around the middle of the 19th century. Various turbine types were invented during this “historical phase”. Initially, the technology spread through the electrification of rural areas of Bavaria and Baden-Württemberg, where the topographical prerequisites for hydroelectric power use were particularly favourable.

Electrification and industrialization and the development of hydroelectric power technology were mutually interdependent, so that the maturity phase was already reached during the 1930s. At that time, the range of turbine types known today already existed. They were designed to make the best possible use of the energetic potentials of the water, with consideration for locally different fall heights and velocities of flow.

The operators of hydroelectric power systems were mainly private individuals, many of whom used small or very small systems with a low power output for their own consumption. They preferred simple and robust technical solutions. In addition to farmers, handicraft businesses and companies also used this possibility for self-sufficiency in electricity supply. These operators established the segment known as “small hydroelectric power”. This mostly involves systems of up to a size of one megawatt<sup>4</sup>. Despite the large number of systems, they account for only a small share of hydroelectric electricity production in Germany.

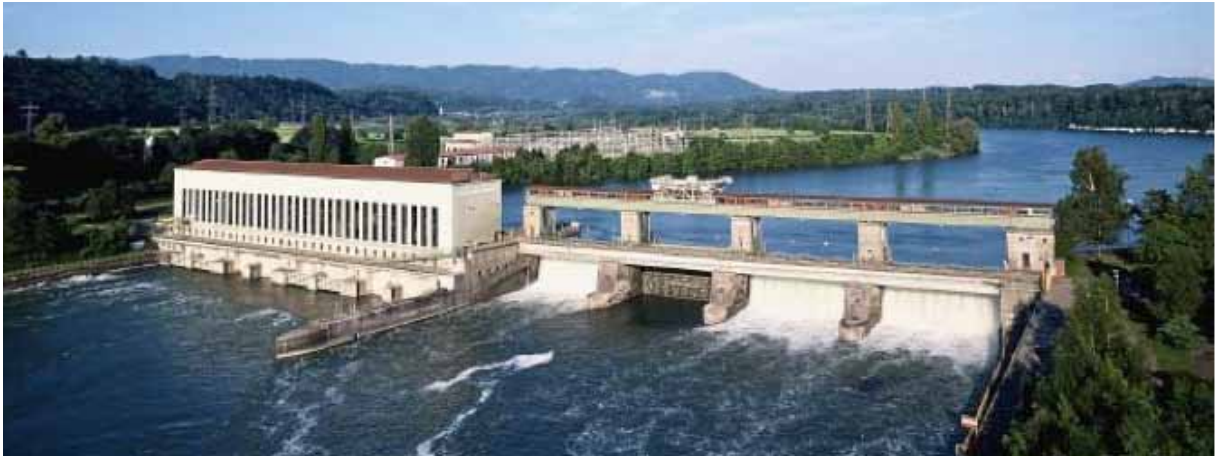


A hydroelectric power system in the district of Traunstein, Bavaria

The demand for larger turbines was met by municipal and regional electricity suppliers. Then as now, a small number of large systems produced the major share of hydroelectric power. The operators are principally power companies, which have always had access to the power grid. The power companies were interested in hydroelectric power plants not only to generate electricity, but also because of their function for regulation and storage.

The different prerequisites for marketing the produced power emerge here. This resulted in different interests of the “small” and “large” hydroelectric operators.

<sup>1</sup> There is no international consensus on the definition of small hydroelectric power. The generally accepted norm e.g. by the European Commission or the European Small Hydroelectric power Association ESHA is a capacity of up to 10 MW total.

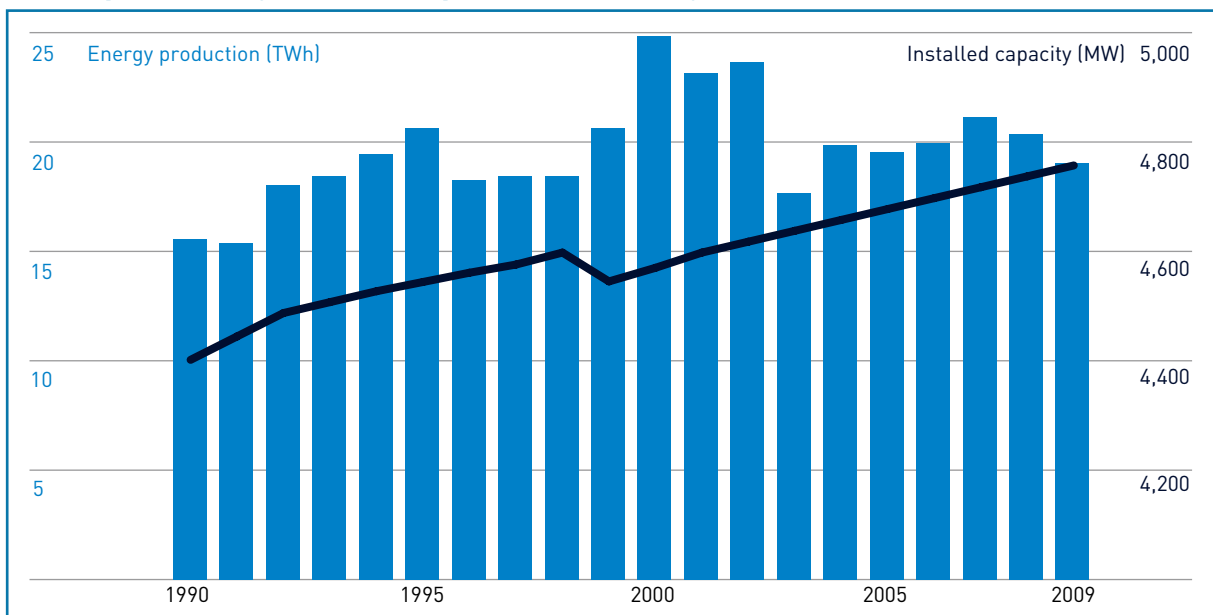


The Ryburg-Schwörstadt hydroelectric power plant on the German-Swiss border (the Rhine).

### Revival through legally mandated feed-in tariffs (1991-1999)

The operators of small hydroelectric power plants, largely located in southern Germany, wanted to be able to market the power they produced so as to cover their costs. The first thing they needed was feed-in permission from the power companies. Once they got that, often only after tedious negotiations, the power companies could dictate the prices – often paying only a fraction of what they themselves demanded from their customers. The negotiating position of the feed-in operators was usually weak – they had no alternative customers for their product other than the regional power company. The feed-in conditions were negotiated with the power companies case by case, and only for a limited period. No long-term cost calculation was therefore possible. In order to secure the foundations of their business, the operators of small hydroelectric power plants had to work to change this one-sided power relationship and escape its dependence.

### Development of hydroelectric power in Germany



Source: BMU as of Aug. 2010

At the beginning of the 1980s, a so-called "Agreement of Associations for Cooperation in the Electricity Industry" was reached with the electricity providers, with the participation of the Association of Hydroelectric power Stations in Bavaria. From then on, this constituted the uniform base for the individual feed-in contracts. However, the remuneration still did not reflect the costs or the value of the electricity produced. The operators of small hydroelectric power plants thus took their demands to the political level, and organized the National Association of German Hydroelectric power plants (BDW). After no substantial progress could be achieved, even from an improved agreement, the hydroelectric power associations at the end of the 1980s demanded a legal regulation. They were supported by the proponents of wind energy, who also saw this as an opportunity to better market their electricity.

A multi-party initiative of Parliamentarians for renewable energies resulted in the Electricity Feed-In Act (StrEG), passed in December 1990. There was thus for the first time a legal regulation governing the remuneration of the feed-in of renewable power to the grid. This success was in large part due to the efforts of the then Bundestag member and chair of the Association of Hydroelectric power Stations in Bavaria, Matthias Engelsberger (CSU<sup>5</sup>), who saw the opportunities of joint strategic action with wind power supporters.



Matthias Engelsberger (d. 2005), Former Member of the German Bundestag (CSU), former chairman of the National Association of German Hydroelectric Power Stations (BDW), and one of the "fathers" of the Electricity Feed-In Act.

The minimum remuneration fixed in the StrEG permitted long overdue modernization and even some expansion of hydroelectric power plants to be carried out, for income was now calculable. However, while the basic economic conditions thus improved, people were increasingly conscious of the poor ecological condition of the streams. The European Habitat Directive and the Water Framework Directive, which required an improvement in the passage for migrating fish and the hydraulic conditions, were of some importance here. This consciousness often stood in the way of the modernization and return to service of old sites, or the opening up of new sites. Due to these impeding factors, the StrEG did provide some positive impulses, but it sparked no significant growth.

### **Modernization under ecological stipulations (as of 2000)**

Nor did the Renewable Energy Sources Act (EEG) 2000 lead to the development of a major number of new hydroelectric power sites. Both the expansion of existing systems and new projects had to take the issue of nature-compatible design into account. Cost proved a major impediment particularly for new systems. EEG remuneration was only enough to ensure operation of existing systems and the modernization of those which were extremely old. At some old sites, expansion measures combined with the modernization of control technology were able to increase power capacity. Optimization of the control systems contributed to the steadiness of electricity generation and to an improvement in the degrees of efficiency in power transformation.

<sup>5</sup>) The conservative party in Bavaria, the "sister party" of the CDU in the rest of Germany.



Fish passage at the Wyhlen hydroelectric power plant in Baden-Württemberg

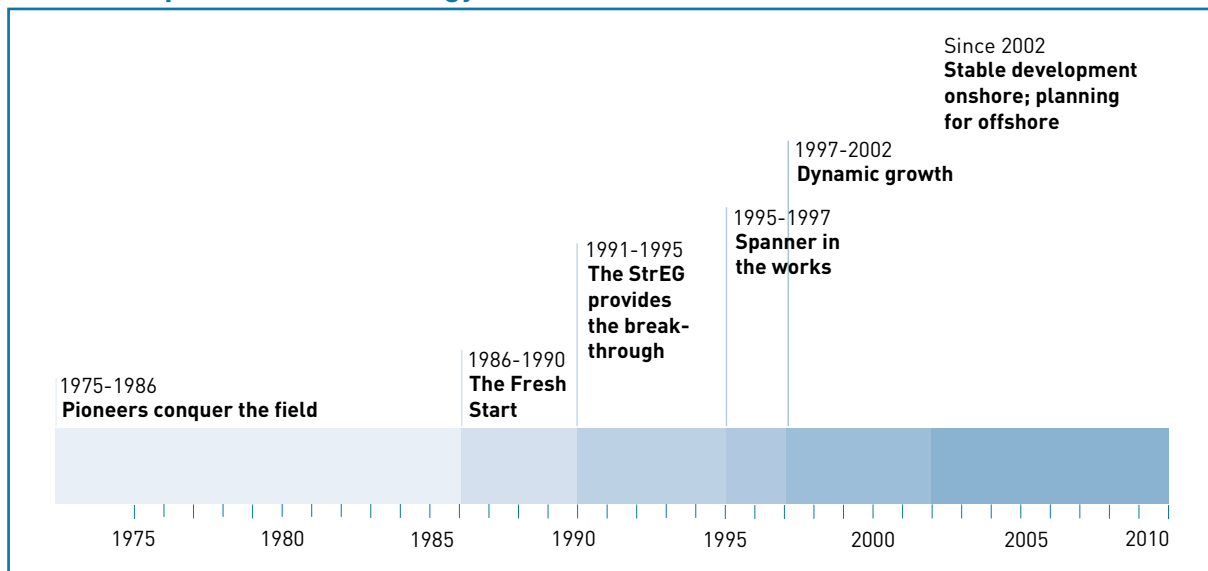
Under the amended EEG of 2004, the remuneration system was expanded to include an “ecological control component” for hydroelectric power. The payment of the remuneration was based on the improved passage of streams, e.g. with pool-type fish passages or detours. The Federal Ministry of the Environment concretized the requirements with the aid of a guide and a demonstration project, which showed how to implement them. The tying of remuneration payment to ecological criteria is exemplarily for showing how conflicts between renewable energies and nature conservation can be reduced. In the view of hydroelectric power operators however, the additional ecological stipulations result in higher costs, which are not covered by the remuneration. This under-financing is cited as the reason why mobilization of the still available potentials lags behind the technical possibilities, despite the slight stimulation of hydroelectric power use.

Due to environmental constraints, many experts expect the development dynamics of hydroelectric power to stay low in future. Renewable energies industry actors however are basically more optimistic. Thus, the German Renewable Energy Federation (BEE) and the National Association of German Hydroelectric power Plants estimate that the share of hydroelectric power in overall electricity generation will increase by approx. 50 percent over the next ten years.

## Wind Energy

The public sees wind power as the leader among renewable energy sources. After the development of hydroelectric power, it is now established as a new form of decentralized and regenerative electricity generation. In 2010, wind energy provided 6.2% of German electricity demand, and in 2004 for the first time surpassed hydroelectric power, with 25.5 TWh to 21 TWh. This success was achieved despite the resistance especially of supporters of conventional energy sources, and regardless of the difficulties which fluctuating energy supply entails for integration into the existing power supply system. In retrospect, the development of wind power in Germany is a success story, which began during the 1970s and has continued to this day.

### The development of wind energy



#### Pioneers conquer the field (1975-1986)

The oil price crisis, pressing environmental problems and the conflict around nuclear power during the 1970s and '80s led to a consciousness shift in society, and forced energy policy-makers to search for alternatives. For the first time, wind energy was seen as a possibility – albeit a minor one – for reducing dependence on imported oil and gas.

Initial wind energy projects in the USA and especially in Denmark aroused the interest of Germany in this technology. By the early 1980s, Denmark had already developed the mass production of wind energy systems, with capacities of up to about 50 kW. The Danish systems were known to be robust and reliable. A programme study led by Professor Dr. Ulrich Hütter,<sup>6</sup> which certified that wind power had great potential for the future, provided a further boost for wind energy use.

Initially, the Federal Government primarily supported large facility research, at great financial expense. The Federal Ministry of Research made a total of DM 218 million (€112 million) available through 1988, with more than DM 90 million allocated to the so-called GROWIAN project, a large wind system with an installed output of 3 MW which involved the Ministry, major power companies, industrial companies and scientists. This technological development experiment soon failed however, due to problems of design and materials.

<sup>6</sup> Prof. Hütter was head of the Institute for Aircraft Design at the Stuttgart Technical College 1959-1980, he pioneered the development of wind power systems and fibre composite components.

Parallel to the large industrial research efforts, dedicated engineers and enthusiastic tinkerers pushed developments forward. Motivated by a vision of an environmentally friendly and decentralized power system, independent of oil imports, and with a phase-out of nuclear power, they built the first operating systems in the output category of 10 - 50 kW. Farmers too were important stakeholders, since they used the power from wind energy for their own needs. However, these first systems were still isolated from the conventional power grid. Wind energy was in its experimental stage, and still contributed almost nothing to the energy supply. However, it was in this phase that public consciousness and civil society engagement proved to be the key for innovation.



The Growian large wind power system



Aloys Wobben, CEO of Enercon GmbH, electrical engineer and pioneer of wind power.

**“Already today, wind energy makes a key contribution to counteracting climate change. Only with a high share of wind energy in the German power mix can a sustainable, independent energy supply be ensured.”**

### The Fresh Start (1986-1991)

The Chernobyl reactor catastrophe in 1986 made the risks of nuclear power drastically clear. Moreover, greater sensitivity to climate change was a key factor in setting course towards the development of renewable energies in Germany. The significance that climate protection had achieved in the political process could be seen in the call by the Bundestag Study Commission on “Precautions for the Protection of the Earth’s Atmosphere”. Its final report in 1990 called for a positive public attitude towards wind energy and other renewable energies. At the same time, the EU was pressing to have the energy markets opened up to new actors.



Dr. Peter Ahmels, Farmer, Manager of the Renewable Energies Section of the Deutschen Umwelthilfe; 1996-2007 president of the German Wind Energy Association.

**“The power produced by wind power systems replaces conventional power plant capacities. Every kilowatt hour produced by wind power avoids greenhouse gas emissions.”**

Until 1991, wind power was mainly fed into local area grids. The grid connection, the feed-in permit and the feed-in tariffs had to be negotiated case by case with the regional power companies. Whether or not a contract could in fact be concluded was often determined by imponderable factors, and depended on the willingness of the electricity suppliers. The construction and operation of wind energy systems thus still involved financial risk. That made the first wind power development support programmes all the more vital.



## The first wind power support programmes

In the mid-'80s, there was yet no systematic support for renewable energies, but initial federal and state level support programmes for wind energy and photovoltaics were seized upon by highly motivated actors interested in developing wind power technology further. The phase from 1986 to 1990 can hence be called the "fresh start" period for wind energy.



Jens Peter Molly, Head of the Wind Energy Institute, Wilhelmshaven.

**"In the early days of wind power development, the key actors were enthusiastic engineers and researchers, small machine builders and the first users of wind power, mostly farmers, individuals or small companies, who were convinced supporters of wind energy."**

A reorientation of subsidy policy also took place: The support programmes had less of a research and development orientation, and now concentrated on the gradual introduction of reliable and market-ready systems. With the "100 MW Wind Programme", the Federal Ministry of Research under Heinz Riesenhuber (CDU) in 1989 provided an important impulse. This programme was to contribute to building a wind energy output of 100 MW within five years. Because of the large number of applications, the programme was already revised the next year, and expanded to 250 MW. The Ministry thus succeeded in creating an important foundation for the launching and development of this technology.

The states of Lower Saxony and Schleswig-Holstein, in the windy North German plain, also began to promote wind power. In 1987, the first state support programme was established under Lower Saxony Minister of Economics Karl Walter Hirche. The combination of federal and state support provided an effective start-up funding base. While critics complained of "over-funding", these incentives resulted in a large number of companies entering the market, and sparked competition that advanced the technological development further.

## Technical developments in the launching phase

Initially, government support of small systems led to a variety of technical concepts, none of which was able to prove itself by the end of the 1980s, let alone become marketable. After the GROWIAN experiment, the further development of robust two and three-bladed small system types with horizontal axes emerged. The three-bladed rotor with a coupled grid connection, the so-called "Danish concept", had already proven itself in Denmark, and now became the point of departure for German developments. Wind energy technology was able to base itself on the traditional know-how of German machine engineering, turbine construction and composite materials technology. Although only small improvements in output were initially achieved, attention was thus awakened for the still slumbering potentials of wind power.

## Initial planning specifications

Due to the great demand for planning and building permits in the coastal regions, Schleswig-Holstein and Lower Saxony took the lead in developing uniform specifications for the planning and licensing systems. Thus, the Schleswig-Holstein municipalities were as early as 1984 already working with "guidelines for the design, erection and operation of wind power systems", which specified the interpretation of existing legislations. Due to these rapid developments, competition among the largely private operators for sites and permits already emerged by the end of the 1980s in the windy coastal regions.

By contrast, case-by-case decisions were still the rule in the inland states. Whether these decisions were positive or negative depended to a large extent on whether wind power was seen as an energy policy alternative or as an economic support for local farmers.

### The breakthrough (1991-1995)

The Electricity Feed-In Act (StrEG) of January 1, 1991 was of key importance for the development of wind energy. The feed-in tariffs it established, and the 250 MW support programme, which came into effect at the same time, caused interest in wind power to grow considerably. The 250 MW support programme provided subsidies to the operators of wind energy systems for a total of 15 years, and enhanced the incentives of the StrEG, which were not yet sufficient.

As a result, an increasingly professional wind energy industry was established, with a large number of small and medium-sized enterprises. The development of wind power was now no longer being pushed only by idealistic environmental values, but also by the commercial interests of business. It was no longer supported only by dedicated individual pioneers or operators, but primarily by a growing number of increasingly large system manufacturers. The numbers and output capacities of wind energy systems increased rapidly.



Hermann Albers, President of the German Wind Energy Association, businessman in the areas of agriculture and renewable energies.

**“Climate protection and wind energy are inseparable. Wind energy is the largest and most affordable resource worldwide. We can guarantee a secure supply from renewable energies, even at times of peak power demand.”**

The previous great variety of technologies – one, two and three-bladed rotors, different designs, small and large systems – were now concentrated into a standardized technical form: a horizontal axis, a three-bladed rotor, an upward rotor<sup>7</sup> and a tubular steel tower. The systems became considerably more reliable and efficient, and could be improved with technical innovations in the area of output electronics. However, there were also many business risks, due to the fact that the technology had still not yet fully matured.

An innovation was the development of new operator forms. The operation of wind energy systems by citizens' action groups (“citizens' wind power plants”) using the principle of self-organization and volunteer task assignment was new in the energy supply sector. The “GmbH & Co. KG”<sup>8</sup> became a typical corporate system for operator companies. It provided not only limitation of liability and the prospect of earnings, but also tax advantages through the depreciation of wind energy systems. In citizens' wind projects, the burden of investment could be distributed to many shoulders and many local residents could reap the profits. This promoted both the spread of the systems and their local acceptance.

However, the spatial spread of ever larger systems put states and municipalities under pressure. They had to deal with new regulations on spatial management and authorization of wind energy projects, in order to cope with increasing conflicts between wind energy use and the interests of the environment and conservation.

<sup>7</sup> In so-called “upward machines”, the rotor is attached to the windward side of the system.

<sup>8</sup> A German corporate form: a limited partnership with a limited-liability company as a partner.

**Spanner in the works (1995-1997)**

The dynamic development of wind energy stalled around the mid-'90s, as it was confronted with new resistance. The conventional energy industry fought the StrEG and sued all the way to the European Court of Justice. Various political agencies sent contradictory signals, some trying to reduce feed-in tariffs under the StrEG so as to protect consumers, others trying to ensure operators a stable environment by retaining remuneration levels. At the same time, state-level support programmes began to expire.

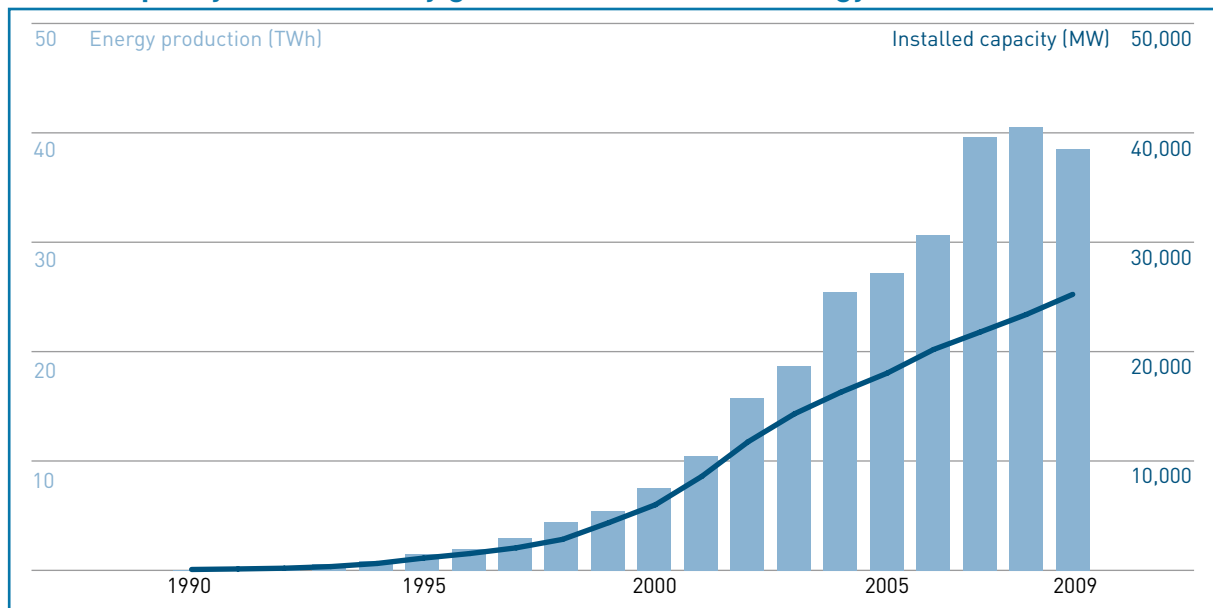
In their battle against the StrEG, some electricity suppliers unilaterally cut back the legally mandated feed-in remuneration, seeking a test case with which to challenge the constitutionality of the StrEG. This strategy met with heavy public criticism. Bundestag members of all parties voiced their disapproval, and called on the electricity suppliers to apply the feed-in legislation as it had been intended by the Bundestag. Only a 2001 ruling by the European Court of Justice ended this era of uncertainty. On the other hand, citizens' action and conservationist groups criticized wind systems for occupying increasing amounts of natural space. A debate arose over the feared "sprawl" of wind power systems, particularly in regions with favourable wind conditions. Municipalities increasingly rejected building applications. The authorization and spatial planning regulations of the building code were no longer sufficient to handle the burgeoning demand for sites and for planning and building permits. The result was a permit and investment jam. Technical bottlenecks too were a factor. Insufficient grid capacity caused some regions to lag behind in wind power development.

The still young industry came under pressure. Some companies faced economic problems, since the design cycles for new systems were very short, and technologies proved to be error-prone. At the same time, there was great competition and price pressure on the market. Moreover, this difficult phase of the mid-'90s was marked by major legal and planning uncertainties. The development of the wind energy market stagnated.

**Dynamic growth (1997-2002)**

Starting around 1997 however, the critical phase was overcome and a rapid development push for wind energy set in. A number of different factors contributed to this development: A new privileged feed-in regulation in the construction code came into effect as of January 1, 1997. With that, wind energy systems now have a basic legal right to a building permit, unless there is an important public interest against it. Such interests include conservation and species protection, the recreational function of the landscape, or the threat of disfigurement of the appearance of a locality. Cities and municipalities can also define "concentration zones" for wind energy, and thus keep all other areas free of wind energy systems.

## Power capacity and electricity generation from wind energy



Source: BMU; as of Aug. 2010

The 1998 election brought in a new federal government with new political actors and concepts, which had a favourable effect on the development of wind power. Of key importance was the move from the Electricity Feed-In Act to the Renewable Energy Sources Act of 2000, which provided further-reaching protection for operators of renewable energy systems, encouraged investment, and ensured a further increase in the number of systems



Wind energy systems are a second economic base for many farmers

The model of feed-in tariffs had many supporters in various political groups: renewable energy associations, environmental groups, farmers' organizations, the Protestant Church and the Metal Workers' Union all supported renewable energies, as did members of all parties represented in the Bundestag. No such broad alliance in favour of the development of renewable energies had ever existed before in the German energy policy debate.

In 2001, the European Court of Justice ruled that the German feed-in system is compatible with EU legislation. Meanwhile, the wind energy industry, a successful and established segment of the power supply system, continued its dynamic growth. Its success was favoured by a combination of environmental and political-economic targets. There were however also critical voices during this period: the growing size of wind parks and the commensurately large investments were accompanied by an increasing anonymization of investors and negative impact on the landscape. As a result, the resistance of local interest groups increased, despite wind power's high level of acceptance among the public.

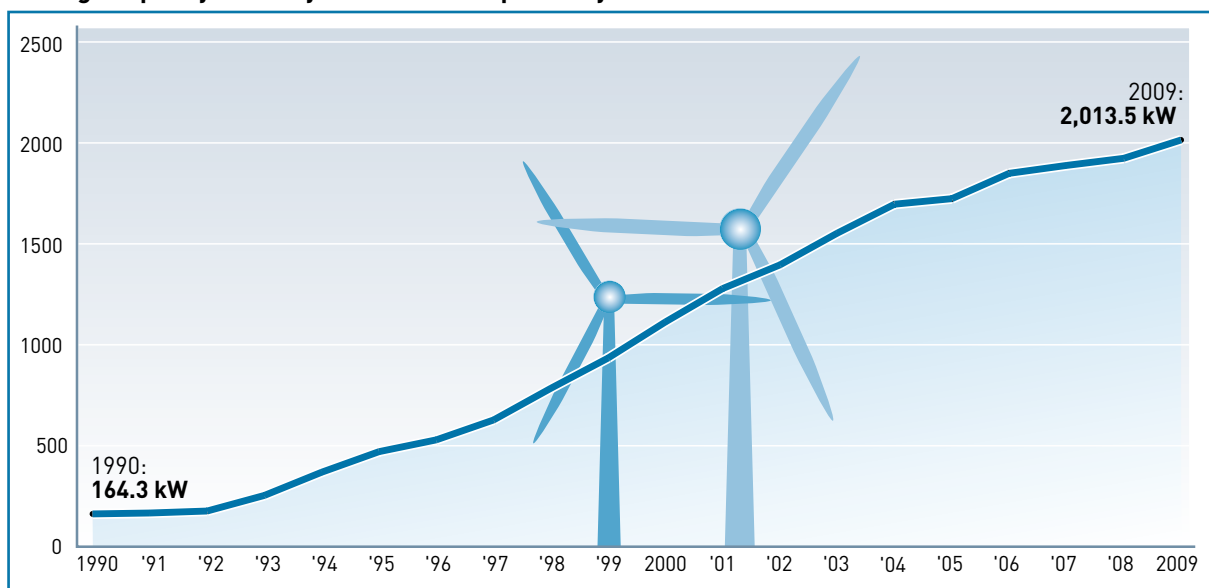
### Stable development onshore and planning for offshore (since 2002)

The dynamics of the additional constructions of wind energy systems onshore slowed down after 2002. It became ever more difficult to develop suitable locations without competition over site use. At the same time, repowering – the replacement of smaller and older systems by newer, more efficient ones – has picked up only slowly to date, due to the construction code stipulations.

The capacity increase of wind energy is nonetheless continuing at a stable level, thanks in large part to increasing outputs per system, which shows the technological progress attained. In 2002, average capacity of new wind energy systems was 1.4 MW; in 2010, it is more than 2 MW, and even 5 MW systems have reached maturity for series production. A total of almost 2 GW of wind energy output are added in Germany annually, so that total installed capacity grew from 12 GW in 2002 to 27 GW by the end of 2010.

### Twelve-fold increase of wind energy system capacity since 1990

#### Average capacity of newly installed wind power systems



Source: German Wind Energy Institute; as of June 2010



Modern wind energy systems in northern Germany

However, the development of wind energy systems can be seen not only in the higher towers and larger rotors, but also in the improved technology. There are systems today, which have been optimized for the wind conditions prevailing on the coast, or in the interior, respectively. Also new generator concepts have improved efficiency.<sup>9</sup> The prices per kilowatt hour output have dropped in step with the technical improvements – by more than half since 1990.

Exports have increased greatly in significance for system manufacturers since 2002. The successful development in Germany was the reason that the German wind industry could sell its innovative products worldwide. About 80% of German production now goes abroad.

### Offshore Wind Energy

In 2002, the Federal Government decided in its offshore strategy to use maritime wind energy in future as well.



Jörg Kuhbier, senator (ret.), Managing Director of the Offshore Wind Energy Forum and president of the Offshore Wind Energy Foundation.

**“To accomplish the development goals for renewable energies, the development and use of offshore wind energy are of great significance. The key is to gain as much practical experience with offshore wind power systems as fast as possible, together with the maritime sector – as a catalyst for the further development of wind electricity generation in the German North and Baltic Seas.”**

<sup>9</sup> For the technical innovations of wind energy, see Renews Special 37 “development of the innovation of the renewable energies”

Many stakeholders have viewed this development critically. Representatives of the interests of the fishing, shipping and tourism industries and of the military, as well as maritime conservationists, fear unwanted effects from extensive offshore wind parks. To determine possible ecological impacts, a comprehensive research project was initiated in 2001, so as to de-emotionalize the debate and to reduce ultimate ecological impacts.

Wind power use at sea is different from that on land. The planning process involves very large systems. These are moreover located far from the coast, in great depths of water, which means major technical and organizational challenges. Offshore wind parks require high investment and expensive technical and organizational measures for grid connection ashore: new submarine cable connections must be planned, approved and implemented.

In 2006 a legal regulation, which provided financial relief for future operators of offshore wind parks was instituted. As was already the case with onshore systems, the grid operators now had to bear the investment costs for connecting offshore systems, which means the cables between the wind park and the next onshore connection point.



The Alpha Ventus Offshore Wind Park in the North Sea

Despite these and other support measures, the original planned development of German offshore wind energy was delayed. The Offshore Foundation<sup>10</sup> was therefore founded in 2005, to speed up the construction of offshore test areas and to spark the development of wind electricity generation in the North and Baltic Seas.

<sup>10</sup> Stiftung der deutschen Wirtschaft zur Nutzung und Erforschung der Windenergie auf See; Official English name: German Offshore Wind Energy Foundation.

The Foundation owns the rights to the North Sea offshore wind park Alpha Ventus, which it places at the disposal of test area operators. The Federal Ministry of the Environment has provided €50 million for the research and development of the test area for a period of five years.

In 2009, the first 12 offshore wind power systems with a total output of 60 MW came into operation in the Alpha Ventus wind park. Preparations have already been made for the grid connection of 25 more approved wind park projects in the North and Baltic Seas. These planned offshore parks, some of which are already under construction, will provide a major contribution to the national power supply in future. By 2020, 10,000 MW of wind power capacity are to be installed in the North and Baltic Seas, and to provide up to 5-6% of Germany's electricity demand.

### **Perspectives**

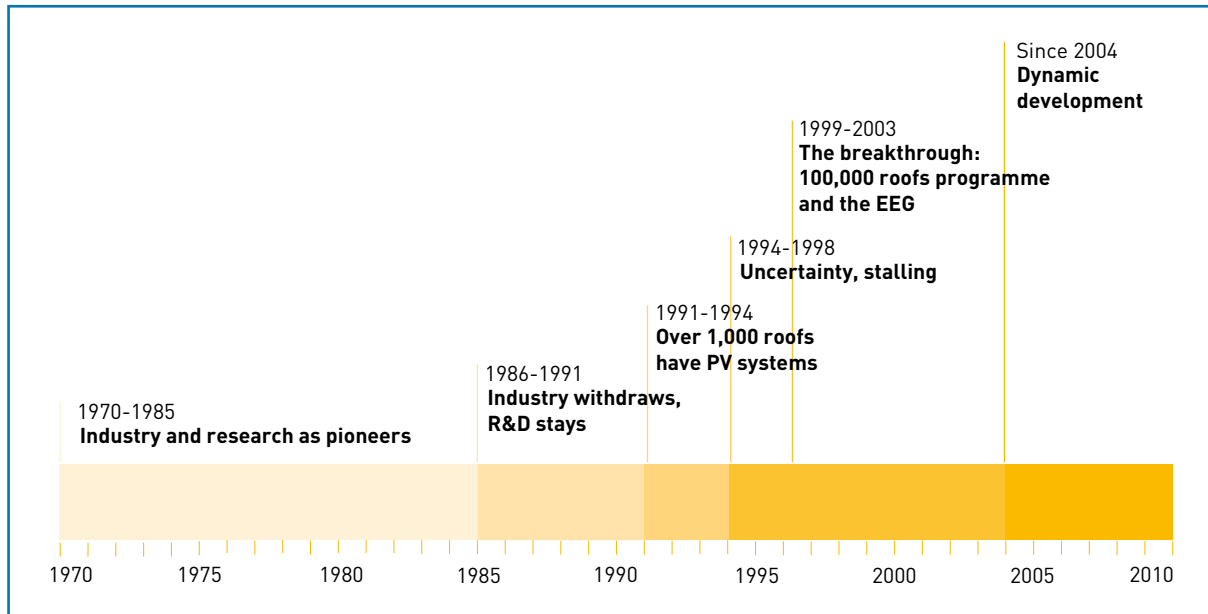
The development of wind energy in Germany will continue in future, too. This is indispensable if Germany is to achieve its climate protection goals, a sustainable energy supply and a reduction of dependence on energy imports. Very important areas of further work include the expansion of the power grid and the development of storage systems.



## Photovoltaics

In Germany, solar electricity generation means photovoltaics for only in areas with higher direct solar radiation, such as Spain, is solar thermal generation also possible. With photovoltaic technology, semiconductors produce power directly from sunlight. As early as 1954, the first silicon solar cell was presented in the USA. Initially, this new and very expensive technology was used only in space-travel, as a power supply for satellites. Photovoltaic development for terrestrial applications began only later, in Germany during the mid-1970s. Its history has undergone the following phases:

### Development of photovoltaics

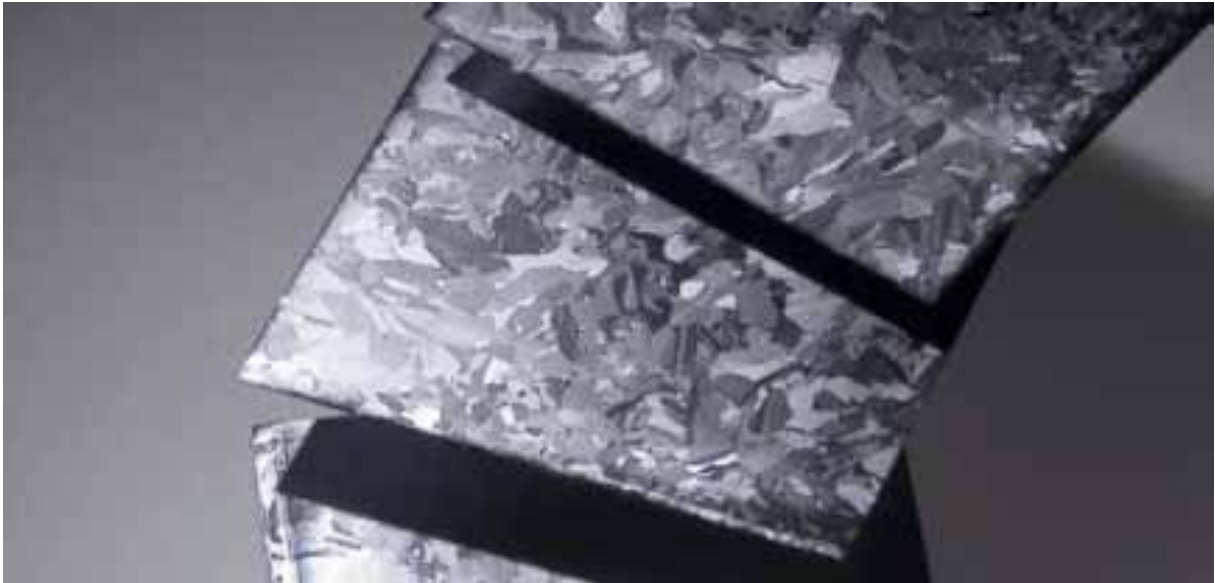


#### Industry and research as pioneers (1970-1985)

During the oil price crises of the 1970s, the USA and Australia, in their search for alternative energy sources, made the first investment decisions for photovoltaics. The interest in this form of the electricity generation grew worldwide, and hence also in Germany.

Supported by the first energy research programme of the Federal Ministry of Education and Research (BMBF), a few large corporations such as AEG and Siemens, and several research facilities tested possible applications of the new technology. The companies already saw industrial production as within reach, and hoped to be able to use photovoltaics economically in the short term. By 1984, all important aspects of photovoltaics and its key structural principles, including their potentials for industrial manufacturing, were known:

- Monocrystalline and polycrystalline silicon solar cells, in which very thin pieces of metal (wafers) form a substrate layer;
- Amorphous silicon, cadmium telluride and copper indium sulphite (CIS), in which a thin semiconductor layer is applied to a substrate layer of glass or foil; and
- A combination of these two technologies (multijunction cells).



Silicon wafers

From 1970 until the mid-'80s, research activities concentrated on improving the basic materials for all components. Demonstration projects too were established, such as that on the island of Pellworm in the North Sea in 1983, at that time the world's largest solar power plant with 300 kW. Moreover, the application of photovoltaics in such small devices as pocket calculators and watches was promoted.

### Industry withdraws, R&D stays (1986-1991)

Although the photovoltaic power plant on Pellworm Island demonstrated the potentials of the technology, the great expectations of the industry for rapid improvement in output and marketability were not realized. Market interest was low, due to the high system prices, so that industrial involvement stagnated. Some companies gave up the development of photovoltaics entirely.



Dr. Gerd Eisenbeiß, 1982-'89 Chief of Energy Efficiency and Renewable Energies at the Federal Ministry of Education and Research; in the 1990s co-founder and spokesperson of the Solar Energy Research Association.

**“The cells were then so thick that they were amortized energetically only after four years. The goal was to produce thinner wafers, to reduce saw losses, to increase degrees of effectiveness, to simplify processes and to prepare the application in systems.”**

In this context, the Federal Government felt forced to act. Starting in 1990, it increased research funding considerably under the Third Energy Research Programme and strengthened the cooperation between government, business and the research community. New research facilities were founded and the existing ones received better equipment. This research expanded knowledge about the possible applications of solar cells and supported product development in the companies.

Committed citizens and businesspeople placed great hopes in the use of the sun as an energy source. They founded associations and sponsorship organizations, including, in addition to the Fachverband Solarenergie e.V.<sup>11</sup>, the Unternehmensvereinigung Solarwirtschaft e.V. (Solar Industry Business Association, today BSW-Solar) and the European Association for Renewable Energies (Eurosolar).

<sup>11</sup> Founded in 1979 as the Verband mittelständischer Solarindustrie (Association of medium-sized solar businesses).

These organizations pressed for the further development of photovoltaics and represented the interests of the emerging industry at the national and international levels. In the late 1980s, the first solar power systems were installed on residential buildings. It now became clear that it would be important for the development of the photovoltaics in Germany to connect the systems to the power grid. Moreover, the development could really move forward only with the help of a government-supported market introductory programme.

### **More than 1,000 roofs with photovoltaic systems (1991-1994)**

The Electricity Feed-In Act, which came into force in 1991, also included feed-in tariffs for power from photovoltaics. However, these rates were far too low, in view of the still very high expenditures required to achieve rapid dissemination of the technology. Therefore, the Federal Ministry of Education and Research that same year initiated the so-called Thousand Roofs Programme, on the basis of a Swiss example.

The test programme for demonstration and implementation purposes, jointly financed by the federal and state governments, was to show that grid coupled feed-in from many small photovoltaic systems was technically possible. While the Electricity Feed-In Act guaranteed grid access and purchase of electricity at a low feed-in tariff, these federal and state supports under the Thousand Roofs Programme provided up to 70% of investment costs. This sent a positive signal to the photovoltaic industry, and provided an important impulse for the further development of the technology.

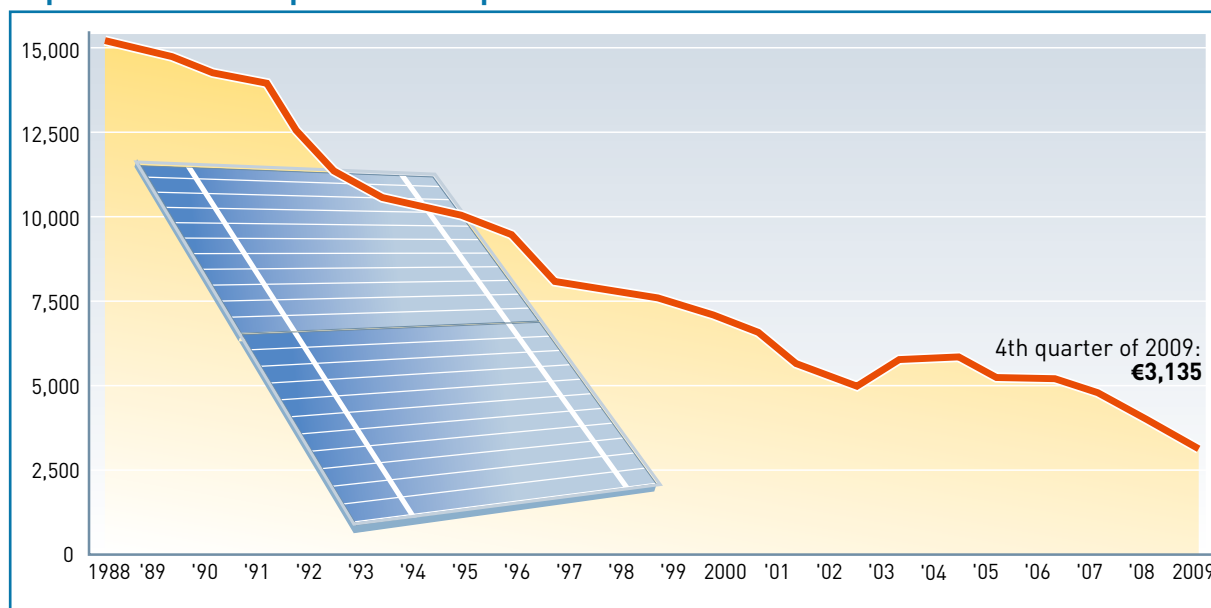


Photovoltaic roof systems

The Thousand Roofs Programme was aimed specifically at house owners and hence for the first time included private households in electricity generation; these people now became power producers. Altogether, more than 2,200 grid coupled systems with a total output of 5.3 MW were supported under the programme through 1995. The Programme was at that time the world's most extensive support instrument for photovoltaic systems. During this phase, the specific electricity generation costs of photovoltaics were still very high, at over €1/kWh. Government support was thus a decisive factor in reducing these expenditures considerably, and opening the way to mass production and technical

innovation. For example, the further development of inverter technology reduced failure quotas and losses in frequency transformation.

### Expenditure development of the photovoltaics



Source: German Solar Energy Society, BSW-Solar; as of June 2010

Not only industrial research, but also publicly funded research was very active during this phase. In 1990, the relevant research facilities joined together in the Solar Energy Research Association (since 2009: Renewable Energies Research Association). This resulted in improved networking of research, which benefitted the development of photovoltaics and boosted innovation.

#### Uncertainty and slowdown (1994-1998)

However, the Federal Government's strategy for the development of photovoltaics in Germany was not consistent, since no ministry yet felt overall responsibility for it. After the hopeful phase in the early 1990s, there was no follow-up support after the phase-out of the Thousand Roofs Programme in 1994. Thus, there was great uncertainty regarding further development and support between 1994 and 1998.

Technical know-how was already far advanced in Germany, and German research facilities were the cutting edge; however, market growth dropped considerably as subsidy programmes ran out. The lack of a follow-up to the Thousand Roofs Programme was a major disappointment for the industry. Major companies cut back considerably on their engagement, or gave up altogether. Despite the difficult conditions however, some businessmen recognized the future potential of the technology, and new companies emerged.

The fact that market entry did not quite grind to a total halt despite the lack of a support strategy at the federal level was due to a variety of municipal and regional initiatives, programmes and projects. These measures kept the market alive. In a few states, the low level of federal support was enhanced by state programmes, and in some cases even by power company programmes.

A municipal support model known as the “Aachen model” was of great importance. About 40 municipalities provided “cost-covering remuneration” for photovoltaic power. Operators of solar systems received contractually guaranteed remuneration at a rate that fully covered their operational costs for a period of 20 years. The strategy developed by the German Association for the Promotion of Solar Power (SFV) set the course for the further development of photovoltaics; it was to constitute a core element of the later Renewable Energy Sources Act. In addition, both community systems (“citizens’ solar systems”) and the activities of associations contributed to cushioning the difficult situation of German system manufacturers.



Wolf von Fabeck, co-founder and managing director of the German Association for the Promotion of Solar Power (SFV),

**“The clashes of interests are particularly strong in photovoltaics. The power industry is afraid of losing customers, if every home-owner can soon run his own cheap PV system.”**

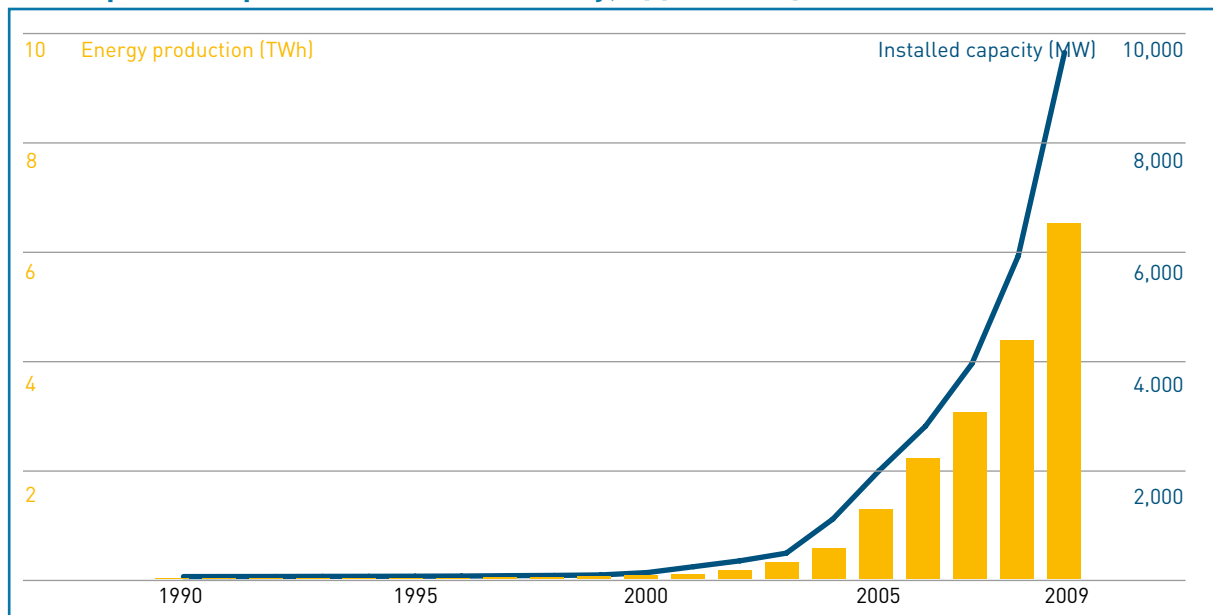
The well documented and positive experiences of the Thousand Roofs Programme ensured that the banks continued to give loans to investors. The expectation that markets for the new photovoltaic technology would emerge in sunnier foreign countries also kept developments going. Finally, the available risk capital of the so-called “new economy”<sup>12</sup> also led to the foundation of some new manufacturing and operating companies during this period, despite unfavourable federal support conditions. Thus a period of some four years was bridged, before the adoption of a market introduction programme was passed after the change of government in 1998.

### **The breakthrough: The EEG and the 100,000 Roofs Programme (1999-2003)**

The measures adopted by the new government, which took over in 1998 provided a considerable upswing in the development of photovoltaics. The 100,000 Roofs Programme, initiated in 1999, and patterned after a Japanese model, was of key importance. It was the world’s biggest credit programme for photovoltaics. Starting in 2000, the Renewable Energy Sources Act (EEG) provided a reliable and long-term framework for photovoltaics and made solar electricity generation economically interesting. As a result, installed photovoltaic capacity increased by a factor of eight between 1998 and 2001, to 186 MW.

<sup>12</sup> “The new economy”, the system built on the digital revolution of computers and new communications media, emerged during the late ‘90s and soon suffered a major crash in many areas.

## Development of photovoltaics in Germany, 1990 to 2009



Source: BMU as of Aug. 2010

The endeavours of the European Union for market liberalization and for the promotion of renewable energies also had a favourable effect on photovoltaic development. In 2001, the EU approved the Directive on the Promotion of Electricity from Renewable Energy Sources in the Internal Electricity Market. It protected the German Renewable Energy Sources Act and its remuneration mode under European legislation.

In 2002, responsibility for renewable energies was shifted from the Federal Ministry of Economics to the Ministry of the Environment, where the motivation to move the new technologies forward by means of the necessary support measures was great. Increasing demand caused the growth of an industrial mass production base, with technological advances and a marked reduction in production costs. The number of employees in the solar industry increased from 2500 in 1999 to approx. 6500 in 2003. The annual output of photovoltaic modules by German companies climbed from 6 to almost 100 MW during the same period.

In view of the effects on the labour market and the economy, the support policies increasingly pursued not only environmental and climate policy goals, but also industrial policy goals. However, the rapid spread of photovoltaics also caused prices to climb, due to the limited supply of systems. In addition, conflicts over protection of historic monuments began to emerge.

### Dynamic development (2004-2010)

The new version of the Renewable Energy Sources Act passed in 2004 sparked a real development boom after the conclusion of the 100,000 Roofs Programme. An interim legislation improved the remuneration of solar power considerably, even before the new version of the EEG came into force. Moreover, the higher remuneration levels were designed primarily to encourage the installation of photovoltaic facilities on buildings. Nevertheless, interest in installing ground-mounted systems on open spaces grew, since this permitted larger batches to be installed. To compensate for this cost advantage, the legislation provided a lower feed-in tariff for open area systems.

The industrial production capacity for solar modules in Germany increased from about 100 MW to 2065 MW between 2003 and 2009. At the same time, the industry's turnover grew from €500 million to about €9 billion. That resulted in a quadrupling of the number of jobs in the photovoltaic industry, from some 6500 in 2003 to 63,000 by the end of 2009. Some 40% of these jobs accrued to the businesses, which installed the systems. The centre of production for the German industry was in eastern Germany, one reason being the subsidies available to the East German states via the EU structural funds. Key centres of the solar power industry have emerged around Erfurt, the capital of Thuringia, around Bitterfeld in Saxony-Anhalt, in Frankfurt on the Oder, Brandenburg, and in Berlin.

However, this success was also accompanied by reverses. In the debate over the second EEG revision in 2008, the rising remuneration payments drew intensive criticism as to their effectiveness. The growing demand for solar systems had been the reason that module prices did not drop proportionally with manufacturing costs. Solar companies thus made very high profits at this time. The new version of the Renewable Energy Sources Act, which came into force in 2009, therefore established a steeper degeneration of feed-in tariffs, cutting the rate of reduction from 5% annually to 8 or 10%. System prices dropped further, by about 30% in 2009, even though the number of installed solar power systems grew considerably and more strongly than expected. Therefore, the feed-in tariffs were reduced twice more in 2010: by an additional 8 to 13% as of July 1, 2010, and by another 3% as of October 1, 2010. Moreover, a development corridor between 2500 and 3500 MW was established: if the rate of new facility construction exceeds this corridor, the degeneration rate increases during the coming years; if it falls short, the rate is reduced.

Finally, the debate over support for solar power and the changes in the feed-in tariffs illustrates the excellent development which photovoltaics has undergone in recent years. For typical home roof systems up to 30 kW of capacity, feed-in tariffs as of October 2010 is some 33 ct/kWh, or more than 40% less than in 2004.



Cleaning of finished solar modules

## Perspectives

The costs of photovoltaic systems will drop still further in future. Solar power in Germany will presumably reach so-called grid parity – equal price as household power – as soon as in three years. It will then cost the same to produce power with new photovoltaic systems as to buy it from the power company. That will be a watershed for investments in photovoltaics, for self-produced power will then be cheaper than what the power company can provide.



Dr. Hubert Aulich, Board Member of PV Crystalox Solar PLC. He started his career in 1974 in the old solar division of Siemens.

**“We need a more intensive dialogue between the solar industry, architects, engineers, builders and urban planners, so that building shells, together with the sun, will become power producers.”**



## Biogas

Electricity generation from biomass is now the third-largest segment supported under the Renewable Energy Sources Act. While electricity generation from solid (wood) and liquid (plant oil) biomass has used long familiar technologies – particularly steam power plants or diesel engines – for electricity generation, the EEG has sparked comprehensive innovations in the area of biogas production and electricity production. In the following, we will confine ourselves to these processes.

Compared with the glittering world of solar cells, the long-established production of biogas and its use for electricity generation have a rather mundane image. Such system components as containers and stirring systems originated in agricultural machinery or sewage gas production, and were transferred to biogas production on a smaller scale by the pioneers of this industry segment. For the electricity production, it was possible to fall back on gas engines, so that here too, no completely new technology had to be developed. By contrast, fermentation was an unknown process. The key challenge was coordinating the technical system components to steer the fermentation process optimally, so as to achieve a high gas and power yield. That task proved to be quite demanding in practice.

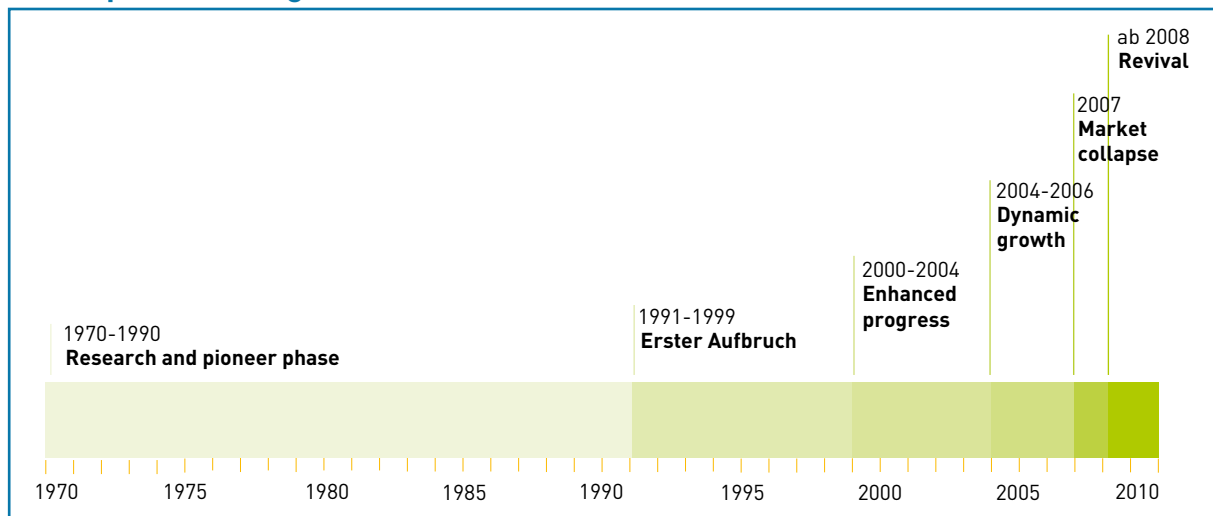
### The origins of biogas use

The roots of biogas use are the use of sewage gas: During the 1920s, Prof. Dr. eng. Karl Imhoff developed a system with closed and heatable digestive tanks for sewage which trapped the sewage gas and made its use possible for such applications as street-lighting. That saved the municipalities costs they would otherwise have expended for city gas. The concept was limited to specific applications, however.

During the post-war period, plagued as it was by fuel shortages, agriculture was discovered as a supplier of combustible biogas. The first agricultural biogas system was built in the Odenwald Forest in Hessen in 1948. During the 1950s, biogas production experienced an initial minor boost – very minor indeed: the total number of agricultural biogas systems in East and West Germany combined was at that time only between 50 and 70.

The supplies of coal and oil improved starting around 1950. Petroleum was unbeatably cheap, so that no demand for biogas fuel developed. Many agricultural biogas systems were shut down again. Not until the 1970s did the oil price crises stimulate interest in biogas as an energy source; initially however, this was limited mainly to sewage fermentation. The focus on agricultural biogas production came only in the 1990s, thus decisively moving the process of innovation forward.

## Development of biogas use



### Research and pioneer phase (1970-1990)

The first farmers in West Germany who built biogas systems wanted to save energy expenditures by turning their farmyard wastes into usable energy. The centres of the emerging biogas phenomenon were certain regions in Bavaria and Baden-Württemberg where small and medium-sized cattle farms prevailed. They used small, technically modest systems, which were set up by the farmers themselves, or with the help of local rural mechanics, sometimes by trial and error – often more the latter. The substrate might rot rather than fermenting, stirring apparatus might fail to homogenize the mixture, or the gas engine might suffer corrosion damage due to the high sulphur content of the biogas. Despite these setbacks, they learned from experience in small steps. The information exchanged among the plant operators occurred mainly via the personal contacts between the farmers.

For the research community, biogas was at best a marginal issue during this period. The potentials for energy use were seen as too low. By the end of the 1970s, studies of potentials attached no great importance to electricity generation via biogas, due to the limited quantities of liquid manure. The Federal Ministry of Education and Research supported only a few pilot projects; other segments were considered more important for alternative electricity generation. Moreover, biogas production was seen as a simple and already largely familiar technology, compared with others. Researchers hence saw few possibilities for making an impact and little reason to devote themselves to the issue.

Nevertheless, some agricultural research institutes and university departments did investigate the fermentation process. Initially, they were motivated by the desire to utilize waste materials and process fertilizer; specifically, they wanted to use fermentation to convert liquid manure from animal production to a higher quality fertilizer, and thus reduce the negative environmental impacts of modern intensive livestock farming, particularly nitrate immission into the groundwater. They saw the biogas produced by the fermentation of liquid manure as more of a by-product.

At that time, economic interest in biogas production was low, and so was the interest of the research community and the level of support. During that period, the Association for Technology and Structures in Agriculture (KTBL) maintained small demonstration systems, and kept the “tender shoots” of biogas production alive.

Major actors included Peter Weiland of the Federal Agricultural Research Centre in Brunswick, Lower Saxony (FAL), Hans Oechsner, head of the Baden-Württemberg State Institute of Farm Machinery and Farm Structures at the University of Hohenheim, and Heinz Schulz of the Bavarian State Agricultural Institute (LfL) in Freising-Weihenstephan. Heinz Schulz, later co-founder of the German Biogas Association, was an important link between the research community and the farmers engaged in practical applications.



Prof. Dr. Peter Weiland, Head of the Institute for Technology and Biosystems at the Johann Heinrich von Thünen Institute (vTI, formerly FAL<sup>13</sup>).

**“After the second oil price shock in 1979, the FAL built a biogas system, large (100 cubic meter) by then prevailing standards, within the extensive support of the Federal Ministry of Education and Research, for the first time completely equipped with the necessary measuring equipment. The goal was to get more insight into the process, to recognize disturbances early, and of course also to optimize fermentation technology overall.”**

East Germany, unlike West Germany, backed biogas production in large facilities during the 1980s. In connection with systems for industrial animal production, five large pilot plants for liquid manure fermentation were built. Here too, the main motivation was solving the liquid manure problem caused by intensive livestock farming, not so much the use of biogas as an energy source. The goal was to reduce the burden of odours, and to make liquid manure usable as fertilizer, without the loss of nutrient value. The initiative was started by a research group at the Institute for Fertilizer Research at the Agricultural Economics Academy in Potsdam. In the context of the state financed investigation programme, they tested various processes and systems to develop concepts for liquid manure treatment in various forms of intensive livestock production. The Institute for Energetics in Leipzig as well as the Institute for Agricultural Engineering in Potsdam-Bornim<sup>14</sup> were also involved in the accompanying research.



Prof. Dr. Bernd Linke, Head of the Bioprocess Technology Division of the Leibniz Institute for Agricultural Engineering in Potsdam-Bornim e.V. (ATB).

**“During the 1980s, we addressed the processing of liquid manure treatment in industrial animal production plants. There, we were able to build upon the know-how from sewage gas extraction. The energetic use of biogas was not yet the main issue.”**

Both in the West and in the East, biogas technology still faced considerable problems. Particularly the process control of fermentation proved tricky. There were setbacks again and again: The fermentation process could tip, so that the facilities would have to be expensively cleaned out and the process started anew. Lack of mastery of the fermentation process meant high cost risks for users. A pioneering spirit and idealistic commitment were needed to push liquid manure fermentation technology forward.

### **A fresh start with the StrEG (1991-1999)**

New findings however showed that biogas did have enough potential for electricity generation after all. The Electricity Feed-In Act also provided feed-in tariffs for it. The equipment of biogas systems with gas

<sup>13</sup>) Since 2008, the FAL has been subdivided into the Johann Heinrich von Thünen Institute, the Julius Kühn Institute and the Friedrich Loeffler Institute.

<sup>14</sup>) Today the Leibniz Institute for Agricultural Technology, Potsdam-Bornim (ATB).

engines was still costly, however. Moreover, the feed-in tariffs under the Electricity Feed-In Act of 1991 were not yet enough to cover the high costs of electricity generation. Nonetheless, funding through the market incentive programme did reduce the profitability gaps enough so that an economic perspective was for the first time opened up for biogas producers.

The slightly higher feed-in tariffs under the amended Electricity Feed-In Act of 1994 provided for a certain increase in momentum and ensured a new start. Besides the minimal remuneration, further investment grants and favourable loans under the market incentive programme supported the construction of usually small biogas systems on farms, which were fed with liquid manure and other organic farmyard wastes.

With the remuneration provision for power from biogas, the biogas yield became a central factor for farmers' profitability. It was already clear quite early that liquid manure fermentation would not ensure sufficiently high profits by itself. The biogas yield could be increased by co-fermentation of solid organic biomass or organic waste. However, this placed higher demands on process control. Despite initial scepticism, the number of co-fermentation facilities increased after the mid-1990s. The range of actors expanded with the waste management industry, for which the fermentation of waste was a welcome opportunity. The development of biogas technologies was still often a process of learning by doing. Evaluation of agricultural biogas research helped provide conclusions for optimized process control. For practical application, the foundation of the German Biogas Association in 1992 was a milestone. It offered an important platform for the technical exchange of experience among users.

The Federal Ministry of Education and Research, too, finally addressed the issues of biogas production and liquid manure fermentation in the mid-1990s. With the research programme Ecologically Compatible Liquid Manure Treatment and Utilization, it pursued the goal of reducing climate-damaging methane emissions from liquid manure production and storage in eastern Germany. The demonstration projects carried out in the context of the programme gave successful proof of large-scale biogas production. For the first time, systems in the capacity range between 300 and 500 kW emerged. These new orders of magnitude inspired the emerging biogas market.



Helmut Döhler, Board Member of the Association for Technology and Structures in Agriculture (KTBL), team manager for biogas

**“Although only very small systems in the range of 10 to 15 KW, or at most 30 KW, had previously been in use in agriculture, the project of the Ministry of Education and Research enabled the development of systems in the 300 to 500 KW range. This was a decisive step for the biogas sector.”**

The interest of the agricultural sector in biogas and electricity production increased. During this phase, individuals who had acquired the necessary know-how set up businesses for the planning and construction of biogas systems of the small and medium output category. Rural mechanical manufacturers with experience in silo, container and stirring unit manufacturing provided the system components, and the biogas system planners added electricity production aggregates and the necessary control technology.

The secret of successful system planning was to optimize these components under stringent business conditions for concrete operational application. Wherever farmyard biogas systems could be successfully realized, that fact was passed on through the grapevine, and fuelled demand.



Gerrit Holz, Technology Manager of BIOGAS NORD AG, Bielefeld.

**“The suppliers in those days were companies like Flygt and UTS Umwelttechnik GmbH (stirring devices), Eisele GmbH (pumps, feeding), or companies like Wolf or Sundermann, established in the area of concrete container construction. The manufacturers adapted the components to the specific requirements of biogas production, and gradually developed them further to system lines of their own.”**

With the founding of the Agency for Renewable Resources (FNR) as a project sponsor, the position of biomass in the funding policy of the Federal Ministry of Agriculture improved. The Renewable Resources Support Programme was after 1995 increasingly oriented towards the energetic use. Income possibilities from biogas electricity generation were an ever more important factor for rural development. In view of the economic potentials and the lack of income alternatives, the willingness of farmers to turn energy plants into biogas and power grew.



Dr. eng. Andreas Schütte, Director of the Agency for Renewable Resources (FNR) since 1993.

**“The Electricity Feed-In Act was the main driver for developments in the agricultural area. Although at first the feed-in tariffs were not costcovering, a perspective for this utilization did exist, and that was important.”**

### Major expansion under the EEG (2000-2004)

With the cost-covering remuneration introduced under the Renewable Energy Sources Act in 2000, the economic framework improved. Previously, the high investment risk in biogas plant construction had been a major restraining factor, particularly since only limited capital was available for agriculture. The remuneration calculable over the long term under the Renewable Energy Sources Act reduced the investment risk. In addition, the basic restructuring of EU subsidies for agriculture in general increased farmers' willingness to consider alternative income possibilities. The shift to area-referenced subsidies caused many farmers to fear a loss of income. The EEG made their decision to shift a part of their operation to producing income through biogas and electricity easier.

After 1999, the number of systems climbed rapidly. The trend was towards much higher system outputs, with average outputs doubling from around 60 kW of electricity (kWel) to about 120 kWel from the end of 1999 to 2004. The gas yield necessary for the economic viability of these systems could only be obtained if other organic substances were co-fermented. The potentials of organic wastes were limited however, so that the construction of new systems dropped slightly after 2002. Further development depended on making crop biomass available as a fermenting substrate. The rural sector consequently supported the cultivation of energy crops for biogas production. Energy plant cultivation finally promised to become an important part in securing agricultural income, in view of the price drop for food and feedstuff production. In this respect, the goals of saving rural development and of supporting renewable energies were compatible. During this phase, the systems-building industry was professionalized and consolidated, delivering not only single-site and operation-specific facilities to the market, but complete systems “off the peg”.



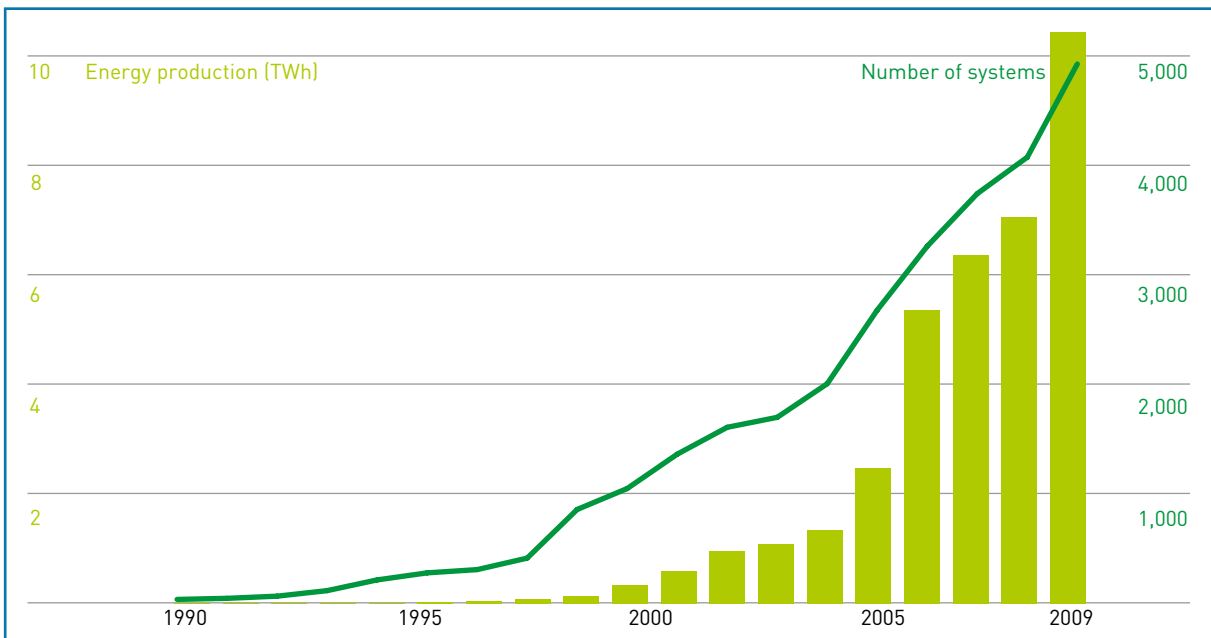
Josef Pellmeyer, Farmer, Biogas System Operator, President of the German Biogas Association; partner in the Eastern Bavarian Biogas Association.

**“Electricity production from biogas has gained greatly in significance in recent years due to the Electricity Feed-In Act. A good and secure legal framework is the key to developing new technologies. Thanks to the Renewable Energy Sources Act and of course the market incentive programme of the Federal Ministry of the Environment, biogas systems have become an important industry, not only for agriculture.”**

**Dynamic growth (2004-2006)**

In 2004, some 2000 biogas systems were operating nationwide. Further increases seemed possible and desirable. With the Federal Ministry of the Environment now in charge, the feed-in tariffs were enhanced by a bonus system under the new Renewable Energy Sources Act of 2004. In addition to the basic remuneration, a cogeneration bonus, a renewable resources bonus (NawaRo) and a technology bonus were provided for those who fulfilled the requirements. Since the bonus system increased the basic remuneration, the economic attractiveness of electricity generation from biogas improved considerably. While the agricultural prices for food were dropping, the NawaRo bonus made especially the cultivation of energy plants lucrative; particularly the demand for energy maize as a fermentation substrate grew. The farmers profited as operators of so-called “NawaRo systems”, or as providers of fermentation substrates for systems owned by others.

**Biogas development in Germany**

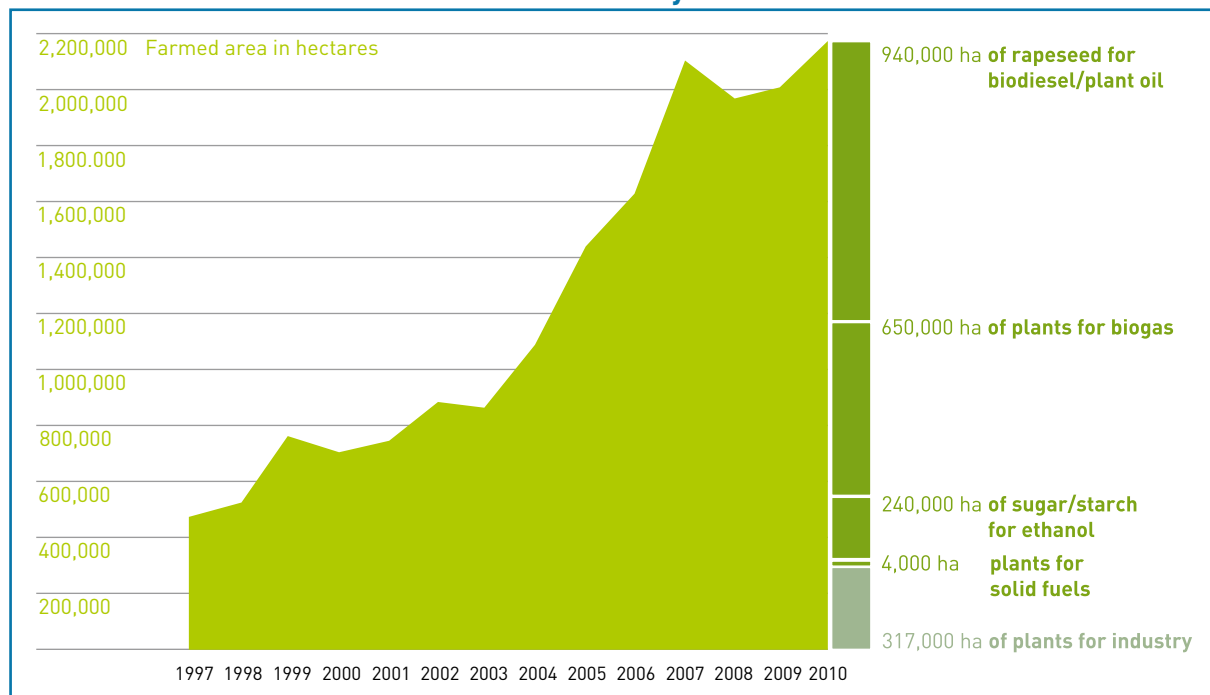


Sources: BMU, power companies, DBFZ; as of Aug. 2010

The biogas scene began to branch off in various directions. On the one hand, there was still the farmyard biogas system integrated into the farming operation. On the other, so-called industrial biogas systems gained in importance, being removed from agriculture. They were conceived as investor projects and designed for large-scale use. The growth of this segment broadened the range of biogas stakeholders to include operator companies with a number of different investors, in some cases even the electricity suppliers. In order to build large facilities, so-called biogas parks, securing the substrate requirement was a critical factor. The large facilities could only be run economically if the operator could assure the necessary substrate quantities by favourable delivery contracts with nearby farmers.

Some farmers profited from this new marketing opportunity. However, this biogas production on an industrial scale also had undesired effects. The expansion of cultivating energy crops caused pressure on agricultural production areas, drove lease prices up, and made operating costs for farmers more expensive. Environmental and conservationist associations and local people were often increasingly critical of maize based biogas production. The heavy growth of energy plant cultivation conflicted with the protection of biodiversity.

### Cultivation of renewable resources in Germany



Source: FNR

With biogas production in large facilities, it became ever more difficult to find efficient utilization possibilities for the power and heat being generated locally. Hence, interest grew in feeding gas directly into the gas grid, rather than to produce electricity. Access to the grid opens up a larger range of uses, and hence also improved marketing possibilities for operators. The revision of the Law on the Fuel and Electricity Industries in 2005 was an initial success on the way to feeding biogas into the gas grid. Since the costs of the necessary gas processing were high however, and were not covered, that market did not open up as yet.

### **The market collapse due to the rise in substrate prices (2007-2008)**

Due to the price rise for fermentation substrates, the biogas industry suffered a severe downturn in new plant construction in mid-2007. With price increases on the food market, substrate prices too rose considerably. The operation of systems, which used high amounts of renewable primary products became unprofitable in many places. Moreover, the 2009 revision of the EEG was not far off. The investors therefore deferred new investments until consultation on the support terms was completed.

Media reporting on biofuels took on an increasingly critical note. Particularly the competition between biofuels and food production (“in the tank or on the plate”) dominated the debate. And biogas production too was viewed critically, with regard to its contribution to climate protection. Environmentalists and conservationists pressed for a repeal of the NawaRo bonus and a better link between feed-in tariffs and sustainability criteria. They called for more incentives for waste use, to take the pressure off natural resources.

Consultations over correction of existing support provisions ended in controversy. In the end however, the agricultural sector was able to protect its interests. The bonus model was corrected so that “farmyard biogas systems” with small to medium-sized outputs were supported, and waste utilization of liquid manure encouraged, although it had only slight potential for cogeneration of heat and power. Competing with this small farmyard system model was the concept of strongly centralized biogas electricity production in systems for the cogeneration. (CHP), also involving biogas feed-in to the gas grid. From the point of view of efficiency, the latter has substantial advantages, since the generated heat is utilized.

### **Revival and perspectives (since 2008)**

In June 2008, the Bundestag passed the Renewable Energy Sources Act of 2009. This decision was directly connected to the Federal Government’s Integrated Energy and Climate Programme (IEKP). The upcoming revision already sparked a revival of the market during the second half of 2008, since it promised continued investment security in future.

The adjustment of the remuneration under the Renewable Energy Sources Act 2009 took into account the interest of the agricultural sector in stabilizing the agricultural biogas production: bonus payments for small systems of up to 500 kWel supported farmyard biogas systems. The liquid manure bonus provided an incentive for increased use of animal waste for farms. The goal of improved waste utilization was to reduce the demand for NawaRo substrates and the resulting competition for fields and foodstuff.

The Gas Grid Access Ordinance, revised in 2008 with considerably improved economic terms with regard to biogas feed-in, brought about a further impulse. The goal of the Federal Government formulated in the Integrated Energy and Climate Programme of replacing 10% of natural gas use with biomethane by 2030 was also seen as a positive signal.





Biogas feed-in system to the natural gas grid: pressurized water cleaning and transfer station

Biogas feed-in is also supported by a number of gas grid operators and electricity suppliers, as it provides a positive image. These operators have an interest in direct marketing of gas to households. They and their association representatives therefore demand that support for biogas feed-in not be tied to the use of any particular energy technology. The Federal Ministry of the Environment on the other hand believes that the biogas fed in should be used primarily in cogeneration systems, since they provide a considerable efficiency increase, and improved heat utilization. Thus, the use of biogas purely for heating purposes, which is technically possible, is not counted towards fulfilment of the stipulations under the Renewable Energies Heat Act of 2009. However, the Federal Government is investigating whether this should be changed, to ensure “technological openness”

The course of innovation of biogas production and its use for electricity production shows that the cost-covering remuneration under the EEG has especially encouraged the process of innovation. The production and use of biogas is much more efficient today than even a few years ago. New fermentation processes, adapted to the respective substrates, have increased methane yields. Higher degrees of effectiveness of internal-combustion and dual-fuel engines provide better power yields. The emissions of harmful substances have been reduced through technical improvements, and it has been possible to considerably reduce the use of ignition oil for co-firing in dual-fuel engines. However, the industry still faces great challenges. One is developing further cost reduction and heat use potentials. Moreover, it is necessary to reduce the negative effects of energy plant cultivation on the environment, and to find solutions for the increasing competition for farmland. Only then will public acceptance for permanent support under the EEG be assured.



Modern biogas system

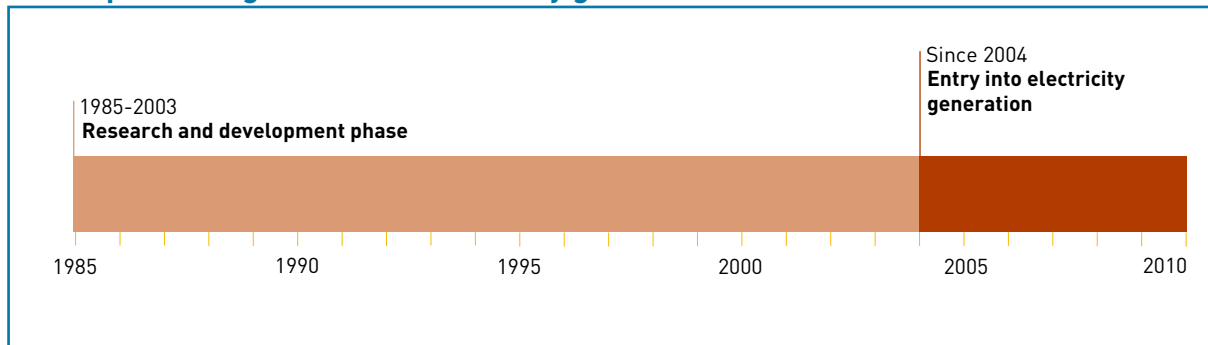
## Geothermal Energy

Geothermal energy has long been used worldwide for electricity generation, usually at places where high temperatures exist relatively near to the earth's surface. This is not the case in Germany. While geothermal heat has been used here too for a long time, due to the lower temperature need for that utilization, compared with electricity generation, its use for the latter purpose began only in 2004, with a small power plant in Neustadt on Glewe in Mecklenburg-Vorpommern. Electricity generation from geothermal energy is therefore the latest form of electricity generation from renewable energies.

Temperatures of at least 100°C are needed to generate electricity from geothermal energy; they exist in Germany only at great depths of between 3,000 and to 4,000 m. Areas with subterranean aquifers and high temperatures are found in the North German Plain, in the Molasse Basin in southern Germany, and in the Upper Rhine Rift Valley.

The development of geothermal energy for electricity generation has seen two phases to date:

### Development of geothermal electricity generation



#### Research and development phase (1985-2003)

As early as the 1960s and '70s, East Germany gained extensive experience in the use of geothermal heat. A search for oil and gas resources led to the discovery of thermal water. Interest in these findings grew during the late '70s, when it became clear that the country's brown coal reserves were limited. In view of the oil price crises, there was also a desire to reduce dependence on oil and other imported fuels. The government therefore had the potentials for the use of thermal water for heating examined throughout East Germany, and set up a programme to build geothermal heat supply systems in certain cities.



Dr. Peter Seibt, Managing Director of Geothermie Neubrandenburg GmbH  
**“The use of geothermal energy avoids the negative environmental effects of fossil fuels. Geothermal energy has the advantage that it is constantly available, and hence capable of base load use.”**

After reunification in 1990 however, these plans were largely abandoned, and many drillings sealed. At the urgings of West German power companies, the municipalities in the new eastern states were linked to the gas grid within a few years. Once the new gas grid connection was installed, there was no longer any incentive to pursue alternative heating strategies, even at sites with favourable thermal water conditions.

In West Germany, investigations into the production of heat and electricity from geothermal energy began in the mid-1980s. Since only a few geothermal energy systems were in operation at that time, there were still great knowledge gaps in all technical areas. Moreover, research funding for geothermal energy was low, compared with that available for wind energy or photovoltaics. The researchers were motivated by the high potential for the use of geothermal energy for heating and electricity ascertained in East Germany. The first studies of potentials after reunification were also promising. Many scientists were convinced of the prospects of geothermal cogeneration. Their engagement led to the foundation of the Geothermal Association in 1991.

The high costs combined with the high discovery risk proved to be a substantial barrier for geothermal energy. In Germany, exploration requires drillings to several thousand metres' depths; each drilling costs between €4 and €8 million. Moreover, there is the risk of not hitting any payload at that depth – i.e., not enough thermal water deposits. During the 1990s moreover, there was little political interest in the use of deep geothermal heat, so that geothermal electricity generation was not included in the Electricity Feed-In Act; hence, this impetus, too was lacking. The early phase of support for renewable energies during the 1980s and 1990s was therefore marked by rather miserly treatment of geothermal energy. The Federal Government even sought to cut support completely at the end of



the 1990s, since it saw hardly any potential for electricity generation by means of this technology. That perspective only changed with the change of government in 1998, which led to a considerable increase in federal research funding.

Derrick Sauerlach Research activities concentrated on the development and testing of geothermal cogeneration. Central to the government funded research was the so-called “hot dry rock” process, one of the “enhanced geothermal systems”, or, also known, as the “petrothermal process”. Water is pressed into the dry subsoil via holes, causing artificial fractures. If these turn out well, water can be injected repeatedly, heated, and returned to the surface again. This permits use of geothermal energy for electricity generation even in areas with no hydrothermal occurrence. To date, all facilities installed in Germany for geothermal electricity generation are based on thermal aquifers. This is pumped to the surface, and when the heat is withdrawn, pressed back down to the aquifer.

### Entry into electricity generation (after 2004)

The Renewable Energy Sources Act of 2000 for the first time established remuneration for electricity from geothermal energy. In 2003, a study by the German Bundestag's Office for Technology Assessment pointed to the potentials of geothermal energy, and thus confirmed its eligibility for support. Cogeneration seemed possible at a scale relevant from the point of view of energy economics. Only very low feed-in tariffs were fixed under the EEG, however. In view of the high investment costs, the remuneration rate was far too low to spark development. Only under the Renewable Energy Sources Act of 2004 were the rates raised considerably, laying the basis for the development of this technology



Werner Bußmann, 1991 - 2006 Member of the Executive Board of the Geothermal Association, German Association for Geothermal Energy e.V.

**“There is tremendous potential in geothermal energy. A Bundestag study has shown that there is so much energy stored at depths between three and seven kilometres that we could cover the electricity needs of Germany 600 times, around the clock.**

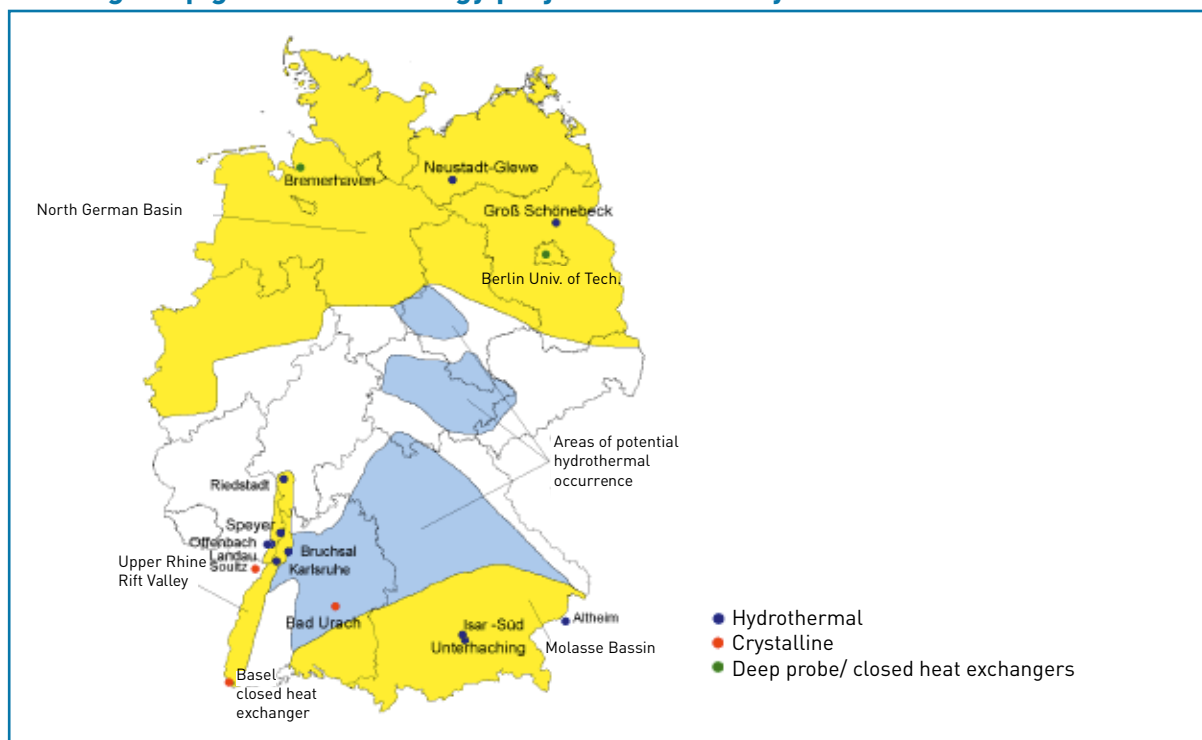


Drilling technician for geothermal drillings

By 2004, the first geothermal electricity generation projects had been realized. However, due to the high drilling risks and the high investment costs for geothermal depth drillings, the number of projects carried out has remained low to this day. In 2010, there were only four geothermal power plants in operation in Germany, which produced power: Neustadt on Glewe in Mecklenburg-Vorpommern, Landau in the Palatinate, Unterhaching, Bavaria and Bruchsal, Baden-Württemberg.<sup>15</sup> There has therefore to date been very little practical experience with electricity generation from deep geothermal energy.

<sup>15</sup> The first is in the northeast, the other three in southern Germany; see map.

## Existing deep geothermal energy projects in Germany



Source: Leibniz Institute for Energy (IE Leipzig)

### Technical and economic challenges

Because of the relatively low temperatures prevailing in Germany, the familiar steam process cannot be used to generate electricity. The degree of effectiveness would be too low for an economic energy conversion. Hence such new procedures as the so-called Organic Rankine Cycle (ORC) process are used for energy conversion. This is comparable to the steam process in the sequence of operations, except that instead of water, organic media such as ammonia, or synthetic materials like silicone oil are used. These media vaporize at temperatures of approx. 90°C, so that they make better use of depth heat. With the so-called "Kalina process", vapour is produced from an ammonia-water mixture. Both technologies are at the beginning of their development and must yet prove themselves in practice.

In addition to the technical challenges, the profitability of the systems is still a key issue. In all power plants built to date, electricity generation has been combined with heat utilization for economic reasons. The prerequisite for this is the proximity to consumers, preferably residential areas, or commercial customers with a high year-round heat requirement. However, the combination of the two site factors, good geothermal conditions and proximity to customers, is available at only a few sites. Moreover, high investments are needed to make the heat utilizable, e.g. a distributive network.

Under the Renewable Energy Sources Act of 2009, the feed-in tariffs for geothermal power were raised considerably once again, to a minimum of 16 cents and a maximum of 27 cents per kilowatt hour. In addition to the EEG, the market incentive programme of the Federal Ministry of the Environment too has since 2008 provided support for geothermal energy facilities used for electricity generation. Moreover, the Ministry of the Environment, the KfW Bank Group and the Munich Re Corporation have initiated a loan programme under which €60 million are available to finance geothermal depth drilling. This safeguard fund for search risks can assume up to 80% of drilling costs in case of non-success, thus decreasing the financial risks of geothermal drilling. Moreover, unplanned additional drilling costs, as well as the construction of heat networks, have each been supported with up to €1.5 million.

Finally, a comprehensive geothermal information system is to achieve improvements in the project design of geothermal systems and a reduction in the search risk. The first information on this has been accessible on the Internet since 2008.

### **Legal framework**

The legal point of departure for finding and tapping geothermal energy is more complicated than for other renewable energies. Geothermal energy belongs to the general public; its use is subject to the Mining Legislation. Before one can start tapping it, four types of mining legislation permits must generally be obtained: a prospecting permit, a prospecting operational plan, an extraction authorization and an extraction operational plan. The effort required for this is thus fairly high, particularly since these permits are always issued for only two years.

### **Perspectives**

Geothermal electricity generation is in competition with other types of subsoil use. These include not only the mining of raw materials, but also the alternative use of the subsoil as a storage system, for example for compressed air or gas. The concept of the capture of the CO<sub>2</sub> produced by coal-fired power plants and its storage underground (CCS) is a new and still largely unexplored technology, which also competes with the use of geothermal potentials. If the carbon dioxide is to be stored in underground caverns or empty oil fields, it can cause subterranean pressure changes, which can restrict the possibilities of geothermal energy drilling. In view of the limited number of suitable geothermal energy sites in Germany, given today's technology, this could rapidly become a very restrictive factor for further expansion.

Whether micro-seismic events (earthquakes) will in future lead to acceptance problems is not yet foreseeable. Micro-earthquakes can be triggered when fracturing the subsoil while building the systems. To preclude fears in the population, it is very important to state the possibility of earthquakes in advance, and to provide information about their causes.

The process of innovation of electricity generation from deep geothermal energy is still in its initial stages. In future however, there is a good chance for considerable growth. Currently in Germany, some 150 projects are in the processing stages, between preliminary examinations and actual construction. Power plant sites for geothermal generation have to date been concentrated in southern Germany, the Molasse Basin and the Upper Rhine Rift Valley, but the first sites in the North German Plain are also under development.

## Overall Perspectives

### Climate and energy policy goals

In 2005, the European Union proclaimed the goal of limiting global warming to no more than 2°C above the pre-industrial level. In order to achieve this, global emissions of greenhouse gases must sink drastically. In order to reach the 2°C goal, the heads of governments of the EU reached an agreement prior to the Copenhagen Conference of December 2009 to support the target of a greenhouse gas emissions reduction of between 80 and 95% by 2050 for all industrial countries. The German Federal Government has confirmed the national goal of reducing greenhouse gas emissions by 40% by 2020, compared with the 1990 level, and also recognized the necessity of another reduction in greenhouse gas emissions of at least 80% by 2050. A key factor is the energy supply. Here, the contribution of renewable energies to overall final energy consumption in Europe is to triple by 2020 to 20%. This means an increase of the renewable energy share of final energy consumption to 18% in Germany. At the end of 2009, the figure was 10.4%.

An important foundation for meeting European climate protection targets at the national level in Germany is the Integrated Energy and Climate Programme, adopted in 2007 at Meseberg Castle near Berlin. The Federal Government's principle strategies in this regard are "increased energy efficiency", "further development of cogeneration technology", and "expansion of renewable energies".

In the electricity sector, the course has been correctly set with the Renewable Energy Sources Act. The legislation has made the rapid development of electricity generation from renewable energy to date possible, and created a stable framework for an innovative and dynamically growing industry. This is to be continued: the EEG includes the fixed objective of producing at least 30% of the German electricity supply from renewable energies by 2020; in 2010, it was about 17%. Under the national action plan presented in August 2010, the Federal Government in fact expects a 38.6% of renewable energy share in the electricity segment, and 19.6% in the total energy consumption. The renewable energy associations expect even stronger growth by 2020: according to the industry forecast of early 2009, the renewable energy share of electricity produced should amount to 47% by 2020.

### Challenges to the grid and the power plant park

Certain municipalities and regions are already proving today that an electricity supply predominantly or exclusively based on renewable energies should work in practice. However, to ensure this in future everywhere, considerable reordering and restructuring of the existing electricity supply system will be required. Moreover, the issue of technical security of supply and output backup in case of low wind or solar input will have to be addressed.

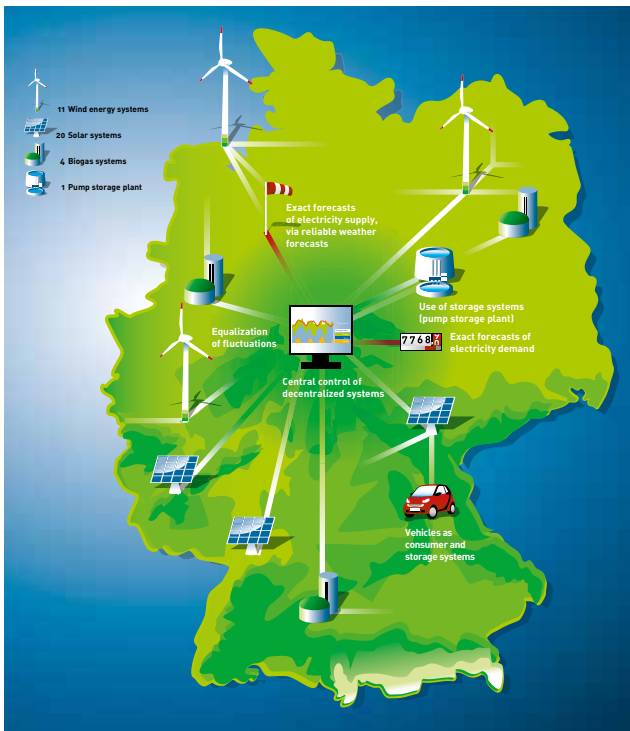
A major share of regenerative electricity production is provided by the fluctuating energy sources wind and solar energy. Here lie the greatest potentials for short to medium-term realization of renewable power. Given further development however, this intermittent electricity feed-in will increasingly run up against the limitations of the existing supply system. The system is oriented towards large base load power plants – particularly nuclear and brown coal-fired power plants – the electricity production of which can be regulated only to a very limited degree. If a grid overload threatens because no more conventional power plants can be switched off, renewable energy sources will have to be shut down, or else the power surpluses will have to be "shunted" off to neighbouring countries. Since this will occur more frequently in future, the investment security of renewable energies – and of others – will be impaired. If the lifespan of the nuclear power plant park is extended to approximately 2040, this conflict too, will go into overtime.



The integration of high shares of fluctuating renewable energies will require storage system technologies, and/or optimum adjustability of the conventional power plant park and of electricity demand. Electricity generation will no longer be unilaterally oriented towards electricity demand; rather, that demand will in future also be more strongly oriented towards short-term electricity supply (“demand-side management”). Targeted connection and disconnection of power consumers from the grid improves the degree of capacity utilization of the grid, and avoids peak loads, especially at times of low solar and wind power yields.

Base load power plants, which are technically and economically difficult to adjust, must gradually be replaced by flexibly controllable power plants. Over the medium to long term, we will need exclusively conventional power plants, which are fast and easy to regulate, in order to be able to appropriately supplement the electricity production from renewable energy sources at any time that is needed. Gas and to some extent hard coal-fired power plants can do this best. Modern control technology will ensure that conventional power plants deliver electricity as needed, in combination with renewable energy systems. The full-coverage flexible control of both the electricity supply and the electricity demand side is a great technological challenge.

### The combined renewable energy power plant



Source: AEE

Another condition with regard to the continued growth of renewable energies is the adaptation of the network infrastructure. The power grid must be oriented toward a high share of renewable energies, across national boundaries. It is necessary to extend, to strengthen and to interlink more strongly the German and European electricity supply systems. The regionally fluctuating power quantities from renewable energies can be compensated for extensively in the combined pan-European grid. The Infrastructure Planning Acceleration Act and the Power Grid Expansion Act have created the initial foundations to facilitate the expansion of the power grid. The regulation of network access too will become more important. The separation of the grid from electricity production (“unbundling”), and the Gas Grid Access Ordinance too are important instruments. Moreover, greatly improved energy efficiency and the resulting reduction in energy consumption are the prerequisites for rapidly achieving high shares of renewable energy use.

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