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A Biography of the Innovation Process

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Abbreviations

AG	Aktiengesellschaft
ARGE	Arbeitsgemeinschaft
AWD	Arbeitsgemeinschaft Wasserkraftwerke Deutschland
BauGB	Baugesetzbuch
BDEW	Bundesverband der Energie- und Wasserwirtschaft
BDW	Bund Deutscher Wasserkraftwerke
BEE	Bundesverband Erneuerbare Energie
BImSchG	Bundesimmissionsschutzgesetz
BLS	Bundesverband Landschaftsschutz
BMBF	Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie
BMFT	Bundesministerium für Forschung und Technologie (later the BMBF)
BMU	Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit
BMVBW	Bundesministerium für Verkehr, Bau- und Wohnungswesen
BMWA	Bundesministerium für Wirtschaft und Arbeit (from 2002 till 2005)
BMWi	Bundesministerium für Wirtschaft und Technologie (since 2005)
BNatSchG	Bundesnaturschutzgesetz
BSH	Bundesamt für Seeschifffahrt und Hydrographie
BT-Drs	Bundestagsdrucksache
BTO Elt	Bundestarifordnung Elektrizität
BUND	Bund für Umwelt und Naturschutz Deutschland
BWE	Bundesverband Windenergie
CCS	Carbon Capture and Storage
CdTe	Cadmium Telluride
CDU	Christlich Demokratische Union
CHP	Combined Heat and Power
CIGS	Copper Indium Gallium Diselenide
CIGSSe	Copper-Indium-Gallium-Sulfur
CIS	Copper Indium Diselenide
CO_2	Carbon dioxide
CSU	Christlich Soziale Union
DASA	Deutsche Aerospace Aktiengesellschaft, today: Daimler Chrysler Aerospace AG

DBU	Deutsche Bundesstiftung Umwelt
dena	Deutsche Energie-Agentur
DEWI	Deutsches Windenergie-Institut
DFS	Deutscher Fachverband Solarenergie e.V.
DFVLR	Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt
DGS	Deutsche Gesellschaft für Sonnenenergie
DGW	Deutsche Gesellschaft für Windenergie
DIW	Deutsches Institut für Wirtschaftsforschung
DLR	Deutsches Zentrum für Luft- und Raumfahrt
DEM	Deutsche Mark
DMG	Deutsche Meteorologische Gesellschaft
DNR	Deutscher Naturschutzring
DPG	Deutsche Physikalische Gesellschaft
DtA	Deutsche Ausgleichsbank
EEG	Erneuerbare-Energien-Gesetz
EFG	Edge-defined Film-fed Growth
EFP	Energieforschungsprogramm
EGS	Enhanced Geothermal System
EnBW	Energie Baden-Württemberg AG (utility)
EU	European Union
EuGH	Europäischer Gerichtshof
EWG	Europäische Wirtschaftsgemeinschaft
FAL	Bundesforschungsanstalt für Landwirtschaft, Braunschweig
FDP	Freie Demokratische Partei
FFH	Flora-Fauna-Habitat
FhG	Fraunhofer Gesellschaft
FNR	Fachagentur Nachwachsende Rohstoffe
FRG	Federal Republic of Germany
FVS	ForschungsVerbund Sonnenenergie
GAU	Größter Anzunehmender Unfall
GbR	Gesellschaft bürgerlichen Rechts
GDR	German Democratic Republic
GFZ	GeoForschungsZentrum Potsdam
GGA	Institut für Geowissenschaftliche Gemeinschaftsaufgaben
GmbH	Gesellschaft mit beschränkter Haftung
GROWIAN	Großwindanlage
GT	Geothermie
GTN	Geothermie Neubrandenburg GmbH
GtV	Geothermische Vereinigung
GtV-BV	Geothermische Vereinigung – Bundesverband Geothermie e.V.
GWh	Gigawatt per hour
HDR	Hot Dry Rock
HFG	Helmholtz-Gemeinschaft deutscher Forschungszentren
HFR	Hot Fractured Rock
HVDC	High Voltage Direct Current

HMI	Hahn-Meitner-Institute Berlin, now: Helmholtz-Zentrum Berlin
IBP	Fraunhofer Institut für Bauphysik
IEA	International Energy Agency
IEKP	Integriertes Energie- und Klimaprogramm
IFEU	Institut für Energie- und Umweltforschung
IPCC	Intergovernmental Panel on Climate Change
ISE	Fraunhofer Institut für Solare Energiesysteme
ISES	International Solar Energy Society
ISET	Institut für Solare Energieversorgungstechnik e. V.
ISFH	Institut für Solarenergieforschung Hameln
ISI	Fraunhofer Institut für System- und Innovationsforschung
ISUSI	Institute for Sustainable Solutions and Innovations
KFA	Kernforschungsanstalt
KfW	Kreditanstalt für Wiederaufbau
KTBL	Kuratorium für Technik und Bauwesen in der Landwirtschaft
kW	Kilowatt
kWh	Kilowatt per hour
MAP	Marktanreizprogramm
MBB	Messerschmidt Bölkow Blohm (manufacturing company)
MW	Megawatt
MW_{el}	Megawatt, electric capacity
MWh	Megawatt per hour
MWp	Megawatt, peak
MW_{th}	Megawatt, thermal capacity
NABU	Naturschutzbund Deutschland e.V.
NGO	Non governmental organization
NRW	Nordrhein-Westfalen
OECD	Organization for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
ORC	Organic Rankine Cycle
PR	Performance Ratio
PTJ	Projektträger Jülich
PV	Photovoltaics
PVD	Physical Vapor Deposition
REN	Rationelle Energieverwendung und Nutzung
RL	Richtlinie
SDLWindV	Verordnung zu Systemdienstleistungen durch Windenergieanlagen
SEA	Strategic Environmental Assessment
SFV	Solarenergie-Förderverein Deutschland e.V.
sm	Seamile (1852 m)
SPD	Sozialdemokratische Partei Deutschlands
SRU	Sachverständigenrat für Umweltfragen
StrEG	Stromeinspeisungsgesetz
TAB	Büro für Technikfolgenabschätzung beim Deutschen Bundestag
TEC	Treaty establishing the European Community

TU	Technische Universität
UMTS	Universal Mobile Telecommunications System
UN	United Nations
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
VDEW	Verband der Elektrizitätswirtschaft
VDMA	Verband Deutscher Maschinen- und Anlagenbau
VSI	Verband mittelständischer Solarindustrie e.V.
VZBV	Verbraucherzentrale Bundesverband
WFD	EU Water Framework Directive
WMEP	Wissenschaftliches Mess- und Evaluierungsprogramm
WMO	World Meteorological Organisation
ZAE	Zentrum für Angewandte Energieforschung
ZGI	Zentrales Geologisches Institut
ZIP	Zukunftsinvestitionsprogramm
ZIPE	Zentralinstitut für Physik der Erde
ZSW	Zentrum für Sonnenenergie- und Wasserstoff-Forschung

Chapter 1
Introduction

Breathtaking international decarbonization pathways, the proposal of a European supergrid or the ambitious solar project in the North African desert may be key features of future roadmaps toward a zero-carbon power sector. But it is safe to say that the primary function of the deployment of renewable energy today is the establishment of a pivotal landmark for a process of transition to sustainable energy and for a policy of climate change mitigation. At the same time, continuing growth in the renewable energy sector clearly triggers innovations and the diffusion of relevant technologies.

Although Germany's hydropower resources are limited, the country has been an influential forerunner in the deployment of renewable energies on a national scale, primarily through the use of wind, solar and biomass energies. Rising revenues and a growing workforce also reflect the growth rates we have seen in electricity generation from renewable energies in Germany over a period of 20 years, rates that would once have been considered impossible. While Germany's gross domestic product fell by about 5% in 2009 due to the worldwide economic crisis, revenues in the renewable energy sector saw a 10% gain that was triggered by domestic as well as international demand.

Funded by the German Federal Ministry of the Environment, the applied research project titled "Biography of the Innovation Process of Renewable Energies in Germany" tracked and analyzed this widely noted success story. Taking primarily a retrospective approach, participating researchers studied the innovation pathways associated with renewable energy sectors in order to identify lessons to be learned for the purposes of future policy making and implementation approaches within the renewable energy sector. We have also tried to shed light on the supportive as well as impeding factors influencing the innovation processes under study.

This book tackles questions like: What caused the outstanding expansion of wind and solar energy in Germany? Who and what represent the driving forces behind the rise in biomass electricity production and geothermal exploration? Were these just incremental processes or were they guided by policies and political actors? How did the actors involved deal with unanticipated setbacks? What was the role of larger-scale political and social contexts, the nuclear phase-out ("Atomausstieg") in Germany for example? Did policies and programs provide

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enough of a helping hand; what has been the role of economic incentives? How did the parties involved mitigate potential conflicts concerning land-use and other issues? And last but not least, what role did the development of technology itself play in, for example, the photovoltaic sector? What was the role of public research initiatives?

The results of this approach have been evaluated to allow an understanding of the complexity of the innovation pathways involved and of their ups and downs. The analytical and interpretive tool used for the comprehensive analysis of the storyline in each of the renewable energy sectors was the method "Constellation Analysis", which integrates elements of policy analysis and of Actor Network Theory, the latter of which focuses on the role of artifacts in innovations processes. Moreover, one aim was to generate an interpretation of the behavior of the actors involved, of their relationships and of the embedded contexts, which played an important role.

Unsurprisingly, the complexity of the relevant innovation pathways can be overwhelming. For this reason, the big picture has been carefully distilled into four analytical core categories, using the methodological approach of Constellation Analysis to examine actors, natural elements, technical elements and (semiotic) systems, such as legislation, tax exemptions, etc. As a result, the analysis has been able to identify forces that drive as well as those that impede in the innovation biography of renewable energies.

On the one hand, all renewable energy sectors have been driven to a nearly equivalent extent by national and international stimuli, which are subsequently presented (Chapter 3). This involves such driving forces as crises-triggering societal rethinking, international climate protection policies and research, European renewable energy policy incentives, as well as governmental promotion and sponsorship, which serve as a major source of stimuli. Key players have been the federal Renewable Energy Sources Act and its preceding act, which set the agenda by creating sustainable feed-in tariffs. Important aspects of the permit procedures, amendments to the planning system, environmental regulations and the electricity markets also brought relevant issues to the fore too.

On the other hand, each sector of the German renewable energy deployment shows unique and outstanding characteristics. We present synopses of the innovation pathways of each renewable energy sector, highlighting phase-specific descriptions of the driving and impeding forces in those sectors. Thus we present a brief recent history of the deployment of renewable energies in Germany, each including a sector-specific analysis of the predominant and outstanding features (Chapters 4–8). Each renewable energy sector has been subdivided into distinct phases within the overall development in that sector and each of those phases has been analyzed with reference to the interaction of influencing actors and factors.

Furthermore, the analysis highlights the role of key cross-sectoral influencing factors (Chapter 9), as well as that of policies designed to encourage industries and initiatives; these factors set crucial milestones. An example of a socio-cultural influence was the Chernobyl reactor catastrophe in 1986 and examples of policy intervention include the German Offshore Wind Strategy of 2002 and the German Climate Protection Program of 2005. Undoubtedly, the German Renewable Energy Sources Act has played a key role, both in fact and in appearance through the mission that underlies it, the policy it embodies and the reliable economic incentives it creates. Itself in force since the turn of the millennium, the Renewable Energy Act was preceded by the federal act known as the "Stromeinspeisungsgesetz" of 1991, which had already successfully set the agenda with respect to the provision of effective electricity feed-in tariffs. And could these innovations really have been triggered with such success without the spirited liberalization of the European electricity markets?

Notable and outstanding phenomena are also at the focus of the discussion of sector-specific innovation pathways described here. Note, for example, the astounding interim slump in biomass use during 2007/2008, coming just after it had enjoyed a definite boost phase. And what were the driving forces associated with the solar (photovoltaic) boom phase that began in 2004? Will this boom continue in view of a recent deliberate reduction of the relevant feed-in tariffs?

It appears that only a few stakeholders might benefit from geothermal energy; could this explain its comparatively modest development in Germany? Is there any viable evidence that innovation in onshore and offshore wind energy have taken separate paths since 2002?

The sectoral branches of renewable energies in the electricity sector feature unique innovation conditions, pathways and dynamics. Yet a certain pattern does seem to emerge: innovation processes do not proceed continuously or linearly, instead, they exhibit phases of depression and setbacks. Phases of highly dynamic innovation may be followed by phases of crisis that pose a challenge for policy making. Despite the distinctive differences among the innovation processes associated with wind, biomass and solar renewable energy, their deployments do have a great deal in common, and we try to sketch out those commonalities as well.

For example, German deployment of biogas (Chapter 4) includes a phase that features a remarkable focus on manure processing, in part as a consequence of German reunification. Technological developments were driven by the feed-in-tariffs mentioned above, these days following in an industrially-shaped development path that also leads toward the integration of biogas into the natural gas infrastructure. Biogas technologies have been driven, to a high degree, by hands-on and application-specific developments on the part of the manufacturers themselves. Yet the dependency on the supply of raw material for biogas results in inherent uncertainties and a multi-faceted complexity associated with the overlying mechanisms of the agricultural markets. A major boom was caused by an amendment of the Renewable Energy Sources Act that provided more attractive economic incentives, while at the same time inadvertently creating major environmental and societal conflicts (biofuel against food debate, etc.).

The solar (photovoltaic) technological approaches (Chapter 5) were labeled from the beginning as "high-tech" innovations. The constellation of actors behind the development of solar power in Germany includes outstanding public-private partnerships among silicon-producers, solar module and wafer manufacturers, planning engineers, craftsmen, landlords, non-governmental organizations and municipalities. Successful solar energy implementation in Germany is still concentrated on roof-top installations; development of field applications has been effectively delayed by a recognized lack of appropriate sites and by restrictive regulations associated with the Renewable Energy Act. Publicly funded model projects at the local and state level substantially supported solar deployment even when the federal incentives were in trouble.

The use of geothermal heat (Chapter 6) has its roots in cities of the former German Democratic Republic, but at the beginning of the 1990s, legislators missed the chance to integrate this sector into the feed-in-tariffs that promoted renewable electricity generation. As they have since been included, some pilot projects have now been implemented in Germany. However, in the face of remarkable drilling risks and costs and the lack of a broad alliance of motivated actors, the innovation process must still be considered as nascent.

When it comes to wind energy (Chapter 7), the boost phases could not have been more powerful. These were triggered by the dominating policy effects of the guaranteed feed-in-tariffs, combined, inter alia, with subsequent society-focused innovations in the German spatial and environmental planning system and by courtroom decisions, some at the European level. The long-term stable and ongoing implementation and diffusion of wind energy in Germany can now be seen as the consequence of iterative, step-by-step and phase-specific adjustment management. Wind energy is still a quantitative forerunner with respect to the dynamics of renewable innovation and diffusion in Germany; not even the important electricity grid integration and storage debate or the bullying of the coal and nuclear lobbies that preceded them were able to halt the increasingly cost-effective deployment.

Hydropower resources (Chapter 8), also once the leading renewable energy sector and forerunner of sustainable engineering, are limited in Germany. Even that exploitation potential that remains has been decisively restricted by European nature conservation requirements and subsequent policies. Yet, toward the end of their work, but of no little importance, the authors acknowledge the pivotal incentive provided by hydropower for the creation of feed-in-tariffs in Germany, which were triggered by the motivation of political pioneers to improve the revenue of small hydro power facilities.

The final chapter of the book (Chapter 10) provides a discussion of lessons learned so far for the supervision of related innovation processes: provide phase-specific interventions, identify and limit unintended consequences as promplty as possible, integrate different levels of actions and actors, steer the decisive driving forces by ensuring comprehensive synchronisation and by systematic analytical monitoring and amending to allow for a sustainable deployment of renewable energy!

Finally, the results of the underlying research project highlight the heterogeneous complexity and the ups and downs of the innovation biographies of renewable energies. Deployment has, in many ways, involved a successful collaboration on the part of the governmental, private and societal actors involved. Likewise, overarching framework conditions, technical preconditions and societal influences have played a decisive role. Hence, there is a constant need for systematic analytical monitoring and amending on the part of the political arena as well. At the end of the day, only a comprehensive yet feasible approach of that kind could provide the opportunity to track down the interdependencies and to allow public, entrepreneurial and civic policy making that will allow sustainable deployment of renewable energy.

Chapter 2
Introduction to the Methodology

Abstract As renewable energy technologies play an increasing role in international climate protection processes, they also play a key role in driving innovation processes within the energy technology sectors. A cross-sectional analysis of the various renewable energy technologies in Germany was accomplished, using a combination of Constellation Analysis (to map the various actors involved) and the concept of innovation biographies (to interpret the innovation pathways). The research aims at showing what drives or hinders the implementation of a renewable energy technology. The data and information used is based on extensive interviews, relevant literature and Internet research. This combination of methods results in a detailed and empirical account of the elements, actors and processes of each renewable energy sector and their mutual influences.

Keywords Constellation Analysis • Innovation biography • Methodology • Cross-sectional • Political science

2.1 Research Questions and Objectives

The expansion of renewable energies is an important cornerstone of the energy transition aimed for in Germany and beyond. At the same time, renewable energies are increasingly proving to be a driving force in innovation-oriented developments. They have become extremely important for the economy and for technology, which shows in growing sales and employment figures, and in the development of technologies that are geared toward efficient energy utilization and technical innovation.

This raises the question of what conditions and stimuli render innovations in the domain of renewable energy successful and what helps them to become accepted? What accounts for a favorable innovation climate? Which innovation conditions are key to the further expansion of renewable energy in the electricity sector?

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This book considers the innovation biography of renewable energies for the generation of electricity in Germany in a cross-sectional analysis. The focus is on the driving forces and restraints that appear in the respective phases of development. These factors are analyzed in order to draw conclusions about the key conditions for innovation. The aim is to provide a detailed account of the development, the progress made in harnessing various energy sources, and their contribution to the generation of electricity. The results are intended to help align the innovation processes and the use of policy instruments for the promotion of renewable energies in an even more focused manner.

The study is targeted at those interested in the relevant constellations of key actors, alliances, driving forces, and restraints, and would like to learn more about the causal system of interaction between societal, technical, ecological and economic influencing factors in the context of renewable energies. This analysis is also relevant to political decision-makers whose tasks include setting the overall course in the context of renewable energies and who are therefore in a position to help unfold their innovation power and economic potential.

2.2 Procedure

In addition to a review of the relevant literature and Internet research, interviews with around 40 selected experts served as an important basis for interpreting the innovation process with its driving forces and restraints.

The relevant factors were arranged according to the time of their occurrence (phase concept) and the role they played in the respective constellations, as well as their significance for the innovation process (process of assessing and interpretation). Constellation diagrams are used as a means of structuring the presentation and contextualizing the complex activities of the actors, lines of motivation and influencing factors. They serve as a visual summary of what is described in detail in the text.

Analysis of the innovation processes (Chapters 4–8) is arranged according to energy sectors (biogas, photovoltaics, geothermal, wind, and hydropower, respectively). We tried to maintain a consistent structure in all of these chapters. In some cases this was not entirely possible because of sector-specific differences.

The sector-specific portrayals are preceded by Chapter 3, which outlines the most important cross-sectoral influencing factors, policies and processes that fundamentally affected all of the sectors analyzed. Contrary to the other sector-specific chapters, in Chapter 3 these factors are arranged according to topics, and not chronologically, so as to avoid repetition.

If certain influencing factors, policies and processes are of particular relevance for a certain sector or if it was thought necessary to describe the effects of a policy on a certain energy sector in greater detail, these points are addressed once more in the context of the respective phases they occurred in within the sector-specific chapters.

2.2.1 A Note on Style

While the hope is that the book will be read in its entirety, it has been structured to accommodate those readers who might only be interested in certain energy sectors. However, the overarching factors and policies are described in Chapter 3. The references are located at the end of each chapter. The web addresses in the references have been shortened to the respective home page.

The relevant legal sources referred to in the text are explained in an “Index of Legal Sources” at the end of the book. The front of the book includes a list of abbreviations used throughout the book. The Système International (SI) has been used where possible. When writing about power in Watts we usually mean electric power, but where we need to distinguish between electric and thermal or calorific power we specify the symbol (W_{el}).

2.3 Methodology Used in the Constellation Analysis

The study is based on the combination of two methodological approaches, the Constellation Analysis (Schön et al. 2007) and the concept of Innovation Biographies (Rammert 2000), as starting points of the analysis.

2.3.1 Constellation Analysis

The Constellation Analysis serves as an interdisciplinary bridging concept for the analysis of complex actor constellations from a multi-disciplinary perspective. It facilitates interdisciplinary communication in the process of analytical research. The object of research – a constellation characterized by actors, policies, socio-economic framework conditions as well as natural and technical elements – enables us to correlate the various disciplines’ views, knowledge and solution approaches.[1]

Division of the innovation process into phases forms the basic heuristic for the Constellation Analysis, in that it creates chronological reference points that are used to map the constellations at hand.

For each phase, the most important elements of the respective constellations are mapped, i.e. recorded and correlated, and graphically represented. These diagrams of the constellations are a simplification of the complex field of actors and interactions. They precede the detailed textual analysis of the respective phase. The constellation diagrams serve as the basis for analyzing the relations between the constellation elements and their effects. In addition, they enable us to elaborate

[1] For a detailed description of the methodological approach of the Constellation Analysis, see Schön et al. (2007).

the constellation's characteristics and their central driving or restricting forces. Finally, the characteristics and dynamics of the constellations are subjected to a comprehensive interpretation.

Application of the method is characterized by an iterative procedure. This comprises several consecutive steps or steps that refer to each other. Back-references between these steps are inevitable. From step to step – the creation of a chronology, the division into phases and mapping of the constellation elements, right up to the interpretation of the constellation – the degree of abstraction increases.

2.3.2 Constellation Elements

We focus on four different types of elements that make up the constellations: social actors, technical elements, natural elements and signs/symbols. The different elements are marked by different colors and graphical representations (see Fig. 2.1).

Actors are individual persons, groups of actors and institutions. All artifacts (material products) are referred to as technical elements. Natural elements include natural resources (water, soil, air), animals and plants, the landscape, and natural phenomena. Signs and symbols comprise, for example, concepts, standards, laws, prices, communication and lead principles.

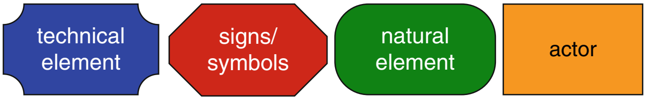

Fig. 2.1 Constellation elements (acc. to Schön et al. 2007)

2.3.3 Relations

Relations denote existing links between two or several elements (Fig. 2.2).

There are the following different types of relations:

- Simple relations: elements are more or less closely connected.
- Targeted relations: an element specifically impacts one or several other elements (targeted relations can be positive/stimulating or negative/inhibitory).
- Incompatible relations: two or several elements have an antagonistic effect on each other; the intentions are incompatible.
- Conflicting relations: there is a conflict between two or more elements, which reflects in one element expressly and intentionally acting against one or several other elements.
- Resistive relations: one element offers passive, non-explicit resistance to an expectation or ascription from other elements.

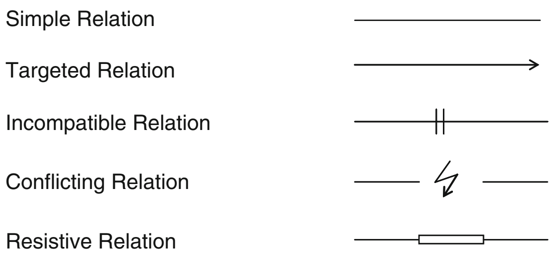

Fig. 2.2 Relations (acc. to Schön et al. 2007)

2.3.4 Context

Each constellation is embedded in a *context*. Context conditions are cross-sectoral framework conditions and superordinate processes that affect all aspects of society and influence not only individual elements within the constellation but the constellation as a whole. These may be political or strategic actions taken at the international level, suddenly occurring phenomena, variations in the availability of resources, political changes of power, cultural convictions, academic paradigms or important events that affect public awareness. Conditions that are classified as context elements form the backdrop or an overall atmosphere that fuel certain developments. Context in this sense favors the development and introduction of certain innovations while complicating that of others.

2.3.5 The Concept of a Biography of Innovation

The methodology applied to analyse innovation processes originates from current innovation and governance research which devised models of innovation theory. They are based on empirical studies, which focus on the process of innovation and on political processes. Some of the approaches and analyses which drew conclusions similar to those in this study shall be briefly outlined here.

2.3.5.1 Innovation Biography

The term "innovation biography" as used in this book is derived from Rammert's (2000) concept of innovation biographies. We have applied theories and methods used in sociological biography research to the exploration of innovation processes. Hence, a typical feature of our approach is that it focuses on the development, which is expressed in the chronological order of the stimuli and events.

The approach of innovation biographies strives primarily to identify driving forces and characteristic patterns, the role of actors and groups of actors, socio-economic, technical and natural factors in the innovation process, as well as institutionalization and limits of successfully applying policies. Particular attention is paid to the identification of “setbacks”.

Presenting innovation processes in the form of biographies allows us to highlight the changes that occur in the course of the innovation driven by a variety of influencing factors. This process comprises alternating phases of success, setbacks, highs and lows as well as regional shifts.

2.3.5.2 Innovation Process

The innovation process is understood as an interactive and recursive process that is embedded in a system of surrounding conditions and actors (see Hipp 1999). Instead of initiation by an “inventor” or a centrally controlling authority, our approach emphasizes the emergence of innovations within reflexive networks. Innovation is no longer viewed as a linearly progressing development, but as occurring in a recursively interwoven, discontinuous process under the influence of multiple factors. Our hypothesis is that innovations pursue an individual course as well as being subject to a number of general principles.

2.3.5.3 Innovation

Innovation is not limited to technical novelties (see Hemmelskamp 1998, 9). Along with technical innovation, a broad understanding of this term also comprises the tapping of new markets and outlets, hence viewing innovation as a result of a variety of activities. This involves the participation of heterogeneous actors in networks that are influenced not only by human and institutional actors but also by non-human elements, such as technical artifacts and sign systems.[2]

Innovation is therefore not only regarded as the creation and dissemination of new products and processes, i.e. the introduction of an innovation in the economy, but as the entire scope of change processes, provided these are not limited to marginal circumstances but associated with fundamental technical, economic, political and societal change.

2.4 Governing Political and Social Processes

The governing of political and social processes is a regular, but also a topical object of research in the fields of political science, sociology, urban, regional and environmental planning, and legal studies with a growing demand for research on the functional principles of governance (Bruns et al. 2008, 16).

[2] Cf. e.g. Rammert (2002); Rammert (2003).

In the Constellation Analysis, governance and control refer to an actor impacting one or several other elements of the constellation, and in doing so changing their behavior, structure, function or properties according to the actor's program. Hence, both terms mean providing intentional and targeted stimuli. While control exerts a directional – legal or administrative – influence, from our point of view, governance must be regarded as the exertion of a *multidirectional* influence on the actions of others. Governance in fact accounts for learning processes that result from recursive processes and interactions between the elements, which may lead to revisions in the sense of *corrective measures*. In other words, governance is not one-dimensional, but embedded in a system of complex relations between a variety of elements and refers to a differentiated, political-administrative multi-level system (local, regional, national and global levels). These levels can either be stimulus providers by issuing policies or addressees of these.

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Chapter 3
Cross-sectoral Interventions, Events and Processes

Abstract Renewable energies in Germany developed within an overall framework of cross-sectoral influencing factors and events. These issues essentially refer to the EU level and the German federal level. The energy and environmental crises, which triggered a change of mindset in society, were among the most important processes that affected the development of renewable energy in Germany. Also, the innovation process was – and still is – closely linked to international climate protection research and policy. The climate protection process and its institutionalization at international and EU level interacted with national problem awareness and respective processes. After the change of German government in 1998, climate protection – and from 2002 also renewable energy policy – was institutionalized with the Federal Environment Ministry. This significantly pushed the process at the national level. Specifications at EU level for the liberalization of the electricity market ultimately led to the energy sector opening up, national reforms being initiated in the energy sector and renewable energy being granted access to the electricity sector. In addition, the feed-in laws for renewable energies were accompanied by a large number of further legal adjustments.

Keywords Overall influencing • International climate protection policy • Energy policy • Energy crisis • Liberalization

3.1 Crises as Triggers for Social Rethinking Processes

Crises have significantly contributed to a stronger awareness of environmental and energy-related problems in politics and among the population. They caused institutionalized actors in particular to engage in comparatively complex activities

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designed to contribute to a solution. Problem awareness in public policy frequently emerged as the result of the initiative of innovative individuals (Hennicke et al. 1997). For them, the growing significance of environmental protection and sustainable energy supply as a common concern fueled the rethinking process. The goal of developing and expanding renewable energy was part of this process, and the crises described below triggered, accompanied or influenced this development.

3.1.1 Environmental and Climate Crises

Environmental crises significantly affected the deployment of renewable energies. There was a slowly growing awareness of environmental issues among certain groups of the German population even back in the early 1960s. This was reflected in publications, among the most important ones was the Meadows Report published by the Club of Rome. Its title was The Limits to Growth, and it raised considerable public attention in 1972 (Meadows et al. 1972). In "Ein Planet wird geplündert" (A planet being raided) Herbert Gruhl reveals the "horrors" of politics, admonishing the irresponsible way of dealing with natural resources that accompanies growth ideologies (Gruhl 1975). Numerous citizens and environmental initiatives[1] were founded around that time, the members of which – along with left-wing students – founded The Greens in 1980.

In his 1961 election campaign, and in view of considerable immission-related environmental problems, then Federal Chancellor Willy Brandt (SPD) promised a "blue sky above the river Ruhr" (Brüggemeier & Rommelspacher 1992). "To make a liveable environment the decisive guideline of their politics" was the declared objective of the social-liberal coalition of the time (Hofmann 1978). In 1971 the coalition adopted the Federal Government's first environmental program (BT-Drs. 6/2710), with environmental protection being defined for the first time as an important governmental task.

Doubts about the future viability of nuclear energy were part of the controversial discussions about the "risk society", a term coined by the German sociologist Ulrich Beck. His book of the same title appeared in 1986, the year of the Chernobyl reactor catastrophe, and was met with great enthusiasm both among experts and the general public. Beck's basic idea is that in the modern world, the social production of wealth also accompanies the systematic production of risk.

In 1987 the World Commission on Environment and Development, convened by the United Nations, published the Brundtland Report,[2] which mentions the guiding principle of sustainable development for the first time. The report significantly influenced the international debate about development policy and environmental

[1]A few years after its foundation in 1972, the Federal Association of Environmental Grassroots Action Groups (BBU) comprised already more than 600 groups (Roth 2009).

[2]Future report of the World Commission on Environment and Development "Our common future", chaired by Gro Harlem Brundtland.

policy, and ultimately prompted the 1992 Rio de Janeiro environmental conference.

At the same time, around 1987, the political arena paid more attention to the anthropogenic aspects of climate change. An important triggering factor in this process was an appeal prepared by the German Meteorological Society (Deutsche Meteorologische Gesellschaft – DMG) in cooperation with the German Physical Society (Deutschen Physikalische Gesellschaft – DPG). They forecast a global warming of 3°C over the next 100 years. The DMG drew on research data collected in its meteorological stations and illustrated changes based on weather data measured on Zugspitze, Germany's highest mountain, for example (Jaeger et al. 1994, 256 sqq.). The representatives of the DPG, who enjoy recognition across the fields of science, economy and politics, urged political decision-makers to include climate protection on their agenda. Representatives of the DPG also advocated that the use of nuclear power should be stepped up in this context.

At the end of the 1980s, the media were increasingly covering climate change,[3] too. Reports about the earth's atmosphere warming (green house effect), melting glaciers, and the expected rise in the sea level sparked a controversial public discussion about the causes and consequences of climate change.

Along with the reports of the IPCC, (see Section 3.2), the Stern Review[4] commissioned by the British government and published on 30 October 2006 was met with an outstanding media response. The Stern Review forecast serious consequences for the world economy if global warming was not stopped. The Review stated that 1% of the gross domestic product would need to be spent on immediate climate protection measures. If no action were taken, the costs of climate change would equal a loss of at least 5% of the global gross domestic product, according to Stern (2007). With regard to further risks and influences, the damage could amount to at least 20% of the gross national product. The massive international media response to the Stern report once again drew the public's attention to climate protection, the need for action and the consequences of not acting.

In addition, the growing number of natural disasters, such as hurricanes, floods and droughts, which can be attributed to man-made climate change, contributed to a stronger public awareness. The extent of possible effects of climate change became visible and created the pressure to act.

This was also reflected in the population's attitude toward new fossil-fuel power station projects. The construction of coal-fired power stations[5] is being

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[3] E.g., GEO special issues on climate protection in the 1980s; Bild der Wissenschaft issues on hydrogen technology.

[4] The Stern Review: The Economics of Climate Change (Stern 2007).

[5] At the time of going to press, seven power station were under construction and 22 power stations were in the design phase (cf. http://www.duh.de/..., accessed August 25, 2009). Critical locations included Hamburg-Moorburg, Hamburg-Brunsbüttel, Berlin-Lichtenberg, Lubmin in Mecklenburg-Western Pomerania and Mainz-Wiesbaden (cf. Die Klima-Allianz: "Der Widerstand wächst – Proteste gegen neue Kohlekraftwerke." www.deutscheumweltstiftung.de/, accessed April 21, 2009).

increasingly questioned due to growing problems of acceptance within the German population.

3.1.2 Oil Price Crises

The 1970s were dominated by two oil supply and price crises[6] that entailed a noticeable shortage of coal and oil. Countries such as Germany, which, unlike Denmark or Great Britain, did not have their own gas or oil supply, were hit particularly hard by the crisis. Reliable supplies and independent energy imports became the guiding themes of energy policy. The supply crises of the 1970s were accompanied by soaring prices for oil and gas, which is why renewable energy, which was so far considered to be too expensive, was suddenly thought of as being able to contribute to the energy supply. Although there were different opinions about the extent to which this would be possible (see Section 3.6.2), the supply crises were the key to change.

The beginning of the second Gulf War saw the price of crude oil drop to just over $20 per barrel. In the second half of the year, the oil price briefly soared to a dramatic $35. This "historic coincidence" boosted the promotion of renewable energies as intended by the Electricity Feed-in Act. In the early 1990s the oil price temporarily dropped to just under $10 per barrel. This development was accompanied by a dwindling interest of many states, especially the USA, in renewable energy. Similarly, the year 1998 was characterized by an oil glut and a steep plunge in oil prices. The financial and economic crises in East Asia are considered to have contributed to the collapse of prices. The decline in demand there, or the anticipated decline in demand, caused the stock exchange prices to drop sharply. The low oil prices made it harder for renewable energy to remain competitive.

After 1999 the average crude oil price rose continually and reached a new all-time peak of more than $50 per barrel in 2004. This price development was caused by a global increase in consumption and to some extent by insufficient oil drilling capacities.[7] Another reason for rocketing prices was speculations in the oil market after the slump in the New Economy (Abdolvand & Liesener 2009).[8]

[6] The first oil price crisis was triggered in 1973 by the Yom Kippur War, in the wake of which the OPEC (Organization of the Petroleum Exporting Countries) drastically curbed oil production. The oil price rose by ca. 70% due to this "oil embargo". The second oil price crisis occurred in 1979, and was essentially caused by production losses and confusion after the revolution in Iran and the subsequent war between Iraq and Iran.

[7] See also the crude oil studies of the Energy Watch Group, which assume that maximum production ("peak-oil") had already been reached in 2006 (www.energywatchgroup.org/..., accessed December 10, 2009).

[8] The trading volume on the oil market is frequently 15 times that of the actual worldwide oil consumption of currently 86 million barrels per day (ibid.).

The historic mark of $100 per barrel was passed for the first time in March 2008. At the beginning of July there was talk of yet another oil crisis when the $140 mark was passed. While the USA associated the rise in prices in this phase with the low oil production rate, the oil producing countries attributed the development to speculations and the loss of the dollar's purchasing power (ibid.). Although the oil price again dropped markedly after this peak, the events show that this limited resource will become more expensive over time, or at least be subject to strong variation in the future.

3.1.3 Nuclear Energy Crisis

The successful squatting of the construction site of the planned nuclear power station in Whyl in February 1975 marked the beginning of a demonstration wave against nuclear power in Germany.[9] A supra-regional anti-nuclear power movement spread and grew rapidly, expanding increasingly to established institutions, parties and associations (Saretzki 2001, 206). Nuclear accidents such as on Three Mile Island, Harrisburg (US) in 1979[10] fueled doubts concerning the controllability of this technology. The discontinuation of the construction work on the controversial nuclear reprocessing plant in Wackersdorf encouraged the protest of the anti-nuclear power movement in Germany.

Acceptance of nuclear power experienced a massive setback as a result of the 1986 Chernobyl accident. This worst case scenario, brought about by a meltdown and an explosion in block IV of the Chernobyl plant, is viewed as one of the most serious environmental disasters of all times. Unlike with previous accidents (e.g., the one in Mayak in 1957[11]), the media reported about this disaster in great detail, clearly revealing the risks of nuclear energy production. So far dubbed "clean energy", nuclear power had now caused the largest environmental catastrophe ever. Time and again the reactor accident is stated as the key event to have marked a turn in the environmental and energy debate. This reflects in the institutionalization of environmental politics in the form of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety founded in 1986 (Jaeger et al. 1994, 256) (see Section 3.4.1).

[9] Demonstrations in Brokdorf in 1976, Grohnde in 1977, Kalkar in 1977, Gorleben in 1979 etc.

[10] On 28 March 1979 the reactor in block 2 experienced a partial meltdown, in the course of which about a third of the reactor core was fragmented or melted.

[11] In September 1957 a concrete tank containing a highly radioactive liquid exploded on the south-east side of the Ural mountain range (close to Ozyorsk) at the plutonium plant "Mayak". Significantly more radioactivity was released than during the Chernobyl accident. The disaster is regarded as the best kept secret of a maximum credible accident in history. See http://www.welt.de/wissenschaft/... (accessed August 25, 2009).

After the reactor accident the consensus about using nuclear energy, which was already being challenged by the anti-nuclear power movement, crumbled. Large percentages of the population advocated a nuclear phaseout, a concept pursued by the politics of The Greens, and also the SPD (then in the opposition). The SPD had decided in 1986 to commit itself to nuclear phaseout[12] (see Section 3.5).

As a result, the necessity of economically viable alternatives had become evident. The potential of regenerative energy was now taken more seriously in discussions about energy policy. Germany linked the nuclear phaseout process (see Section 3.5) with proactive activities in support of renewable energy and with the goal of reducing greenhouse gas emissions.[13] However, proponents of the continued utilization of nuclear energy revealed that the idea of a nuclear phaseout was contradictory to reducing greenhouse gas emissions: they claimed that nuclear power was indispensible since it was a technology low in CO_2 and because it was capable of meeting the electricity demand (see Section 3.1.4).

However, the hazardous incidents that occurred in German nuclear power stations in 2001 and 2007[14] strengthened the nuclear power opponents' position of continuing a phaseout and to switch off old power stations because they were regarded as entailing too much risk.

3.1.4 Energy Supply Crises and Electricity Gap Debate

Due to the gas dispute between Russia and the Ukraine, the Russian gas supplier Gazprom repeatedly discontinued gas supplies to the Ukraine between 2006 and 2008. Numerous European buyer countries, including Germany, were affected by these cuts as well. Despite the fact that Germany's population was at no point in time threatened by a supply bottleneck, the crisis still revealed to what extent an increase in the share of Russian gas in the German energy mix would involve supply risks. The aim of the Federal Government to lower import dependencies, among other things by using domestic renewable energy, met with approval once more. Biogas producers and gas grid operators also used supply uncertainty on the gas market as an argument for domestic renewable energy. They pointed to this uncertainty when arguing that the share of biogas in natural gas should be increased by feeding larger amounts into the grid.

Along with gas supply bottlenecks, shortages in the electricity sector are also a concern. According to statements made by the German Minister of Economics, Michael Glos, in 2008, Germany was threatened by an "electricity gap" if nuclear

[12] Press release of the SPD parliamentary group on 26 January 2000.

[13] Germany agreed within the context of the Kyoto Protocol to reduce six greenhouse gases by 21% between 2008 and 2012.

[14] Accidents in Brunsbüttel (2001) and Krümmel (2007).

power stations are switched off as planned and the construction of modern coal-fired and gas-fired power stations are postponed.[15] The Federal Minister was drawing on an analysis conducted by the federally owned energy agency for power station and grid planning in Germany, called "dena", according to which Germany will be faced with the threat of electricity undersupply from 2012 onward. According to dena (2008, 1), this electricity gap can only be prevented by extending the power stations' runtime and building additional fossil power stations, not, merely by implementing power saving potentials and expanding the use of renewable energy sources. Moreover, the increasing pressure to act with regard to climate protection (IPCC 2007) is used as an argument to maintain nuclear power. According to dena, its low CO_2 emissions make nuclear power less detrimental to the global climate than the conversion of coal into electricity.

The Federal Ministry for the Environment as well as members of renewable energy associations and The Greens rejected the electricity gap debate and labelled it as a "fear campaign". These critics were supported by several studies that refuted the claims of the dena report.

A study commissioned by Greenpeace (EUtech & Greenpeace 2008) opposed dena's findings. It concluded that there would be no electricity gap in the event of a nuclear phaseout, neither short-term nor long-term. According to this study, the premises implied by dena about the medium-term development of the power demand, the amount of output supplied by combined heat and power, as well as assumptions concerning the development of the future energy mix (ibid. 1) needed to be subjected to critical review.

Based on its own calculations of the existing power station capacity, the Federal Environmental Agency, too, proved that the planned nuclear phaseout would not endanger the electricity supply, if the goals of energy efficiency and expansion of renewables were consistently pursued (Loreck 2008, 12). The Federal Ministry of Economics came to similar conclusions, when it assumed in its 2008 Monitoring Report that the electricity supply would be secure in Germany despite nuclear phaseout by 2020 (BMWi 2008). In September 2008, the German Federal Network Agency also opposed dena's assessment, certifying that Germany had sufficient generation capacity to safely meet the demand until 2020.[16]

In spite of these studies' findings, the utility oligopolies RWE, E.ON, Vattenfall and EnBW maintain discussions about runtime extensions for nuclear power stations. Their interests are to preserve the structures they have been benefiting from over decades and to secure their economical power in the long run (DUH 2008, 8). The debate took place in the period of the Federal Government's preliminary negotiations about the "climate package" (see Section 3.7.3).

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[15] http://www.bmwi.de/BMWi/... (accessed October 21, 2008). BDI president Jürgen Thurmann, too, opposed a nuclear phaseout based on the argument of climate protection (press release of 22 May 2007).

[16] http://www.verivox.de/nachrichten/... (accessed August 20, 2009).

3.1.5 Food Crisis

The food crisis is the result of a global supply and price crisis. After food prices had been stable for many years, they surged globally from 2006 onward. The high prices had been triggered by various factors, and they worsened the food shortage most of all in “Third World” countries.

The Food and Agriculture Organization of the United Nations (FAO) explained the rise in prices with a long-term increase in the demand for food and a simultaneous short-term decline in the supply (FAO 2008, 9). In addition to the steady decline in corn production experienced by major corn producers (China, EU, India, USA), draughts and floods in the years 2005–2007 caused further production losses. The high crude oil price affected corn supplies as well, since a rise in the crude oil price entails higher transport and fertilizer costs. According to the FAO, speculations at the commodities exchanges are responsible for the continually high food prices, which had increased by 30% in 2007 (FAO 2008, 11). Some countries responded to the expected losses by imposing export restrictions for corn, and in doing so aggravated the worldwide shortage.

Two factors in particular are deemed responsible for the increase in demand: economic growth in major industrializing nations such as China and India[17] and the newly emerging demand generated by the biofuel sector, which is partially subsidized and in part also increases as a result of the high crude oil price. The significance of demand-based greater energy recovery is regarded as an undisputed cause of the food crisis. This stimulated the debate about the “finite nature” or “limits to bioenergy utilization”. Limited availability of acreage and usage competitions in the bioenergy sector clearly show that, unlike wind and sun as energy suppliers, bioenergy is not indefinitely available.

3.2 International Climate Protection Research and Politics

The growing pressure to act with regard to climate protection and renewable energy (RE) development is closely interlinked. Climate change and climate protection policies have reinforced the process of RE development by revealing that alternatives, especially to fossil energy sources, are urgently needed. This section deals with the milestones in international climate protection policy, with Germany frequently acting as a trailblazer (Weidner 2008). It is important to outline international activities revealing the entwinement and interplay between national and international politics at multiple levels, while national and international levels alternate between roles of “driving” and “being driven”.

[17] Whether the changed consumption behavior in China and India has really contributed to the current price rise is doubted by the FAO. Their growing demand for grain, it argues, is met by their own production. China’s and India’s grain imports have dropped from 14 million tons at the beginning of 1980 to 6 million tons in the last 3 years, but the future influence on high food prices could be greater (FAO 2008, 11).

3.2.1 International Climate Protection Process

3.2.1.1 World Climate Conference in Geneva

In the 1970s only a small number of scientists were aware of climate change and the need for climate protection. It was not until the mid-1970s that research on climate protection began to attract more interest from the sciences (Oberthür 1993, 23; Jaeger et al. 1994). The first World Climate Conference in Geneva (1979), which had been organized by the World Meteorological Organization (WMO) in cooperation with the United Nations Environment Programme (UNEP), is considered the dawn of more recent climate (effects) research. After initially discussing a relatively broad range of anthropogenic climate influences and impacts, subsequent years focused on greenhouse gas issues.

At the World Climate Conference in Geneva, participants resolved to step up scientific research activities and international cooperation and adopted the first World Climate Research Programme (WCRP). The Geneva Conference provided crucial impetus, similar to the United Nations Conference on the Human Environment in Stockholm (1972)[18]: it inspired some countries to launch national climate protection programs (Jaeger et al. 1994, 256; Bechmann & Beck 1997, 122). International and national conferences followed soon after the first World Climate Conference. Similar to other areas of international environmental politics, international organizations took on a leading role in the case of climate issues, too. In this case the United Nations Environment Programme, which was brought into being in 1973, took over the role of a promoter, catalyst and organizer.[19]

3.2.1.2 Climate Conferences in Villach and Switzerland

In 1985 an international conference on the "Assessment of the Role of Carbon Dioxide and of Other Greenhouse Gases in Climate Variations and Associated Impacts" took place in Villach (Austria). After a number of smaller international meetings, this conference represented a turn in the discussion of increasing greenhouse gas emissions. There was a fundamental consensus concerning the size of the problem at hand, in conjunction with an appeal to scientists and political decision-makers to sound out possible counter-measures (Jaeger 1992). The final statement[20] indicated that the first half of the twenty-first century might be faced with a rise in temperature "which is greater than any in man's history". However, this declaration was the consensus of the experts invited and not that of the official representatives (Jaeger 1992). Two years later the conference "Developing Policies for Responding

[18] The United Nations Conference on the Human Environment (UNCHE), also known as the Stockholm Conference, took place in Stockholm from 5 to 16 June 1972. It was the first environmental conference convened by the United Nations.

[19] Strübel (1992, 18), cited in Bechmann & Beck (1997, 148).

[20] www.icsu-scope.org/downloadpubs/scope29/statement.html (accessed September 10, 2009).

to Climate Change", also held in Villach, focused on drawing up specific measures designed to reduce the greenhouse effect. Around 50 experts concentrated mainly on strategies of mitigation and adaptation. The conference marked the transition "from scientific stocktaking to a political discussion" (Matthes 2005, 26).[21]

The demand for an international regime designed to protect the climate was substantiated in particular by the "Brundtland Report" of 1987 (see Section 3.1.1). International political concern with the issue began with a conference held by the Canadian government in Toronto in 1988. The Toronto Conference was titled "The Changing Atmosphere: Implications for Global Security". The "Toronto target" was the first recommendation formulated in a specific political action plan for climate protection. CO_2 emissions and other climate gases were supposed to be reduced by 50% by 2050. As a first step the participants from science and politics recommended a 10% increase in energy efficiency between 1988 and 2005 and a 20% reduction of global CO_2 emissions compared to the emissions level of 1988 (Matthes 2005, 27). In addition, they expressed the necessity of adopting a comprehensive framework convention for the protection of the atmosphere.

3.2.1.3 The Intergovernmental Panel on Climate Change (IPCC)

Subsequently, in 1988 the WMO and the UNEP established the IPCC (Oberthür 1993, 24–25). As a kind of professional knowledge community (epistemic community), the IPCC adopts a special role in the discussion of the problem and in the political implementation process (Bechmann & Beck 1997, 138). Germany was represented at the first IPCC meeting by Hartmut Graßl,[22] who attended the event at his own expense, and who was also a committed member of the Commission of Inquiry "Provisions for the Protection of the Earth's Atmosphere".[23] The Ministry of Transport,[24] responsible for climate protection at the time, saw no need to delegate an official representative to the IPCC Conference.

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[21] In November 1987 a conference of high-ranking political decision-makers was held in Bellagio (Italy). It drew on the results of the Villach conference (Matthes 2005, 26).

[22] Prof. Dr. Hartmut Graßl was the director of the Max Planck Institute for Meteorology, Hamburg, between 1989 and 2005. From 1994 he was in charge of the World Climate Research Program (WCRP) for several years, which is organized jointly by the WMO and the International Council of Scientific Unions.

[23] The Committee of Inquiry was appointed by the 11th German Bundestag and existed from 1987 to 1995. Its first report in 1988, presented at the researchers' convention on climate change in Hamburg, focused in particular on replacements for the greenhouse gas CFC and on measures for rational energy use (www.nachhaltigkeit.info/artikel/..., accessed November 10, 2009).

[24] The German Meteorological Service (Deutscher Wetterdienst) is still part of the Federal Ministry of Transport, Building and Urban Affairs today. It is no longer responsible for matters of climate protection, though. Climate issues were primarily associated with weather phenomena at the time.

The first IPCC report of 1990 emphasized the observability of climate change and linked its existence to greenhouse gas emissions[25] (the greenhouse effect). It ascertained that the anthropogenic greenhouse effect represented a dangerous threat to mankind (IPCC 1990). The report formulated some first targets for climate protection and for the reduction of CO_2 emissions.

3.2.1.4 UN Framework Convention on Climate Change

The presentation and adoption of the first IPCC report in 1990 and its reception at the second World Climate Conference in Geneva in the same year intensified the pressure on the international community of nations to take specific measures for climate protection. The World Climate Conference of 1990 and the IPCC report brought before this conference are regarded as the political breakthrough for climate issues (Fischer 1992, 5; Gehring 1990, 703). At this conference 650 scientists and top-level government representatives from 140 nations acknowledged that the need for action was urgent. It was agreed to begin negotiations toward the establishment of a binding agreement on climate protection under international law. In December 1990 the United Nations plenary meeting initiated the negotiations process on global climate change by founding the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change (INC/FCCC). The INC drew up the UN Framework Convention on Climate Change[26] under the participation of 150 states in a laborious process stretching over five meetings held between February 1991 and May 1992 (Coenen 1997, 163).

3.2.1.5 Rio Conference on Environment and Development

The Conference on Environment and Development (Sustainability Summit) in Rio de Janeiro in 1992[27] dealt with climate protection as its central issue. The Framework Convention on Climate Protection was signed in Rio by most of the conference participants. The signatories agreed to publish regular reports on current greenhouse gas emissions and related trends. Since the Convention stressed the requirements of global climate protection and with this the necessity of a transition to renewables, the potential of renewable energies was placed not only in the context of sustainable development but expressly in that of climate protection. Germany's environment minister at this time, Klaus Töpfer (1987–1994), significantly advanced the process of climate protection.

[25] The greenhouse gases addressed by the 1997 Kyoto Protocol are carbon dioxide, methane, nitrous oxide (laughing gas), perfluorocarbons, hydrofluorocarbons and sulfur hexafluoride.

[26] The United Nations Framework Convention on Climate Change (UNFCCC) aims to slow down man-made global warming and to mitigate its impact.

[27] The United Nations Conference on Environment and Development (UNCED) took place in Rio de Janeiro, Brazil, in 1992. It adopted the Agenda 21, an action program containing recommendations for sustainable development, and is regarded as a milestone in global environmental and development policy.

3.2.1.6 After the Framework Convention on Climate Change: The Climate Marathon

The annual Conferences of the Parties (COP) to the Framework Convention on Climate Change as the supreme and sole decision-making commission, mark important political stages in the implementation of targets set by the Framework Convention.

A significant milestone was the first Conference of the Parties to the Framework Convention in Berlin in March 1995, chaired by German Environment Minister Angela Merkel. At this conference, the fundamental decision to formulate binding greenhouse gas emission reductions for the industrial countries was adopted in the form of the so-called Berlin Mandate. It stipulated that a protocol of adequate measures against man-made climate change should be adopted within 2 years.

In the same year, the IPCC published its second Climate Report. Based on new findings on climate change, this report emphasized the man-made impact on global climate change and the necessity of taking political counter-measures. The report can be regarded as a well-founded reference for defining CO_2 reduction targets for climate protection.

Additional progress was achieved at the second Conference of the Parties in Geneva, which took place in July 1996. The Conference was regarded as an inspiring success, since a large majority of the delegations clearly supported the results of the second IPCC report and agreed that additional measures to significantly reduce greenhouse gases were urgently needed. The result of the second COP was a ministerial declaration according to which greenhouse emission reduction targets should be codified by law. It was considered remarkable that, contrary to their former statements, the USA now explicitly supported the IPCC and their findings. Sixteen parties, however, rejected the IPCC Report's conclusions, among them the OPEC states, Russia, Australia and New Zealand (Coenen 1997, 190), and objected to legally defined reduction targets and time schedules.

3.2.1.7 Kyoto Protocol

The third Conference of the Parties, which took place in Kyoto in 1997, is considered the most important milestone in international climate negotiations. In December 1997, the participating parties adopted a protocol specifying CO_2 reduction targets based on the second IPCC Report. The Kyoto Protocol[28] supplemented the Framework Convention on Climate Change (UNFCCC) with more stringent and in part legally binding measures. The signatories of the Kyoto Protocol defined individual emission reduction targets for six greenhouse gases that

[28] The Kyoto Protocol is an optional protocol linked to the United Nations Framework Convention on Climate Change (UNFCCC) and adopted on 11 December 1997. It sets binding targets for the reduction of greenhouse gas emissions.

affect the climate.[29] The European Union as a whole committed to greenhouse gas reductions of 8% (compared to 1990 levels) between 2008 and 2012. Based on their share within the EU, Germany pledged to reduce its greenhouse gas emissions by 21% compared to 1990. This target became binding for Germany in July 2001, when the German Federal Parliament and the Federal Council of the German Parliament unanimously ratified the Kyoto Protocol. Since then internationally binding reduction targets of 21% by 2010 form the declared basis of the Federal Government's climate protection policy.[30] After ratification by Russia on 18 November 2004, the Kyoto Protocol entered into force on 16 February 2005.

3.2.1.8 Third and Fourth IPCC Report

The IPCC continued its climate reports in 2001 and 2007: the third IPCC Climate Report in 2001 further raised the public's awareness of climate change. Surveys confirm that the use of renewable energy was highly accepted in the population.[31] In addition, the economic implications of climate change were now being discussed (for example in Kemfert 2004). The third IPCC Climate Report formed the technical basis for the Rio+10 summit in Johannesburg in 2002 and has since served as a reference for climate research and climate policy.

The fourth IPCC Climate Report (IPCC 2007) confirmed the correlations between CO_2 emissions and climate change. The Report again met a strong response both from politicians and the public.

3.2.1.9 Renewables Process

The 2002 "World Summit for Sustainable Development" (WSSD) in Johannesburg, also known as Rio+10, is considered the beginning of an international political process for the promotion of renewable energy. For the first time, renewable energy was a topic on the agenda of an international conference.

Gerhard Schröder, Germany's federal chancellor at the time, invited the participants in Johannesburg to come to Bonn for a first governmental conference on renewables ("renewables 2004"). This was the result of the realization that "specific initiatives for the expansion of RE and for the reduction of fossil energies and their subsidization were generally not attainable at multilateral UN conferences[32]"(Hirschl 2008, 577).

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[29] Carbon dioxide, methane, nitrous oxide, perfluorocarbons (PFC), hydrofluorocarbons (HFC) and sulfur hexafluoride. Reduction of the individual gases were converted to "CO_2 equivalents", and then added up to a total value.

[30] www.bmu.de/klimaschutz/aktuell/... (accessed August 25, 2009).

[31] Cf. e.g., forsa (2005), BUND (2007), Agentur für erneuerbare Energien (2008). Mautz & Byzio (2004, 112) speak of "energy transition as a guiding principle of society".

[32] These targets failed as a result of the coalition of the US and the OPEC states known from the context of climate policy (ibid.).

The "renewables 2004" in Bonn was an intergovernmental conference of high-ranking politicians, which enjoyed extensive media coverage (ibid.).[33] The organizers hoped that the event would help publicize the issue on a large scale, and therefore not only involved representatives from the RE sector but also numerous social actors from the industrial and economic sectors. The main outcome of this conference was the International Action Program, which specified a large number of different actions and commitments toward the promotion of renewable energy. Germany's special contribution to the Action Program laid in federal chancellor Gerhard Schröder's announcement that the Federal Government would make available 500 million euros over a period of 5 years starting in 2005 from the Kreditanstalt für Wiederaufbau (Reconstruction Credit Institute) in order to expand the use of renewable energy (Mangels-Voegt 2004). The German hosts, i.e., the Federal Ministry for the Environment and the Federal Ministry for Economic Cooperation, had thus kicked off an international political process, with Germany's energy policy serving as a model.

Another important result of the Conference was the establishment of the Renewable Energy Policy Network for the 21st Century (REN 21) (Staiß 2007, 243), which was given the official go-ahead in Copenhagen in June 2005.[34] As a global political network of governments, international organizations and representatives of civil society (ibid.), it was intended to provide an international forum for leading initiatives in the field of renewable energy. REN 21 was supported by the International Energy Agency Network (Hirschl 2008, 578).

Further conferences were convened within the framework of the REN 21. The Beijing International Renewable Energy Conference in 2005 was significant due to the fact that it was held in an emerging country. China placed special emphasis on international cooperation with a view to establishing renewable energy in developing countries. The Washington International Renewable Energy Conference in 2008 with representatives from international (non-governmental) organizations and the private economy adopted 145 initiatives geared toward markedly increasing the share of renewables worldwide. The fourth conference in this series takes place in Delhi in 2010.

3.2.1.10 G8 Summit in Heiligendamm

In June 2007 the 33rd summit of the leaders of the Group of Eight[35] was held under German presidency in Heilgendamm. Its lead theme was "Growth and

[33] Hirschl (2008, 578) perceives an important positive effect of the conference in the fact that its voluntary context allowed the participating countries to "positively" deviate from their usual positions in climate and energy policy. The federal environment minister of the time termed the conference a milestone in the transition to an energy system that places climate protection and the real development potential of the world's poor countries at the center of attention.

[34] Cf. REN 21 Renewable Energy Policy Network. 2005. "Globaler Statusbericht 2005 Erneuerbare Energien". Washington, DC: Worldwatch Institute.

[35] The Group of Eight is comprised of the leading industrialized nations of Germany, the United States of America, Japan, Great Britain, Canada, France, Italy and Russia. The European Commission is also represented in the commission with observer status.

Responsibility", while the conference concentrated on the necessity of reducing greenhouse gases and expanding renewable energies.

Ultimately the G8 countries declared their support for the statements and targets of the IPCC Report and the results of the most recent UN climate report. For the first time the community agreed on the necessity of joint greenhouse gas reduction targets. In its final declaration it proclaimed a stronger recognition of climate change as a problem requiring a global and international solution. The announcement that the climate negotiations were to continue under the umbrella of the UN was considered quite remarkable, as it was contrary to the original attitude of US president George W. Bush. Implementation of the declared targets was, however, postponed to the negotiations of the Bali climate conference (Bals 2007, 4).

Participants had not been able to agree on fixed reduction targets or the two-degree mark.[36] A coalition of Japan, Canada and the EU advocated emissions reductions by at least 50% by 2050, hence acknowledging the necessary dimension of reductions, yet could not agree on a common base year. Moreover, Russia and the USA were not in favor of this declaration. Promoting renewable energy was recognized as a contribution to emissions reductions (Summit Declaration 2007, 35, 76), but did not play any significant role in the summit declaration.

At least the G8 decided to initiate the negotiation process for a post-Kyoto treaty at the World Climate Conference in Bali in December 2007 and to conclude this process by 2009 (Summit Declaration 2007, 52). With this, the UN was recognized as the central forum for international climate negotiations.

Environmental groups, non-governmental organizations and many more actors expressed their disappointment with the outcome of the summit. There had been great expectations concerning the German dual presidency of 2007 (EU presidency in the first half of 2007 and simultaneous presidency of the G8 summit), which from the perspective of environmental organizations could have been used to make climate change even more of a top priority in international politics (Bals 2008, 6).

3.2.1.11 World Climate Conference in Bali

A key target of the World Climate Conference in Bali[37] in December 2007 was to begin negotiations for a follow-up treaty to the Kyoto Protocol, which would expire in 2012, and to draw up a joint action plan and time schedule for the further negotiations process. In view of the resistances[38] this "Road Map" and the agreement on the main modules of a future treaty were regarded as a success.

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[36] This refers to the commitment to restrict the rise in temperature to below 2°C compared to the pre-industrial level.

[37] The Climate Conference on the Indonesian island of Bali was the 13th Conference of the Parties of the Framework Convention on Climate Change (cf. Löschel et al. 2008, 28 sqq.).

[38] Not all countries accepted the base line of the Kyoto Protocol, which prescribes and quantifies a reduction of carbon dioxide emissions. Nations with a strong economic development (USA, China) opposed for economic reasons. The developing countries, in turn, demanded greater support of the industrialized countries in dealing with the problems and costs incurred by climate change.

The participants aimed at successfully complete the negotiations by the 15th Conference of the Parties, which was to take place in Copenhagen in 2009 and to have this lead to a new climate treaty (Kyoto Protocol follow-up treaty) (Bali Action Plan 2007, 3).

The results of Bali fell short of what Germany and the EU had hoped for. Quantified target specifications for greenhouse gas emission reductions applied only to the Kyoto parties and not to the USA (Bals 2008, 23; AWG Report 2007, 5).[39] The parties attending the Bali Conference pledged to take additional climate protection measures that are measurable, reportable and verifiable, and that can be compared by taking into account specific national situations. It had not been possible to achieve international commitment to these targets, though. However, a positive result was that the so-called newly industrializing nations also pledged to take extensive measurable, reportable and verifiable action to lower greenhouse emissions. In turn they demanded technological and financial support from the industrialized countries. An Adaptation Fund, long demanded by the developing countries, was launched to finance measures designed to counter the adverse effects of climate change. It would be financed from the share of proceeds (2%) of Clean Development Mechanism (CDM) certificates.

All in all the Bali Road Map was also a signal to the financial market that emissions trading and the CDM should be continued and stepped up after 2012.

3.2.1.12 Fifteenth Conference of the Parties in Copenhagen

In December 2009 the 15th COP on the Framework Convention on Climate Change took place in Copenhagen (see Table 3.1). The Bali Road Map had stipulated that the parties sign a new, binding treaty to follow up the Kyoto Protocol before its expiry in 2012, and Copenhagen was viewed as the last opportunity to do so. In view of the many years of preparation, the meeting was frequently termed “possibly the most important conference in the history of mankind”.[40] However, the UN Climate Conference is deemed to have failed. It led to the Copenhagen Accord,[41] a minimal consensus that was binding neither under international law nor politically. Its signatories “took note of” the fact that global warming should be limited to 2°C compared to the pre-industrial level. They did not, however, commit themselves to any generally binding, internationally verifiable mitigation targets for greenhouse gas emissions. Consequently several developing countries rejected the compromise.

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[39] All of the G8 states (i.e. also the USA) declared their support for emission reductions by at least 50% by 2050 at the G8 Summit in Japan.

[40] Schellnhuber, J. in: http://www.epd.de/nachrichten/nachrichten_index_68662.html (accessed November 20, 2009).

[41] http://unfccc.int/resource/docs/2009/cop15/eng/l07.pdf (accessed December 23, 2009).

Table 3.1 Key milestones in the international climate protection process (Coenen 1997, 162; supplemented)

1979	First World Climate Conference (WMO) in Geneva
1985	Villach International Conference on the Assessment of the Role of Carbon Dioxide and of Other Greenhouse Gases in Climate Variations and Associated Impacts
1987	Villach Workshop Developing Policies for Responding to Climate Change
	Publication of the Brundtland Report “Our Common Future”
1988	Toronto Conference
	Establishment of the Intergovernmental Panel on Climate Change (IPCC)
1988	First Report of the Committee of Inquiry “Provisions for the Protection of the Earth’s Atmosphere” at the International Conference of Researchers in Hamburg
1990	Adoption of the First IPCC Assessment Report
	Second World Climate Conference in Geneva
	Establishment of the Intergovernmental Negotiating Committee for a Framework Convention (INC/FCCC)
1991–1992	Five sessions of the INC to work out the Framework Convention on Climate Change between February 1991 and May 1992
1992	Adoption of the Framework Convention on Climate Change (UNFCCC) at the UN Conference on Environment and Development in Rio by approx. 150 states
1994	Entry into force of the Framework Convention on Climate Change
1995	First Conference of the Parties (COP) of the Framework Convention on Climate Change (UNFCCC) in Berlin
	Publication of the Second IPCC Assessment Report
1996	Second COP of the Framework Convention on Climate Change in Geneva
1997	Third COP of the Framework Convention on Climate Change in Kyoto
2001	Publication of the Third IPCC Assessment Report
2002	Rio+10 Summit in Johannesburg / World Summit on Sustainable Development – WSSD
2004	First Intergovernmental Conference on Renewables (“renewables 2004”) in Bonn
	Establishment of the global policy network REN 21
2007	Publication of the Fourth IPCC Assessment Report
	G8 Summit in Heiligendamm
	Thirteenth COP in Bali
2009	Fifteenth Conference of the Parties (COP) in Copenhagen

After the failure to conclude a successor treaty to the Kyoto Protocol expiring in 2012, hopes are pinned on the 16th COP in Mexico City, which is to take place from 29 November to 10 December 2010.

3.2.2 Establishment of the International Renewable Energy Agency (IRENA)

The establishment of an International Renewable Energy Agency was proposed for the first time in 1981 (Bundesregierung 2008, 6), but was initially abandoned due to a variety of resistances, for example, from the established energy industry. Supported by Spain and Denmark, Germany reverted to the idea of creating an international renewable energy agency as originally set out in the 2002 government coalition agreement. The founding process, which began in early 2007, culminated in the official Founding Conference in Bonn on 26 January 2009.[42] IRENA's head office is in Abu Dhabi, while Bonn hosts IRENA's Center of Innovation and Technology. A Liaison Office for cooperation with the UN and other international institutions in the field of energy was opened in Vienna.

IRENA is the first worldwide organization concerned exclusively with renewable energies. The Agency offers consulting services to industrialized, industrializing and developing countries (IRENA 2008a, 2; IRENA 2008b; BMU 2008b, 13 sqq.; Bundesregierung 2008, 8).[43] IRENA understands itself as a political counterbalance to the International Atomic Energy Agency (IAEA) founded in 1957 and to the International Energy Agency (IEA) founded in 1974.[44] Its studies and consulting services aim to reveal local potential and expansion options, and to make suggestions with regard to financing models and the necessary regulatory framework conditions. By June 2009 a total of 109 states had signed the founding treaty, among them a large share of European and African states. In mid-March 2009 India signed the founding treaty as the first of the five major industrializing nations (IRENA 2009a).

3.3 Incentives for Energy Policy at EU level

The challenges at hand can only be mastered if activities toward energy and climate policy are coordinated among EU member states. The provision of an environmentally friendly, safe and competitive supply of energy cannot be managed by individual nation states alone. In addition, energy and climate policies are regarded as issues that could help to promote the process of European integration. According to Geden & Fischer (2008, 113), this is not so much about a real shift of regulatory competence to the EU level but about gaining acceptance for the "European idea". At the EU level, energy and climate policies are currently thought of as matters that have the potential to demonstrate the EU's ability to act.

[42] Ultimately the efforts benefited from the simultaneous foundation of other partnerships, such as the REN 21 (Hirschl 2008, 484 and 532 sqq.) While REN 21 is a relatively open policy network with only a small secretariat that is operated by the GTZ and the UNEP, IRENA was devised as an independently acting agency right from the start (IRENA 2009a).

[43] The Agency provides its consulting services at the request of its member states only (Bundesregierung 2008a, 7).

[44] This Agency is accused of not taking a neutral stance toward the entirety of energy sources, but rather to heavily support conventional and nuclear energy supply (Scheer 2008a, 1; similar Gabriel 2009, 1). Gabriel therefore regards IRENA as an alternative to the lobby interests of the conventional energy industry (2009, 2).

3.3.1 Liberalization of the Energy Markets

The EU had been encouraging the liberalization of the energy markets since the late 1980s. The aim was (and is) to establish a functioning single European energy market.[45] The legal basis for resuming discussions about energy management structures within the EU was section 8 – a section that had been added to the EEC Treaty as part of the Single European Act of 1986. It stipulated the step-by-step implementation of a single market by 31 December 1992 (Matthes 2000, 178). In the light of this, the Council of Ministers adopted the "New Community Energy Policy Objectives" on 16 September 1986. It was not until 2 years later, on 2 May 1988, that the Commission presented the report "The Single European Energy Market" (COM 1988), in which the Commission takes stock of the situation concerning various energy sources and develops some first ideas about the creation of a single energy market. In 1989 the EU Commission published two draft directives on increasing the transparency of energy prices and on electricity transits. These drafts were significant in particular due to the announcement of further liberalization steps and due to the resulting breakup of closed supply areas (Matthes 2000, 178–179).

3.3.1.1 Single Market Directive 96/92/EC

After several years of controversial debate within the EU, Directive 96/92/EC concerning common rules for the internal market in electricity[46] was adopted on 19 December 1996. The directive had received a great deal of support from the conservative-liberal German government in power at the time, which saw itself faced with a national "veto coalition of the energy sector"[47] (Hirschl 2008, 568). It was hoped that this "change of levels" would remedy the situation and bring about new impulses for national liberalization.

The Directive entered into force on 19 February 1997 and obliged the member states to gradually liberalize the electricity sector by 1999. As a result, Germany was able to adopt a revision of its Energy Industry Act (see Section 3.9.3).

The aim of liberalization was to open up as many sections of the energy market's value chain[48] to competition. The competition was supposed to ensure that consumers

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[45] The EU Commission had presented a first draft directive on the liberalization of the energy markets as early as 1992. Yet it was not adopted.

[46] The sources for the legal information used in this chapter are given in the Index of Legal Sources.

[47] This sector had successfully fought changes to the 60-year-old legal status quo, especially the abandonment of the protected regional monopolies.

[48] In the case of electricity it is made up of (1) generation, (2) (wholesale) trade, (3) electricity grids (high and extra high voltage), (4) sales and (5) distribution networks.

are supplied with electricity at the best possible prices based on the market situation. Unbundling is therefore an integral part of reforming the energy generation, transmission and distribution business (Monstadt 2004, 162).

Transport of electricity is tied to a costly grid infrastructure. Offering several, parallel power grids therefore did not seem to make economical sense. For this reason the grid operators' regional monopoly was maintained at this stage of the liberalization process. However, the power utilities were required to separate their transport networks and/or distribution networks from the other markets subject to competition both legally and operationally and in terms of information and accounting ("unbundling"). So-called vertical unbundling did lead to the formation of spin-offs, yet in Germany these were still owned by the parent company, so the process of unbundling initially remained incomplete. Along with unbundling, guaranteed third-party grid access to the transmission and distribution networks[49], as well as regulation of the system usage charges[50] and grid connection conditions count among the major requirements specified by the EU.

The actual wording of the directive allowed for various ways for implementation, depending on the respective national situations. In practice, however, this resulted in a deviation from the original goal of harmonization and integration of the energy markets (see Section 3.9.3.3).

3.3.1.2 Acceleration Directive 2003/54/EC

In order to lend weight to the objectives of the Single Market Directive and to accelerate its deficient implementation, the Commission adopted the so-called Acceleration Directive 2003/54/EC in 2003. This directive abandoned the choices concerning the organization of the market and called for the binding introduction of regulatory authorities in the member states. The responsibilities of these authorities were specified in detail. The German energy industry joined forces with the Federal Ministry of Economics to combat the introduction of a regulatory authority "imposed" by Brussels (Hirschl 2008, 569). Implementation in Germany was delayed until the German Energy Industry Act (see more in Section 3.9.3) was once again amended in 2005 and the "German Federal Network Agency" was founded.

[49] This grid access regulation is designed to permit non-discriminatory third-party access to the supply grids. Denying access to the grid is only possible if the grid does not have the required wheeling capacities.

[50] Grid operators must make available their grids at a certain fee, while grid usage charges may be government-regulated.

3.3.2 Renewables and Climate Protection Policy at EU Level

Supporting renewable energy, which forms one of the most distinctive interfaces between environmental policy and energy policy, has gained importance over the last years as a result of the climate objectives formulated by the EU (Geden & Fischer 2008, 95).

3.3.2.1 Support Programs for Non-nuclear Energy

Although the EU Parliament had resolved in 1991 that the amount of subsidies for renewable energy should be equal to the amount spent on nuclear fusion research, the Commission prevented the introduction of a separate legal section for this. The EU Parliament subsequently created collective programs for non-nuclear energy, which were also used for fossil energy. The programs "Joule", "Thermie" and "Altener" were available for projects involving renewables, while the latter was devised exclusively for renewables. Although the Green Paper "Energy for the Future" (COM 1996) propagated stronger promotion of renewable energy (see Section 3.3.2.2), the subsidies from the Altener program were on the verge of being cut.

In addition, application for EU subsidies – especially if the prospects of receiving support were questionable – presented a challenge for applicants. Applications were time and energy consuming because of stringent, extensive and complicated guidelines, the requirement to compile an international application consortium of three to five project partners, and lengthy approval procedures. Preparing a project draft could take a part-time employee several months. The subsidy practice in the EU therefore seriously disadvantaged smaller and medium-sized businesses (Kreutzmann 1997, 26–27).

3.3.2.2 Green Paper and White Paper of the European Commission[51]

The idea of subsidizing renewable energy was addressed at EU level in the mid-1990s, when Germany already had the Electricity Feed-in Act (StrEG), and the expansion especially of wind power was beginning to prove successful. As a precursor in the political process for expanding renewable energy, the EU presented the Green Paper "Energy for the Future: Renewable Energy Sources" (COM 1996).

In November 1997 the European Commission adopted the White Paper "Energy for the Future" (COM 1997) which sparked a lively political discussion. This White Paper had stated the necessity of decreasing the dependency on energy imports, complying with environmental and climate protection requirements, and creating

[51] The European Commission frequently introduces a legislative process (e.g. adoption of directives) with the so-called Green or White Papers. Green Papers are published with the purpose of initiating a consulting process at the European level. White Papers contain proposals for relevant measures and activities of the European Community.

jobs as the reasons for using, expanding and technically advancing renewable energy. A key but non-binding target at EU level was to double the share of renewable energy in the gross energy consumption of 6% in 1995 to 12% by 2010. According to the estimation in the White Paper, this target could be reached mainly by expanding biomass and secondly by expanding the use of wind power (Schmela 1998, 24–25)

A first step toward this target was made with the "Campaign for Take-off", which is described in the White Paper and was launched in 1999. The Community provided EUR 1 billion in subsidies for the implementation of the campaign. The Green Paper on a European strategy for energy supply security pointed to the important role of renewable energy as well (COM 2000).

3.3.2.3 European Strategy for Sustainable Development

The issue of sustainability had been added to the Treaty of the European Community as early as 1998, where it was defined as a fundamental goal of European politics. Three years later, in 2001, the EU Council adopted the European Strategy for Sustainable Development. It focuses on climate change, traffic, health, natural resources and global environmental protection.

New EU Sustainability Strategy and Lisbon Strategy

On 15 and 16 June 2006 the Brussels EU Council Summit updated the European Sustainability Strategy.[52] It was hoped that the modified "renewed strategy" would be more effective in tackling the challenges of sustainable development. It had also been necessary to modify the strategy because of additional accessions to the EU. Climate protection and the responsible management of resources remained key fields of activity within the strategy. The Commission has been submitting progress reports on the Sustainable Development Strategy since 2007.

The European sustainability strategy is complementarily correlated with the "Lisbon Strategy",[53] which was devised to make a significant contribution to the overall objective of sustainable development.

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[52] http://www.bundesregierung.de/... (accessed September 1, 2009).

[53] The Lisbon Strategy was adopted at a special summit of the European heads of state in Lisbon in March 2000. It aims to assist political alignment in EU countries, which is intended to make the EU the most competitive and most dynamic knowledge-based economic area of the world by 2010. This strategy, which was simplified in 2005 after an evaluation of the half-time results, is supposed to make a significant contribution to the economic upswing in Europe. Cf. http://ec.europa.eu/growthandjobs/ index_de.htm (accessed September 1, 2009).

3.3.2.4 EU Directive 2001/77/EC on the Promotion of Renewable Energy

The EU aimed to double the share of renewable energy in overall national energy consumption. The Commission's drafts for the relevant EU directive initially envisaged rules concerning the promotion of market access for renewables that would be the same for all of the EU's members.[54] However, this concept was incompatible with regulations in various EU member states, and it was met with opposition from associations and the European Parliament. While the Commission exerted a great deal of pressure on the German government to change the Electricity Feed-in Act (StrEG) and to abolish the remuneration system, the majority of the members of the European Parliament favored the compensation system. In other words, the Parliament supported the German government, which in turn opposed a directive that would be incompatible with specific national subsidy schemes such as the StrEG or the Renewable Energy Sources Act (EEG) (see Section 3.7.2). In 2002 the proclamation of the advocate general of the European Court of Justice, stating that the StrEG did not represent impermissible aid, forced the Commission and the representatives of the energy utilities to give up their position. Finally the EU Commission presented a draft directive that did not prescribe a harmonized support scheme.[55]

On 27 September 2001 the European Parliament and the Council adopted the "directive on the promotion of electricity produced from renewable energy sources in the internal electricity market" (2001/77/EC). It provided the legal backing for the EEG 2000 and its remuneration system in terms of European law (Oschmann & Sösemann 2007, 2).

The main objective was to raise the share of electricity produced from renewables in the gross power consumption of the EU from an average 13.9% in 1997 to ca. 21% in 2010. The directive obliged the member states to create suitable instruments that would help attain concerted, yet non-binding national targets. For Germany this target was to generate 12.5% electricity from renewable energy sources by 2010.[56] The EU's original objective had been to define binding targets for the member states, but this had not been accepted.

3.3.2.5 EU Biofuels Directive 2003/30/EC

Directive 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport, adopted in May 2003, defined a certain minimum share of these renewable fuels. For this purpose, various biofuels were first distinguished from other renewable energy sources (Art. 2). The EU-wide indicative target was to

[54] The Commission, or to be more precise, the competition commissioner and his directorate-general, preferred quota-based certificate schemes, and rejected feed-in models as being inefficient.

[55] This was favored by the advocates of the principle of subsidiarity, who had objected simplification as well and wanted to maintain the member states' scope for action (Hirschl 2008, 434).

[56] In 2001 Germany generated ca. 7% of its electricity from renewable energy sources.

attain a minimum share of 2% in the overall amount of gasoline and diesel fuels by the end of 2005, and to raise this share to at least 5.75% (Art. 3) by the end of 2010.[57] The directive stipulated that the member states submit mid-year reports on national measures taken and on their experience gathered in this context (Art. 4 (1)). The Commission's progress report of January 2007 found a biofuel market share of merely 1% in the overall fuel consumption for the first period until 2005 (COM 2006). Even this report conceded that the 2010 target would probably not be met, at the same time it viewed the use of biofuels as the "currently only viable way out of the traffic sector's almost complete dependence on mineral oil" (ibid.). It was recommended to revise the directive and to stipulate a minimum share of 10% for 2020.

As was the case with the 2001/77/EC electricity directive (see Section 3.3.2.4), the biofuel directive was not amended, but will be replaced on 1 January 2012 with the integrated directive 2009/28/EC (see Section 3.3.2.7) within the context of the climate and energy package (Art. 26 (3)). Furthermore, the target of 10% biofuels in the traffic sector's total final energy consumption by 2020 has become legally binding so as to benefit long-term security for investment. It applies equally to all of the member states, excluding partial national targets (Art. 3 (4)). An important integral part of the directive on the use of biofuels is the respective sustainability criteria specified in Articles 17–19 (Futterlieb & Mohns 2009, 23).

3.3.2.6 2007 Meeting of the EU Council – Reduction Targets for Greenhouse Gases

Climate protection targets were at the center of the debate at the EU Council meeting (on Environment) held in Brussels on 20 February 2007 (under German presidency). The participants reaffirmed the "ambitious" objective of preventing global warming by more than 2°C.

On 9 March 2007, and under German presidency, the EU's heads of state and government adopted a "historic resolution" on Europe's future climate policy. German Chancellor Angela Merkel was able to push through binding, raised CO_2 reduction targets at the EU summit. Although the climate protection regime was controversial among EU member states, the EU's heads of state and government resolved an "EU action plan for CO_2 reduction": the EU would commit to a 30% reduction of greenhouse gas emissions by 2020 compared to 1990, provided that other developed countries commit themselves to comparable emission reductions, and economically more advanced developing countries adequately contribute according to their responsibilities and respective capabilities. In a second step the industrialized countries would commit to reducing their emissions by 60–80% by

[57] The reference values for Germany were also 2% (2005) and 5.75% (2010). These targets do not necessarily require an admixture, but the respective percent share in the overall fuel demand to be covered by biofuels (cf. Art. 3 (2)).

2050 compared to 1990. In anticipation of international negotiations, the European Union agrees even at this point in time to lower its emissions by at least 20% by 2020. As one of the most important measures for implementing the targets, the Council stipulates that the share of renewable energies in the EU's overall primary energy consumption should be tripled to 20% by 2020 (so-called 20/20/20 target). These resolutions of the European Council point beyond the 2008–2012 commitment period of the Kyoto Climate Protection Protocol. It is agreed that implementation of these targets is to be based on EU internal-burden-sharing (BMU 2007a, b). The member states are asked to draw up national action plans setting out targets for the individual sectors. This provided renewable energy in Europe with a crucial stimulus.

3.3.2.7 EU Directive 2009/28/EC on the Promotion of Renewable Energy

About 5 years after the directive on the promotion of renewable energy had entered into force in 2001, it became apparent that the non-binding targets aimed at increasing the share of RE are not met by most of the EU member states within the defined period. In 2006, 21 member states had not even met half their targets. Due to this implementation deficit and worries about not being able to reach the climate protection goals, a target agreement for 2020 was adopted in 2007, according to which 20% of Europe's total final energy consumption was supposed to be covered by renewables. Unlike its 2001 predecessor, the draft directive presented in January 2008 suggested a legally binding stipulation of the target in EU law. Directive 2009/28/EC on the promotion of the use of energy from renewable sources came into force in June 2009.

In contrast to the old EU directives on power from renewable energy (2001/77/EC) and on biofuels (2003/30/EC, see Section 3.3.2.5), the new directive covered renewable energy in a comprehensive way: it included all of the renewable energy sources as well as the application areas of electricity, heating/cooling and transport.[58] The EU target of 20% is translated into national targets for the EU member states.[59] The national targets are binding, implying that infringement proceedings may be instituted in the event of non-compliance (Futterlieb & Mohns 2009, 90). Furthermore, the 20% target refers to the total final energy consumption and no longer to the electricity market only. This makes the target clearly more ambitious compared to the previously valid directive. Nitsch (2008, 13–14) worked out that the German national target of 18% in the total final energy consumption would necessitate a share of ca. 35% renewable energy in power consumption, provided

[58] http://www.euractiv.com/de/energie/... (accessed September 1, 2009).

[59] In addition, the directive specifies a non-binding indicative trajectory for each member state (interim targets). It also stipulates that 20% of the respective national targets shall be met in 2012, 30% in 2014, 45% in 2016, and 65% in 2018.

the target was mainly reached via the electricity market. But increasing support for renewable energy in the heating and cooling sector could reduce the share of renewables in the electricity sector accordingly. The directive requires the member states to submit national action plans to the Commission by 30 June 2010, and to present reports regularly thereafter.

A further key point of Directive 2009/28/EC is the extension of conditions concerning access to the electricity grid (see Section 3.9.3.3). Plants generating electricity from renewable energy sources shall be granted priority access to the grid. In Directive 2001/77/EC this type of access had still been optional. In addition, the directive stipulates accelerated and facilitated administrative procedures, certifications and permission to construct RE plants. Instead of a de facto harmonized system of subsidies, three flexible instruments were included in the directive, which are intended to allow for cost-efficient expansion of renewable energy based on the respective available potential. Member states that have already reached their respective national target may carry out "statistical transfers". Moreover, member states may run "joint projects" or projects with third-party countries. The new directive is the first to define sustainability requirements for the production of liquid biomass for energetic use (see Chapter 4). It was welcomed by the RE associations, especially the solar industry. After a draft directive, which had clearly accommodated the interests of the conventional energy industry, the final version largely assisted the interests of the RE sector (Futterlieb & Mohns 2009, 77–78).

3.3.3 European Emissions Trading (Cap and Trade)

In order to meet the climate protection targets set out in the Kyoto Protocol, the European Union introduced an emissions trading scheme. The Emissions Trading Directive 2003/87/EC entered into force in 2003. It created the legal basis for trading greenhouse gas emission certificates in Europe and required each member state to publish a national allocation plan at the beginning of each trading period (every 3 and then every 5 years) – i.e. an overview of the allocation of emission certificates.

Six years later the European emissions trading scheme was amended by the climate and energy package. In June 2009 the latter was adopted in the form of Directive 2009/29/EC. The lead principle of this resolution was the 20/20/20 target, which has formed a distinctive module within the European climate strategy since spring 2007 (see Section 3.3.2.6). From 2013 onward, the national action plans will be replaced by a European emissions trading budget – the European "cap" – which will be reduced each year by 1.74%, until in 2020 CO_2 emissions will have dropped by 21% compared to 2005 (Löschel & Moslener 2008, 249). The share of certificates to be auctioned off in the context of European emissions trading will rise from 20% to 70% between 2013 and 2020. The remaining certificates will be allocated free of charge, but in 2027 full auctioning will be implemented (Schafhausen 2009, 37).

Advocates of emissions trading consider this instrument as a key element in a long-term climate protection strategy. They see the advantages predominately in the scheme's simplicity of defining an international emissions mitigation target and leaving implementation up to the actors of the market. This they regard as a way of reaching the politically prescribed environmental target at minimal macroeconomic costs. Moreover, advocates argue that emissions trading provides an incentive to reduce emissions by adjusting the quantities and advancing the respective technology deployed, and to develop long-term strategies to reach these goals (SRU 2006).

Opponents mainly criticize the concrete legal specifications of emission allowance allocation in National Allocation Plans, claiming that insufficient CO_2 reduction targets are a political reality. It is assumed that the powerful German electricity industry cartel has been undertaking selective lobbying activities to systematically erode this instrument and to significantly weaken its effectiveness (Corbach 2007). The new emissions trading directive 2009/29/EC is being met with criticism as well, because of the large number of derogations which are regarded as watering down a generally positive approach (Futterlieb & Mohns 2009, 90; BWE 2008).

In the medium term, a conflict will also arise between emissions trading and the promotion of renewable energies. This so far largely hypothetical conflict is based on the fact that additional renewable energy sources could contribute to reducing the pricing pressure on fossil-based energies, implying that a rise in CO_2 certificate prices would matter less (Bode 2008, 244). From 2013 onward, operators of power plants will be committed to purchase all of their emission certificates by auction. Since Directive 2009/28/EC (see Section 3.3.2.7) also requires the expansion of renewables, the demand for emission certificates from the power industry will drop, which in turn will lead to a drop in certificate prices. As a result, other sectors will be able to buy emission certificates at more favorable prices, and the promotion of renewable energy will not effect greater climate protection (Bode 2009, 48).

Long-term synergies based on the coexistence of both systems as well as an additional climate protection effect would become possible, for instance, if the emissions saved as a result of renewable electricity use were directly deducted from the total budget of available emissions trading certificates. However, the critical point in this context is that emissions trading activities are decided at EU level, while decisions on the promotion of renewable energy are taken by the member states (Löschel & Moslener 2008, 251).

3.4 Emergence of National Problem Awareness and Process of Institutionalization

The institutionalization of renewable energy in national politics, administration and also in associations and interest groups forms a basic prerequisite for the innovation process of renewable energy in Germany. At the same time, the public perception of climate change, the need for climate protection and pollution control and the benefits of using renewable energy sources are important aspects of the process. Key turning points in politics and public awareness originated in the 1980s.

3.4.1 Institutionalization of Environmental Protection

The institutionalization of climate protection and supporting renewable energy was preceded by the institutionalization of environmental protection.

3.4.1.1 The Greens in the German Bundestag

The German party Die Grünen (The Greens) was founded in 1980. The Greens were voted into the Bundestag as early as 1983, and soon after, in 1985, a member of The Greens (Joschka Fischer) was appointed minister for the environment. At the time The Greens were made up of left-wing students, members of environmental protection action groups and members of the anti-nuclear movement. Their strong concern with environmental issues forced the other parties in the Bundestag to deal with these issues. The Greens were instrumental in establishing environmental politics in the Bundestag during this phase.

3.4.1.2 Administrative Institutionalization of Environmental Protection

In the 1970s and 1980s energy policy and environmental policy were separate areas. It is true that in the course of the 1980s the energy debate was becoming increasingly entwined with environmental policy (SRU 1981), but it was only the Chernobyl accident in 1986 that ultimately provided the stimulus for establishing the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. Up until then the Federal Ministry of the Interior, the Ministry of Agriculture and the Health Ministry had been responsible for matters of environmental protection. The establishment of this Ministry under the Kohl government with Walter Wallmann as environment minister, followed in 1987 by Klaus Töpfer, was mainly a reaction to what was perceived as an insufficiently coordinated way of dealing with the environmental consequences of Chernobyl (e.g., radiation level in food).

Once the Ministry of the Environment had become a stand-alone department, environmental policy was visible and addressable within the German federal government (Gabriel 2006). In the 1980s climate protection and CO_2 reduction had mainly been part of the emissions mitigation policy to reduce smog and forest dieback.

3.4.2 Climate Protection in Politics and Administration

The following events and influencing factors were key to the national institutionalization of renewable energies.

3.4.2.1 Renewable Energy in the Former German Democratic Republic (GDR)

The territory of the former GDR has Germany's largest lignite resources. Consequently, large-scale lignite-fired power plants formed the backbone of east and central Germany's energy industry (Matthes 2000, 45–46). Moreover, the potential of renewable energy in the GDR was estimated to be extremely low due to the area's geological and climatic conditions. In 1988 the predicted combined share of all renewable energy sources in the primary energy demand was still at a mere 0.4% for the year 2000 (Friedrich-Ebert-Stiftung 1988, 51–52). Other forecasts assumed a maximum share of 1% in the primary energy balance by 2000 (Gruhn 1982, 105). Increasing this share would have been possible by promoting research and development, but this would have required higher investments.

In the GDR, environmental protection clearly ranked much lower than reliable energy supply, all the more so since less importance was attached to social acceptance than in the FRG (Weidenfeld & Korte 1992, 285–286). Avoiding the adverse environmental effects of processing lignite was no primary motive, even if environmental considerations did play a role in the promotion of using geothermal energy (Broßmann 2008, pers. comm.). While the GDR had launched a policy geared toward industrial energy efficiency in the 1970s, it had hardly created any incentives to save energy in private homes. This also reflected in the fact that the electricity price of 8 Pfennig/kWh in 1988 had not changed since 1948 (Friedrich-Ebert-Stiftung 1988, 55, 57).

The regenerative technologies that were used after 1980 were not primarily deployed to generate electricity. Biogas production was used mainly in fertilizer processing and to substitute mineral fertilizer, and heat was used as a waste product. Equally, geothermal energy was predominately, albeit only selectively, used as a means of heat supply. Wind energy was sometimes used to operate irrigation systems, but not for electricity generation (Friedrich-Ebert-Stiftung 1988, 51; Gruhn 1982, 105). A wind energy potential of 200–400 MW was forecast for the Baltic Sea coastal area, yet its economic utilization was viewed with skepticism (Gruhn 1982, 106). Hydropower, which according to Matthes (2000, 46) was scarce due to the topographical conditions, contributed to the overall power supply only to a small extent (1.8% in 1980). Similarly, solar energy was used in few, selected circumstances only (Friedrich-Ebert-Stiftung 1988, 52).

3.4.2.2 Committee of Inquiry "Protection of the Earth's Atmosphere"

Newly formed interfaces between science and politics played an important part in climate protection matters. The convening of the German Federal Parliament's Committee of Inquiry "Provisions for the Protection of the Earth's Atmosphere" in 1987 marked the emergence of anthropogenic climate change as an important political field of action. By this time parliamentary groups in the Bundestag were convinced that climate protection was an important issue that required attention.

The Bundestag appointed Bernd Schmidbauer, environmental spokesman for the CDU, head of the Committee of Inquiry. Together with Michael Müller (SPD), who partially acted as an adversary, and partially as an advocate within the Committee, he shaped the Committee's work. Wolfhart Dürrschmidt, today head of division in the Federal Ministry for the Environment, was in charge of climate and energy matters in the Committee's secretariat. During the 3 years of its existence, the Committee established close ties with the IPCC following extensive personnel and scientific exchanges.[60]

The convening of the Committee had been the result of applications of the CDU and The Greens. The CDU had once more wanted to advance nuclear power within the context of climate protection. The Greens, by contrast, were of the opinion that climate protection needed to be accomplished without nuclear power. The SPD ultimately agreed to the application for a Committee of Inquiry as well, and in the end it was supported by all of the parliamentary groups (Dürrschmidt 2007, pers. comm.). This constellation had a positive effect on the reception of the Committee's results in the Bundestag: despite the large number of differing opinions and interests[61] the reports of the Committee of Inquiry were unanimously adopted (Dürrschmidt 2007, pers. comm.).

World Congress on "Climate and Development" in Hamburg

In autumn of 1988 one of the first international congresses on "Climate and development"[62] took place in Hamburg. This Congress had been prepared and held by the German Ministry of Research in cooperation with the United Nations and the German Ministry for the Environment. The Committee of Inquiry (see above) presented its first interim report to the Congress. The Hamburg Congress provided a crucial impetus for advancing climate protection on the national level. It transported the issue of threatening climate change from the field of science to the field of politics (Dürrschmidt 2007, pers. comm.).

Final Report of the Committee of Inquiry

As a result of the Committee of Inquiry's work and its final report in 1990 (see Enquête-Kommission 1990), current scientific findings and the urgency of climate protection measures were directly transported into politics. Without the Committee of

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[60] IPCC (Intergovernmental Panel on Climate Change) scientists were invited to attend the Committee of Inquiry. Not only the Committee of Inquiry benefited from this. The members of the IPCC, too, realized that there was great potential for scientific and political cooperation at the national level (Dürrschmidt 2007, pers. comm.).

[61] There were, for instance, considerable differences concerning the margin nuclear energy should have in view of climate protection.

[62] Cf. http://www.germanwatch.org/... (accessed August 25, 2009); cf. also Beisheim (2003, 225).

Inquiry, the climate protection process in Germany would certainly have been more sluggish. The Bundestag emerged as a driving force in this process. It set the German course for climate protection and development of renewable energy primarily by preparing draft bills and resolutions on restructuring departments.

The Federal Government's Climate Protection Program

A short version of the Committee of Inquiry's final report was issued in the form of the Federal Government's climate protection program in 1990. This task was assigned to the Environment Ministry (under Environment Minister Klaus Töpfer), because the Chancellery deemed this ministry better suited to promote climate protection than the Federal Ministry of Economics. Henceforth, the latter systematically opposed the Environment Ministry's climate protection activities, arguing that three quarters of the climate protection tasks concerned energy policy and that it was the Federal Ministry of Economics that was competent in that case (Dürrschmidt 2007, pers. comm.).

3.4.2.3 Establishment of Climate Protection in the Federal Ministry for the Environment

In 1990 climate protection was placed under the control of the Federal Ministry for the Environment. Until 1990, climate protection matters had been the responsibility of the Federal Ministry of Transport, which had not attached a great deal of importance to these issues. On 15 January 1990 the Federal Chancellery under Chancellor Helmut Kohl addressed a short letter to the Federal Environment Ministry, requesting it to submit a list of climate protection goals and suggestions for measures to be taken. The Environment Ministry made extensive use of this request. Neither the Ministry of Transport nor the Economics Ministry were overly interested in the topic at the time, and they obviously did not realize what implications the letter may have. At this time Bernd Schmidbauer, chairman of the Committee of Inquiry, found Environment Minister Klaus Töpfer to be a dedicated contact, which significantly contributed to the acceptance of the Environment Ministry's commitment.[63]

Initially there were two departments in the Federal Environment Ministry that dealt with climate protection: the Energy and Environment Department and the Department for Climate Protection and International Cooperation, established only in 1991. The latter was assigned the task of preparing the 1992 Earth Summit on sustainable development to be held in Rio de Janeiro and to coordinate international negotiations on the preparation of a climate convention.

Under the red-green government and Jürgen Trittin as environment minister, the Environment Ministry aimed to initiate an energy transition process[64] based on the

[63] The source for this section are personal reports from the Federal Ministry for the Environment.

[64] The term originates from the title of a study conducted by the Öko-Institut in 1980, which prepared a forecast about nuclear phaseout and energy generation from mineral oil.

success of the EEG. The conference "Energiewende – Atomausstieg und Klimaschutz" (energy transition – nuclear phaseout and climate protection) that took place in Berlin in February 2002 is regarded as the starting point for this energy transition policy.

With the environment minister Sigmar Gabriel assuming office in 2005, the process of energy transition was explicitly placed in the context of innovation policy. This clearly labeled the change in energy supply as an innovative technical accomplishment of great importance for the German economy. The promotion of renewable energy was now categorized as "innovation promotion". Minister Gabriel emphasized that development of renewable energies was a progressive and innovative move. He also highlighted the economic potential of renewable technologies. Linking renewable energy technologies to "innovation" enhanced the renewable energy sector's public image and made it an attractive field.

3.4.3 Institutionalization of Renewable Energy Policy

3.4.3.1 Administrative Establishment of Renewable Energy Policy

Establishment of this political field in the administrations of the federal and state governments is considered a key prerequisite for (political) allocation and (administrative) adoption of the corresponding portfolio responsibilities and for administrative governance. No appreciable administrative steps can be expected before portfolio responsibility has been defined and the portfolio's tasks have been outlined.

The 1998 change to a red-green government brought about a process of restructuring and reorganizing the ministerial administration. It broke up old routines and created the opportunity for the establishment of renewable energy competences within the federal administration (see Section 3.4.2.3).

From 2001 the Federal Environment Ministry, headed by environment minister Jürgen Trittin, had at its disposal research funds allocated by the Zukunftsinvestitionsprogramm (ZIP – Future Investment Program).[65] These funds were used among other things for the promotion and accompanying ecological research on renewable energy (Kaiser 2007, pers. comm.).

Along with the EEG (see Section 3.7.2), the German Government took additional measures to expedite implementation of its energy policy goals. On 18 October 2000, for instance, it adopted the climate protection program (see Section 3.5.3), and in that same year it co-founded the German Energy Agency[66] (dena).

[65] The future investment program was financed by interest savings that the federal government obtained from additional redemption payments on debts from UMTS allocation funds. Between 2001 and 2003 an annual 50 million euros from these savings were used mainly for research and development of projects in the field of renewable energy and fuel cells (BMU 2002, 19).

[66] The German Energy Agency (dena) was founded by the Federal Ministry of Economics and the Kreditanstalt für Wiederaufbau (KfW) on 29 September 2000. The federal ministry and the KfW each have a 50% share in dena. The objective was to establish a center of expertise for energy efficiency and renewable energy.

3.4.3.2 Transfer of Responsibilities/Continued Institutionalization

The responsibility for renewable energy research and development originally laid with the Federal Ministry of Research, which attended to the promotion of basic research and development, but not to the technologies' introduction on the market (Dürrschmidt 2007, pers. comm.). While the responsibility for basic research remained with the Ministry of Research, application-oriented research and development was initially transferred to the Federal Ministry of Economics in 1998. Commercial launch also fell within this ministry's sphere of competence. So between 1998 and 2002 the Ministry of Economics was temporarily responsible for all aspects of renewable energy, spanning research and development, market launch and energy efficiency. However, the Federal Ministry of Economics had not been able or not wanted to close the gap to market launch, since major assistance for the introduction of renewable energy on the market was viewed as subsidization.

Yet, under the red-green Federal Government, energy transition had advanced to one of the core environmental objectives since 1998 (Mautz & Byzio 2005, 113). After the federal elections in the fall of 2002, the responsibility for research and development in the field of renewable energy, as well as that for market launch and the EEG shifted from the Federal Economics Ministry to the Federal Environment Ministry. This had been the result of an organizational order of the Federal Chancellery agreed upon in the coalition agreement. The members of the Bundestag knew that the concern to expedite the development of the respective technologies was not only going to be competently and proactively dealt with at the Environment Ministry's executive level but also by its staff (Dürrschmidt 2007, pers. comm.). According to Mautz & Byzio (2005, 113) the shift in administrative responsibility indicates that the relevant protagonists viewed energy transition primarily as a project of environmental policy and less as one of economic policy. The economic relevance of renewable energy had not fully been recognized at that point in time, neither by economic stakeholders nor economic policy-makers.

In 2002, even before it was officially commissioned, the Federal Environment Ministry had already drawn up an offshore wind power strategy. With the Chancellery then also transferring offshore issues to the Environment Ministry it was able to further extend its authority in the field of renewables.

3.4.4 Establishment of Associations

The institutionalization of interest groups is regarded as an indication of the renewables sector becoming increasingly established in the economy and in society, and of interest groups becoming professionalized.

The 1980s saw the formation of first RE associations, some of them at state level. The umbrella organization "German Renewable Energy Federation"

(Bundesverband Erneuerbare Energie e.V. – BEE), founded in December 1991, i.e., not even a year after the Act on feeding electricity generated from renewable energy into the grid (Stromeinspeisungsgesetz – StrEG) had entered into force, now pooled these interests at federal level. The objective had been to improve the coordination of the individual associations' activities with regard to policies and the public, to lend more weight to these associations, and to enhance the equality of opportunities concerning renewable energy as compared to conventional energy generation. The long-term goal is to switch energy consumption entirely to renewable energy.

The unanimous adoption of the StrEG indicated the establishment of the political field of renewable energy. In turn this was viewed as an occasion to establish means for a more effective protection of interests. Potential rivalry between the individual energy sectors was likely, as the wording of the StrEG did not provide for a quantitative allocation scheme, i.e. a quota system or competition between the technologies. This situation allowed for the establishment of a common organization for all of the renewable energy sectors (Suck 2008, 194).

The BEE describes its parliamentary advisory council as a particularly important connecting link between the BEE and politics. This advisory council is made up of members of parliament of all parties who regularly convene with members of the BEE. The BEE's representation of the sector's interests is also becoming increasingly important in Brussels (Lackmann 2006, 37), reflecting not least in the fact that the BEE is a member of the European Renewable Energies Federation (EREF), the European umbrella organization for renewable energy.

The EREF currently comprises 26 associations with more than 30,000 members, including over 5,000 businesses. The association representatives of all the sectors dealt with in this analysis are members of the BEE. Their role in the innovation process and their activities are investigated in more detail in the chapters on the respective energy sector.

Activities within the BEE are described as consensus-oriented. However, internal disputes about who should have how much influence on the BEE's policy have repeatedly become known.[67] These rivalries within the umbrella organization may be explained with a shift in power: while the initiative to establish the BEE originated from what was then the main RE interest group, namely the German Federal Association of Water Power Companies (BDW), the political weight increasingly shifted to the wind power associations (Suck 2008, 195)[68] in the course of wind power's expansion during the 1990s. Similarly, the bioenergy and solar energy associations gained in importance as well.

[67] In its issue of February 2007, for instance, the journal Erneuerbare Energien, reported on conflicts between wind power interest groups and hydropower interest groups (Baars 2007, 6).

[68] The most important ones were the interest group "Windkraft Binnenland (IWB)" and the "Deutsche Gesellschaft für Windenergie (DGW)" which merged with the German WindEnergy Association (BWE) in 1996.

3.5 Energy and Climate Policy Strategies and Objectives at National Level

3.5.1 Guidelines on Energy Policy Issued by the Federal Government in 1991

On 11 December 1991 the Federal Government presented a set of guidelines for the "Energy Policy for the United Germany". According to these guidelines the priorities of energy policy – supply safety, economic efficiency, environmental soundness, and sustainable resource management – needed to be rearranged. Environmental aspects and the integration of the national energy policy in the European common market became increasingly important.

3.5.2 Change of Government to Red-Green in 1998

The Federal Government's priorities in energy policy clearly shifted toward environmental policies in the fall of 1998. The red-green government's coalition agreement of 20 October 1998 stipulated a forced turnaround in energy sources and announced changes in energy legislation. "The Federal Government will eliminate the obstacles that are still impeding an increased use of regenerative energies […]" (SPD, Bündnis90/Die Grünen 1998, 20–21).

On the occasion of the 5th COP to the Framework Convention on Climate Change[69] held between 25 October and 5 November 1999, a year after the change of government to red-green, Federal Chancellor Gerhard Schröder expressed his intention to "double the German share of renewable energies by 2010". In doing so, Germany had adopted the European doubling target specified in the EU White Paper (see Section 3.3.2.1) of 1997 as early as 1999.

3.5.3 National Climate Protection Programs

3.5.3.1 National Climate Protection Program 2000

Following the suggestion of Federal Environment Minister Jürgen Trittin, the federal cabinet adopted a national climate protection program on 18 October 2000, which was intended to reduce Germany's carbon dioxide emissions (CO_2) by up to 70 million tons by 2005.[70] This extent of CO_2 emission reduction was necessary for

[69] United Nations Framework Convention on Climate Change (UNFCCC).

[70] http://www.bmu.de/klimaschutz/nationale_klimapolitik/... (accessed September 1, 2009).

Germany to fulfill its international climate protection commitments. At the Berlin Climate Summit in 1995 Germany had agreed to reduce its CO_2 emissions by 25% by 2005, compared to the 1990 level. In 1998 the new Federal Government reaffirmed this target. The internationally binding climate protection target at EU level, i.e. within the context of the Kyoto Protocol, specified reductions of only 21% between 1990 and the period between 2008 and 2012. The German government did not manage to meet its 25% target, but it got very close. In 2004 greenhouse gas emissions had dropped 19% below the balance of 1990. In part this reduction in emissions had been the result of industrial plants in former East Germany being closed down. Still, this achievement made Germany an internationally recognized pacesetter in climate protection.

3.5.3.2 National Climate Protection Program 2005

The national climate protection program was revised and updated by the Federal Government's resolution of 13 July 2005 (BMU 2005). At the same time this revision and update served to take stock of the Federal Government's climate protection policy pursued so far. This showed that the success of Germany's climate protection efforts varied in the different sectors. Despite negotiated agreements, emissions in the industrial sector and in the energy industry had increased instead of decreasing over the past years. Also, environmental groups criticized the 2005 climate protection program for not being ambitious enough. It had mandated that greenhouse gas emissions in Germany be reduced by 21% between 2008 and 2012 (compared to 1990). This, it was argued, meant it referred only to the fulfillment of the Kyoto commitment up to 2012, but lacked a strategy to reduce carbon dioxide emissions by 40% by 2020 (compared to 1990).

3.5.4 Nuclear Phaseout Resolution of 2001

After lengthy "consensus talks" the German Bundestag adopted the amendment to the Atomic Energy Act, which entered into force on 27 April 2002. It implements the agreement (called "Nuclear Consensus")[71] of June 2000 between the Federal Government and the power utilities, about the continued operation of German nuclear power stations.[72]

A major issue of this agreement is to define the nuclear power stations' remaining operating time. It is calculated on the amount of residual electricity. The volume of residual electricity is the amount of electricity a plant is permitted to produce before

[71] "Vereinbarung zwischen der Bundesregierung und den Energieversorgungsunternehmen über die künftige Nutzung der Kernenergie" (Agreement between the German federal government and the power utilities about the future use of nuclar power) of 14 June 2000.

[72] In 2007, 17 nuclear power stations were still being operated.

its operating entitlement lapses. According to these calculations, the last nuclear power would be switched off around 2021. In addition, regulations were defined concerning the storage and nuclear power processing of fuel elements in German interim storage facilities. The construction of new nuclear power stations was prohibited, while research, especially into safety issues, was agreed to be continued.

3.5.5 Sustainability Strategy 2002

Around the time of the World Summit on Sustainable Development in Johannesburg, and after widespread public debate in Germany, the German government presented a strategy for sustainable development titled “Perspektiven für Deutschland” (Perspectives for Germany) in April 2002, which formulates concrete sustainability targets for all of the political fields.[73] The strategy has since been the benchmark of government action in Germany, its implementation and revisions being documented in progress reports.[74]

The “Strategy for the expansion of wind energy at sea” (“Offshore Strategy”, see Chapter 7) of January 2002 is part of the national sustainability strategy adopted in April 2002 (Bundesregierung 2002b).[75] The strategy, for which the Federal Ministry for the Environment took over leadership, shows that the German government sees the main share of future wind energy use at sea. The goal of the expansion phase scheduled to take place between 2007 and 2010 was to install a wind power capacity of 2,000–3,000 MW, and up to 25,000 MW in further expansion phases (Bundesregierung 2002a). However, the expansion goals specified in the strategy have so far not been met. Obviously the challenges and risks of implementing offshore wind parks and connecting them to the grid were underestimated.

3.6 Government Aid for Renewable Energy

The Electricity Feed-in Act and later the Renewable Energy Sources Act were accompanied by a number of supplementary funding instruments. Apart from research promotion at the federal level (see Section 3.6.2) the states participated in funding schemes as well (see Section 3.6.3).

[73] Cf. Bundesregierung (2002a): The German national sustainability strategy “Perspectives for Germany” is very similar to the EU strategy of 2001.

[74] Bundesregierung (2004): “Fortschrittsbericht. Perspektiven für Deutschland”; Bundesregierung (2005): “Bilanz und Perspektiven”.

[75] The utilization of offshore wind energy was viewed as necessary by the German government in order to meet the statutory climate protection commitments and substitution targets.

3.6.1 Market Incentive Program

The Federal Government's market incentive program (Marktanreizprogramm – MAP) of 1994 initially promoted only a restricted spectrum of renewables. In the domain of heat it supported the construction of solar heat plants and the reconstruction of geothermal heat facilities. In the field of electricity, the program subsidized the construction of small hydropower plants (up to 500 KW) and wind power plants (450–1,000 kW). The electricity generating technologies benefited from this in particular because these investment subsidies supplemented the compensation as per the StrEG (see Section 3.7).

Although renewables technologies for the heat sector were largely known already, comparably high investment costs hampered a pronounced market penetration. From September 1999, the Federal Ministry of Economics massively extended the scope and budget of the MAP (Staiß 2007, 212).[76] The goal was to strengthen the market launch primarily of the heat-generating technologies and to contribute to the improvement of their profitability so that they would develop in a free market (see-Hoffmann 2002, 53). Along with solar collector plants, hydropower plants, the utilization of deep geothermal energy, and photovoltaic arrays for schools, biomass combustion plants and individual biogas facilities have been funded as well. The authority responsible for implementation is the Federal Office of Economics and Export Control (BAFA). The MAP is viewed today as the key instrument for the launch of renewable energy in the heat market.

According to IfnE (2010, 5) more than 95% of all renewable energy plants built in Germany were subsidized by the MAP in the last 2 years. Since 2000 the MAP provided significant impetuses for the increased use of biomass heating systems and solar heat, and contributed to the fact that the amount of heat available from renewable energy has more than doubled since 1999.

3.6.2 Federal Research Funding

During the 1970s, energy research and research funding were dealt with by several portfolios. Parts of support came under innovation funding, which was essentially granted by the Federal Ministry of Education and Research during the 1970s. In 1972 the ministerial tasks were restructured. The newly formed Federal Ministry of Research and Technology under minister Horst Ehmke was assigned a number of key tasks in various fields including technology, development and innovation, nuclear technology and nuclear research, and space and aviation research. This ministry promoted the research and development of renewable energy to a notable extent (Nitsch 2007, pers. comm.).

[76] The funding volume was increased tenfold due to the green electricity taxation.

3.6.2.1 Energy Research and Energy Technologies Program (1977–1980)

While there had been several nuclear research programs since 1956 that promoted nuclear energy research, "public research specifically into non-nuclear energy" was promoted for the first time by the Research Ministry[77] within the context of its "Energy research framework program" (1974–1977) (BMFT 1978, 26). This novelty had been triggered among other things by the effects of the oil price crisis and worries about a shortage of imported energy sources, such as oil and gas (Semke 1996, 919). Between 1977 and 1980 this framework program was further pursued as the "First energy research program" (BT-Drs. 8/2039, 28–29). The objective had been to speed up the process of substituting crude oil with other sources of energy (Neu 2000, 4). The four focus areas included the rational use of energy, coal and other fossil-based primary sources of energy, "new sources of energy" (nuclear fusion, but also renewable energies) and the expansion of nuclear energy (BMFT 1978, 12), with the major share of funding (4.53 billion German marks) going to the promotion of nuclear energy, though (Nitsch 2007, pers. comm.).[78]

Major research institutes were involved in the research program, e.g., the Jülich Nuclear Research Center (KFA Jülich), the Fraunhofer Institute for Systems and Innovation Research (ISI) in Karlsruhe, and the German Center for Aeronautics and Space (DLR).[79] The DLR prepared a comprehensive analysis of the entire range of possibilities in connection with renewables (Nitsch 2007, pers. comm.). The study on the potentials of renewable energy was characterized by a great deal of optimism on the one hand, but it was also biased toward the energy world of the time (Bohn & Oesterwind 1976). Early studies concentrated mainly on furnishing proof of the technical feasibility and on the structural terms of an energy industry that is based on renewable energies, with hydrogen being assigned an important role.[80] Large-scale technologies, such as solar heat power plants or major photovoltaic plants, were of interest here. One had become used to thinking in terms of megawatts and gigawatts (Nitsch 2007, pers. comm.) instead of thinking about small-scale solutions.

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[77] Under Hans Matthöfer, Federal Minister of Research and Technology from 1974 to 1978.

[78] The total budget had been 6.53 billion german marks. Nuclear energy was allotted 4.53 billion marks, coal (especially its conversion into liquid and gaseous energy sources) received a total of 940 million german marks, rational energy use 490 million marks, and new energy sources 570 million marks. When deducting nuclear fusion, the promotion of those energy sources that are defined today as "renewable" was merely 191 million marks (BMFT 1978, 160).

[79] At the time the DLR was going through a crisis during which aeronautics activities were curbed. Since the DLR had concerned itself with the conversion of energy with respect to aerospace technology, it now began to deal with questions of terrestrial energy supply as well.

[80] Cf. Program survey "Sekundärenergiesysteme. Strom, Kohleveredelungsprodukte, Wasserstoff, nukleare Fernenergie, Fernwärme. Kurzfassung." Report by the KFA Jülich No. 1148, Programmgruppe Systemforschung und technologische Entwicklung. Commissioned by the BMFT in 1974.

Now a vision of a "hydrogen world" evolved from a special group of people at the DLR with know-how concerning the exploitability of hydrogen, and the simultaneous initiatives of Ludwig Bölkow[81] in Munich. Several studies[82] mapped detailed energy systems of the future with hydrogen playing a more or less significant role in them. However, the role of hydrogen was overestimated at the time (Nitsch 2007, pers. comm.). The advantage, though, was that renewable energies attracted a great deal of attention from the public and particularly from the print media.[83] It had become possible to show that renewable energies do in fact have the potential to supply the world with energy. Hence, the first hurdle had been taken. Prior to the studies, there had been doubts about whether the physical potential of renewable energy sources would at all be sufficient (Nitsch 2007, pers. comm.).

3.6.2.2 Paradigm Shift in Research Policy

Until the late 1970s research had been based on the assumption that renewables, too, would need to meet constantly growing energy demands. Environmentally aware experts, however, advocated a paradigm shift: "Renewable energies and efficiency go together, they need to be conceived and planned as one" (Nitsch 2007, pers. comm.). The publication of the study on transition to renewables[84] triggered a change of perspective of the energy supply industry and associated scholars. The energy transition was expected to bring about increased energy efficiency, a reduction in the share of fossil fuels and an increase in the share of renewable energies in the overall energy supply.

But there were other developments going on as well: the trend toward "small is beautiful", for instance, i.e., the idea of a decentral system of energy supply consisting of numerous small plants. It was in this context that engineers began to realize that energy supply must go beyond the design of large-scale systems. In the mid-1980s experts had come to the conclusion that energy systems and the respective technologies

[81] Ludwig Bölkow founded the Ludwig Bölkow Foundation (Ludwig-Bölkow-Stiftung) in Ottobrunn in 1983. The objective of the Foundation was to make technology more ecological. Studies were performed on solar installations in the desert and on a more efficient storage of hydrogen as an energy source.

[82] Cf. Winter & Nitsch (1989); Nitsch & Luther (1990); DLR et al. (1990); Bradke et al. (1991); Traube (1991); Nitsch & Wendt (1992); Langniß (1994); Enquête-Komission (1995).

[83] Several titles of German news magazins like Der Spiegel show that energy from sun and water were of public interest: In 1976 it published an article titled "Energie aus Sonne und Wasser für die Welt" (Energy from sun and water for the world). It also published articles on the potentials of hydrogen in 1972, 1976 and 1977. In 1987 the magazine's cover story was: "Wasserstoff und Sonne. Energie für die Zukunft" (Hydrogen and sun: energy of the future) (Spiegel 1987, No 34, Issue 41, 17 August 1987).

[84] The idea of an energy transition was for the first time elaborated in a survey presented by the Öko-Institut Freiburg in 1980. It had the title "Energiewende" (energy transition) (Krause et al. 1980).

must be developed step-by-step and “from the bottom up” (Nitsch 2007, pers. comm.), not least because past experience had shown that energy systems could not simply be imposed on society.

3.6.2.3 Second Energy Research Program (1980–1990)

In addition to supply safety, which had been the main objective in the first energy research program, this new edition also included boosting the economy as well as protecting the environment (Semke 1996, 920). Depending on the individual sector’s stages of development, the government funded basic research, materials research, prototyping of plants and the analysis of environmental impacts. Unlike its subsequent program, which promoted some first pilot plants, this program was chiefly about “industrial laboratory facilities” (Sandtner et al. 1997, 258–259).

From the end of the 1980s, special programs launched by the Federal Research Ministry (“Technologies for the utilization of solar power”) and the Federal Ministry of Economics (“Biological-technical systems for the generation of energy and the production of raw materials”)[85] promoted research on renewable energy.

3.6.2.4 Third Energy Research and Energy Technologies Program (1990–1996)

The third program focused on the further development of existing energies into long-term solutions for the future, the development of CO_2-free energy sources (renewable energies and nuclear fusion), and the efficient use of energy and explicitly the steady reduction of CO_2 (BMFT 1993, 7). It also placed significantly more emphasis on the reduction of greenhouse gases (Semke 1996, 920). In the mid-term the program stipulated further cost reductions and increased capacities for the technologies already developed. To this end, funding was also granted to various large-scale demonstration projects (Sandtner et al. 1997, 259). The use of renewable energies for heat generation from solar energy was considered to some extent as well. A funding concept for alternative biomass use and energy crops was launched in order to examine alternative uses in view of the agricultural surplus. In 1993 the partial program “Nachwachsende Rohstoffe” (renewable biomaterials), which had been issued as early as 1990, became the responsibility of what was then the Federal Ministry of Agriculture (BML) (BMFT 1993, 18). The aim of this market launch program, which is still being pursued today, is the efficient use of renewable biomaterials as an industrial raw material or for energy generation.

German institutes and companies managed to work their way up to the top of the world thanks to the promotion of renewable energies research. Yet there remained a gap between the excellent R&D work and market entry. The Research Ministry assumed that the results would immediately find their way onto the market or that

[85] Cf. BT-Drs. 8/3144 of 31 August 1979, p. 21.

the Ministry of Economics would close the gap by offering more application-oriented R&D support and taking suitable large-scale measures for market launch. Yet the Federal Ministry of Economics did not undertake any such measures since it thought that the new technologies should not need state subsidies to succeed in the market. It saw no reason to support medium-sized businesses in asserting themselves in an oligopoly (Dürrschmidt 2007, pers. comm.).

3.6.2.5 Fourth Energy Research and Energy Technologies Framework Program (1996–2005)

Published in 1996 by what was then the Federal Ministry of Education, Science, Research and Technology, the fourth energy research and energy technologies framework program defined the context for German energy research from 1996 to 2005 (Prognos et al. 2007, 14). In 2002 application-based R&D promotion was transferred to the Federal Environment Ministry, including measures for market introduction and shaping the overall conditions for expanding renewable energies. At a total of 537 million euros, renewable energies constituted the largest funding item in this framework program (excluding biomass). The Federal Environment Ministry devised an overall concept designed to close the above-mentioned gap between research and market introduction in a way that was in line with the legal framework conditions, targets and outlooks. The key motor in terms of the fourth energy research program was Germany's and its industry's negotiated agreement to reduce CO_2 emissions. The program therefore concentrated especially on technological options that promised appreciable contributions to climate protection and sustainable resource management (Prognos et al. 2007, 14).

The successful 100,000 Solar Roofs Program conducted between 1999 and 2003 (see Section 5.3.5.5) and the market incentive program for renewable energies (mainly in the heat sector) coincided with the period of the fourth framework program (Prognos et al. 2007, 35). Thus, the direct promotion and remuneration payments on the federal level became significantly important during this period. "As a result of increasing federal promotion, other funding programs, such as from the states, municipalities or power utilities, lost their relevance" (ibid., 42).

3.6.2.6 Fifth Energy Research Program "Innovation and New Energy Technologies" (2005–2008)

The fifth energy research program was drawn up by the Federal Ministry of Economics (then the Federal Ministry of Economics and Labor). Other ministries, including the Federal Environment Ministry, contributed within the scope of their responsibilities. The program forms part of the Integrated Energy and Climate Program of the Federal Government (IEKP, see Section 3.7.3). As with its predecessor, the objective of the program is to expedite innovation processes in order to launch technologies onto the market more quickly. Based on the evaluation results of the fourth framework program, the program defines primary and secondary funding domains, with the latter receiving a smaller share of funding (BMWA 2005, 23–24).

While the Federal Ministry of Economics was responsible for the branch of efficient energy conversion research, e.g., fuel cells, hydrogen and system analysis, the Federal Environment Ministry was in charge of renewable energies research. Basic research concerning renewable energy was transferred to the Federal Research Ministry, while the Federal Ministry of Agriculture was assigned the field of bio-energy research. The research program stipulated a clear shift in funding in support of energy efficiency and renewable energies (BMWA 2005, 10).

3.6.3 Funding on State Level

State funding of renewable energies contributed significantly to energy research. These contributions had amounted to 80 million euros in 2003, which corresponded to a third of the Federal Government's total research spending. It varied a lot throughout the country, with North Rhine-Westphalia topping the list of states with up to 15.7 million euros spent on the REN Program (program on the rational use of energy and use of inexhaustible energy sources).[86] This program was adopted by the North Rhine-Westphalia state government in October 1989 and has since undergone revisions and updates on an annual basis. The program was the result of an initiative launched by a group of committed and influential members of the administration (Hennicke et al. 1997). In 2002 the terms of funding were revised in favor of renewable energy taking into account the 100,000 Solar Roofs Program and the market incentive program. In 2007 the state of North-Rhine Westphalia provided REN broad-based funding to support solar collector arrays, photovoltaic systems, hydropower plants, apartment ventilation systems using heat recovery as well as biomass and biogas plants. The states of Brandenburg[87] and Bremen launched similar REN programs for the promotion of energy efficiency and renewable energies.

3.7 StrEG and EEG as Key Policy Measures

It was still under the conservative-liberal government that the Electricity Feed-in Act of 1991 created an important stimulus for the introduction of renewable energy on the market. In 1998, when after his 16-year tenure chancellor Helmut Kohl was unseated by the first red-green government consisting of SPD and Bündnis90/Die GRÜNEN, this change of government opened up a political time slot for fundamental changes in energy policy, part of which was the adoption of the Renewable Energy Sources Act.

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[86] The program promotes investment in energy saving and the use of renewable energy sources. It differentiates between demonstration promotion (focus on feasibility) and widespread promotion (focus on marketability).

[87] Guideline of the Ministry of Economics in Brandenburg for the promotion of energy efficiency and for the use of renewable energies (REN Program) of 18 July 2007.

3.7.1 The Electricity Feed-In Act (StrEG)

Until the late 1980s the necessity of statutory remuneration were denied. Within the political arena, existing voluntary association agreements[88] under private law were considered to be sufficient to compensate for renewable energy feed-in.

Nevertheless, in 1989, after the German reunification, a draft law for an electricity feed-in act (Stromeinspeisungsgesetz – StrEG) was presented. The increasingly significant wind power lobby of the north-western states and hydropower plant operators from Bavaria and Baden-Württemberg influenced the agenda setting process and advocated guaranteed minimum feed-in payments. The draft had originated from an initiative launched by a group of members from various Bundestag fractions.[89] It had been drawn up largely by members of the Bundestag itself, which was considered an uncommon way to introduce new legislation. The relevant ministries, usually responsible for drafting laws, had only been consulted concerning specific passages.

The bill drew on the reports of the Committee of Inquiry "Vorsorge und Schutz der Erdatmosphäre" (Provisions for the Protection of the Earth's Atmosphere). An important historic predecessor of this Act was the 250 MW large-scale wind power testing program launched by the Research Ministry in the late 1980s. This program simulated a feed-in tariff in the form of fixed subsidies per kilowatt hour of wind power fed in, thus encouraging trust in renewable energies, and served as the basis for the feed-in act initiative.

The bill was fervently supported by members of the Bundestag like Dr. Wolfgang Daniels from The Greens, and Michael Müller and Hermann Scheer from the SPD. The StrEG was also advocated by members of the CDU/CSU (e.g., Bernd Schmidbauer and Matthias Engelsberger[90]), especially due to its significance as a means for securing the energy supply and as an incentive to modernize hydropower plants in the small-scale capacity range.

During tumultuous times, not even 2 months before the first all-German Bundestag election in December 1990, it was almost crowded off the agenda (Berchem 2006). Finally, the Bundestag unanimously adopted the bill on 7 December 1990, and it entered into force on 1 January 1991. According to Scheer (2004, 16 in Suck 2008, 171) the adoption of the StrEG did not receive much attention. This is owed to the circumstance that the electricity industry was simultaneously absorbed with negotiations on taking over the East German electricity market. It is also presumed that the power utilities seriously underestimated the effect of the StrEG at the time of its adoption in 1990 (Tacke 2004, 206–207; Berchem 2006).

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[88] Association agreements ("Verbändevereinbarungen") have been a peculiar German way of corporate self-regulation.

[89] For the history of the Electricity Feed-in Act, see Kords (1993), Berchem (2006).

[90] Bernd Schmidbauer was the CDU/CSU's environment spokesperson in the Bundestag and member of the Committee of Inquiry "Vorsorge und Schutz der Erdatmosphäre" (Provisions for the Protection of the Earth's Atmosphere). Matthias Engelsberger, a member of the CSU and also of the Bundestag, represented the interests of medium-sized businesses (wood processing, hydropower) in Bavaria.

The electricity market, which had so far been dominated by the transmission and supply monopoly of the electricity market's companies, was now opening up to private renewable electricity generators as a result of the StrEG – this was a significant improvement compared to the previous situation. The Act defined the terms of purchasing electricity from renewable energy sources and access of this electricity to the grid. Within the Federal Government, the Economics Ministry, responsible at the time for matters relating to energy, played the main part in the preparation of the StrEG. However, it hardly identified with the Act's contents and objectives. "The Federal Ministry of Economics believed that an act that stipulated subsidies did not at all fit into the political landscape" (Dürrschmidt 2007, pers. comm.). The attempts at discrediting the StrEG and to repeal an amendment expected for 1994 showed how little the Economics Ministry was really prepared to tread new paths in energy policy.

3.7.1.1 First Revision of the StrEG in 1994

The first revision of the StrEG in 1994 aimed at adjusting the compensation rates. Yet the efforts to amend the Act were met with strong objections from the Federal Economics Ministry. On the other hand, Angela Merkel, environmental minister from 1994 to 1998, and the parliamentary state secretary Walter Hirche (FDP) strongly supported the Act's further development. Many members of the Bundestag and of the Chancellery supported its continuation as well (Dürrschmidt 2007, pers. comm.). So ultimately, due to the massive pressure, the Federal Ministry of Economics had to accommodate the amendment. The Federal Environment Ministry contributed the relevant technical information.

Meanwhile the electricity industry had become aware of the StrEG's effects and began to fight the Act with great determination. Between 1995 and 1997 the Act threatened to be overturned. The core of resistance came from the power utilities united in the Association of German Electric Power Utilities (VDEW). These associations argued that the StrEG did not comply with the rules of the market economy and doubted that the Act conformed to the German Constitution. They tried to file a model lawsuit with the Federal Constitutional Court under civil law and by doing so questioned the legality of the StrEG. Upon the recommendation of the VDEW, some of the power supply companies cut the statutorily defined compensation for power from renewable energies for one of their customers.[91] This cut back was met with massive criticism from the public. Members of the Bundestag across all parties expressed their disapproval of the power utilities' activities and demanded that they respect the feed-in act as adopted by the Bundestag.[92] From the district court, the lawsuit went to the

[91] Badenwerk AG in Karlsruhe, Kraftübertragungswerke Rheinfelden and Stadtwerke Geesthacht each paid only the rates declared in association agreements to one of their customers (Tacke 2004, 207).

[92] Der Spiegel, 8 May 1995; cf. Deutscher Bundestag, minutes of plenary proceedings 13/39 of 19 May 1995.

Federal Constitutional Court, before the cartel chamber of the Federal Court of Justice finally judged that the StrEG did not violate the Constitution.

3.7.1.2 Second Revision of the StrEG in 1998

An important novelty of the StrEG amendment in 1998 was the introduction of what was called the 5% cap.[93] It was intended to restrict the strain on grid operators who fed in large shares of wind power. Apart from that, the so-called "small amendment" did not lead to a rise in compensation, but introduced some clarifications and additions. For instance, the amendment broadened the spectrum of organic material that fell under the remuneration. Besides products, organic waste and residual material from agriculture and forestry the StrEG now also covered "biomass" in general (in other words, energy crops). In addition, the amendment specified that offshore plants fell under the compensation regulations as well.

3.7.1.3 Ruling of the European Court of Justice

With its ruling of 13 March 2001, the European Court of Justice ultimately stated that feed-in and minimum payment regulations generally comply with European Community Law (Oschmann & Sösemann 2007, 2). The judgment referred to a dispute between PreussenElektra and Schleswag. It specified that the German Electricity Feed-in Act does not represent state subsidies in the sense of Article 87 (1) of the EC Treaty. It also ruled that the Act does not infringe free movement of goods within the EU.[94] Consequently, any legal concerns regarding higher compensation for electricity from renewable energy sources had been ruled out. The Electricity Feed-in Act was no longer viewed as encouraging impermissible state subsidies (Schmela 2000, 18). Despite their defeat before the European Court of Justice, the power utilities managed to create an atmosphere of uncertainty especially within the still unstable wind power sector. Having involved the European Court of Justice in the German feed-in compensation dispute shifted the political process to the European level (Hirschl 2008, 135–136). At the time the European Commission too was dealing with the modalities of a feed-in compensation when drafting a directive on the promotion of renewable energy (see Section 3.3.2.4).

[93] This rule specifies that the upstream grid operator has to refund the additional costs incurred by exceeding the 5% share as soon as the share of renewable energies exceeds 5% of the kilowatt hours sold by the power utility.

[94] Cf. comments in Natur und Recht 2002, p. 148.

3.7.2 The Renewable Energy Sources Act (EEG)

3.7.2.1 The Renewable Energy Sources Act of 2000

The governing coalition believed that the amount of compensation defined in the StrEG no longer sufficed neither to achieve the German and European target of doubling the share of renewable energies in the electricity mix nor to introduce renewable energies on the market on a broad scale.[95] In addition, some regions were expecting to reach the "second 5% cap".[96] The new red-green coalition therefore planned to enact a new regulation on the feeding in of "green" electricity for 1 January 2000.

Preparations for the new law – the Renewable Energy Sources Act (EEG) – began in 1998. The Federal Ministry for the Environment was the key driving force behind it, with the Renewable Energies Department contributing the relevant technical information. In the context of research done by the department, studies on the potentials of renewable energies were commissioned in order to qualify further discussion about revising the StrEG.[97]

Still, the Federal Ministry of Economics did not manage to get any relevant legislative proposal off the ground at the end of the 1990s. Finally it was once more the Bundestag that took the initiative and drafted a bill for the EEG (Kaiser 2007, pers. comm.). In this case, members of The Greens acted as the drivers. They were supported by members of the SPD faction that wanted to prevent the newly establishing sectors from being weakened. The bill was finally adopted by the Bundestag on 25 February 2000, and it entered into force on 1 April 2000.

Important changes in the EEG compared to the StrEG (as at 1998):

- Coupling the remuneration to the average price was abandoned. Specified compensation rates per kilowatt hour were fixed, which aimed to create security for investment – independently of the development of the electricity price.
- Remuneration was guaranteed not only for the period of the Act's validity, but for 20 years.
- The amount of compensation differed according to sectors and plant size.

After extensive debates the Ministry of Economics and the Environment Ministry[98] agreed on a joint bill for the "law that gives priority to renewable energies", later

[95] The remuneration specified in the StrEG was coupled to the average power price, which dropped in the course of the continuing liberalization of the energy market.

[96] Cf. Green faction in the Bundestag (1999, 23).

[97] For example, see the pilot study by Nitsch (2000). The results of these examinations were presented at the Bundestag's expert sittings and were drawn on for the decision-making process.

[98] There was dissent on the compensation rates, on rotor surface model versus reference yield model, distribution of the grid connection costs and grid reinforcement costs.

referred to as the “Renewable Energy Sources Act”.[99] The long-term compensation guarantee increased the banks’ willingness to invest. This started off a dynamic development which mobilized investment capital and – in the case of wind power – made it possible to begin serial production.

What was new was that the power supply companies, which so far had been excluded from the feed-in regulations, were now, from 2000 onward, to benefit from these compensations as well. This circumstance gave rise to worries about small plant operators being threatened. If the large power utilities were to branch out into renewable energies, small-plant operators would not be able to compete. Yet the power utilities did not go into renewables – possibly because they expected profits that were even higher those that could be made with the guaranteed feed-in rates.

Section 16 of the EEG of 2000 allowed electricity-intensive businesses to benefit from a compensation regulation which exempted them from paying higher prices for electricity generated from renewable energy (Oschmann & Sösemann 2007, 2). This regulation can be viewed as a concession to the (power-intensive) economy.

3.7.2.2 Revision of the Renewable Energy Sources Act in 2004

Revision of the EEG 2004 was assigned to the Federal Ministry for the Environment. The Ministry began with the elaboration of a draft immediately after the Bundestag elections (Suck 2008, 422). The opposition’s response was surprisingly positive. Due to the draft’s focus on promoting crop energies, the agriculture portfolio cooperated as well. Yet the industrial sector had been exerting increasing pressure on the EGG. The industrial associations BDI (Federation of German Industries) and DIHT (German Association of Chambers of Commerce and Industry), the traditional energy industry (VDEW) and the economics portfolio fiercely attacked the draft. The energy-intensive industrial enterprises[100] feared higher energy prices would threaten their competitiveness and demanded an exemption clause (Suck 2008, 423).[101] All in all, the traditional energy sector was interested in restraining the promotion of electricity generation from renewable energy sources. In various contexts, members of the Federal Economics Ministry argued against the far-reaching objectives aimed to expand renewable energies as advocated by the Federal Environment Ministry. The Federal Economics Ministry tried to water down the Federal Environment Ministry’s draft for an EEG revision by proposing lower targets and modified regulations (Hinrichs-Rahlwes 2007, pers. comm.). In a “major effort of the portfolios and the innovative sections of the economy”

[99] Draft of a law on the promotion of power generation from renewable energy sources (EEG) and on changing the oil taxation law of November 29, 1999. The EEG entered into force on April 01, 2000.

[100] Especially metal processing businesses and the aluminum industry.

[101] In view of the threat of job losses, the Federal Ministry for the Environment ultimately felt pressured to permit such a hardship provision for the energy-intensive industry.

(Dürrschmidt 2007, pers. comm.) and thanks to cross-party political support in the Bundestag, the EEG was adopted despite fierce attacks and various modifications to the government's draft. The Act that was finally adopted reflected the ideas of the Federal Environment Ministry much more than those of the Federal Economics Ministry.

As a result of the sector-specific and case-specific regulations, the EEG's scope and complexity had once again increased considerably compared to the 2000 version. In the proponents' view the success of the Act can be ascribed precisely to this differentiated and selective promotion. Critics, on the other hand, fear a danger of excessive governance and inadequate interference of public policy right down to executive levels.

On 1 August 2004 the law amending the Renewable Energy Sources Act (EEG 2004) entered into force. With this amendment, ca. 330 (particularly) electricity-intensive enterprises and railroad companies were relieved to an even greater extent from additional costs arising from green electricity.[102] According to Hirschl (2008, 563), the hardship provision is regarded as reciprocal deals with the economic sector that serves to eliminate blockades and to support concerns that would otherwise have little prospects for implementation (ibid.). In this case the introduction of an EEG hardship provision was coupled to the promise of creating a regulating authority in the energy market (cf. EnWG amendment 2005; Section 3.9.3.3).

3.7.2.3 Revision of the Renewable Energy Sources Act in 2009

Revision of the EEG 2009 was also assigned to the Federal Ministry for the Environment. Preparation of the EEG revision was closely linked to the adoption of the IEKP (see Section 3.7.3.2). The sector-specific monitoring studies on the EEG 2004[103] had been completed as early as summer 2007. They provided an extensive field report about the effects achieved with the EEG 2004,[104] which formed the basis of the amendment draft for the EEG 2008/09 presented in October 2007. After portfolio agreement in October and November 2007, the Federal Cabinet adopted the bill in conjunction with further accompanying laws and ordinances on energy efficiency (IEKP) on 5 December 2007. The government's draft of the EEG had been discussed in the commissions of the Federal Council as early as January 2008. The first reading in the Bundestag took place on 21 February 2008, and on 5 May 2008 a hearing

[102] The so-called "Härtefallregelung" (hardship provision). Doubts were raised about whether this increasing advantage of the electricity-intensive companies was still in accordance with the Constitution (Oschmann & Sösemann 2007, 3).

[103] Cf. BMU (2006) and the studies of ARGE Monitoring PV-Anlagen (2006) on photovoltaics and of IE Leipzig (2007) on biomass.

[104] The EEG field report (BMU 2007c) had been presented to the German Bundestag by the Federal Environment Ministry in consultation with the Federal Ministry of Agriculture and the Federal Ministry of Economics, and was resolved by the Federal Cabinet on 7 November 2007. In it the portfolios had already agreed on recommendations for shaping the system of promotion based on minimum remuneration and bonuses for the individual sectors.

proceeded in the Bundestag's environmental commission. After the commission had finally agreed on a motion for an amendment of the EEG, the coalition parties found solutions to the controversial issues[105] on 30 May 2008, enabling the newly composed EEG to be adopted in the Bundestag as early as 6 June 2008.

There was continued consensus on further forcing the expansion of electricity generated from renewable energies. In order to accelerate the dynamic, the remuneration rates in the EEG 2009 were adjusted upwards in almost all of the sectors, most of all for offshore wind and geothermal energy, since no appreciable expansion had set in this field. The compensation rates for solar power generation, by contrast, were heavily cut, since so far the annual cost reductions of 10% had exceeded expectations (reductions of 5% had been assumed). The new degression rates in the range of 8–10% do justice to this development.

3.7.2.4 Further Development of the EEG Equalization Scheme

The ordinance on the EEG Equalization Scheme (AusglMechV), which was enforced in 2010, aims primarily to reduce costs for grid operators, distributors and consumers and also to raise the transparency of the Equalization Scheme. Unlike so far, the transmission system operators shall now sell EEG electricity directly at the electricity stock exchange. The difference between the sales revenue and the remuneration paid to the RE plant operators as per the EEG, is allocated to the power distributors. Due to this regulation electricity generated from RE no longer needs to be physically passed on from the transmission operators to the distributors, which was frequently associated with risks and additional expenses due to inaccurate forecasts. However, critics expressed doubts about whether this new regulation would ultimately have a positive effect on the development of renewable energies (Jarras & Voigt 2009).

3.7.3 Integrated Energy and Climate Program of the Federal Government

The promotion of renewable energies has been codified in a package of acts and ordinances since 2007. This revealed that attaining the climate protection targets was an integrated task. It was no longer only the electricity industry, but also the mobility sector, the heat market and energy efficiency that gained in significance as fields of activity.

3.7.3.1 Meseberg Resolutions in Preparation for the IEKP

During its closed meeting in Meseberg in August 2007, the federal cabinet adopted the "Integrated energy and climate program (IEKP)" presented by the Federal

[105] Matters of dispute included the compensation rates for solar power, for instance, which the CDU and the CSU would have preferred to be much lower.

Ministry of Economics and the Federal Environment Ministry. This cabinet decision sparked off the compilation and coordination of a package of measures in which the EEG now formed part of a number of related acts. The IEKP reflected the awareness that several energy sectors relevant for climate protection required stimuli in order to reach the ambitious CO_2 reduction targets. The objective of the program is to reduce CO_2 emissions by 40% by 2020 compared to 1990. This reduction target, which is extremely ambitious by international standards, clearly assigned Germany the role of a pacesetter within the EU.

In view of the forthcoming world climate summit in Bali (2007), the cabinet hastily adopted the IEKP as a legislative package and presented it in the Bundestag. Never before had climate protection been the focus of the political agenda to this extent.

The Meseberg resolutions included the following key items:

- Expansion of the share of renewable energy: in the case of electricity from renewable energy, the cabinet agreed on an expansion target of 25–30% by 2020. Expansion of renewable energy in the electricity sector is expected to reduce CO_2 emissions by 55 million tons each year.
- Expansion of electricity and heat generation in cogeneration power plants: an amendment to the heat-power cogeneration act was expected to double the share of heat-power cogeneration in electricity generation by 2020, i.e. raising its share to 25%. An average funding volume of 750 million euros per year was allocated to this task. An investment grant of up to 20% and a volume of 150 million euros is provided for the expansion of local and district heat.
- Increased demands on the energy efficiency of buildings: in a first step the Resolutions specified that energy efficiencies of buildings should be raised by 30% in 2008, and by another 30% by 2012. Minimum energy standards were to be defined for old houses, specifying more concrete maintenance obligations for owners.
- Increased means for climate protection: for the budget year of 2008 a total of 2.6 billion euros (including up to 400 million euros from selling emission permits) was provided for climate protection. This corresponded to an increase of ca. 200% compared to 2005.[106]

3.7.3.2 Integrated Energy and Climate Program (IEKP)

The first package of measures for the “Integrated energy and climate program (IEKP)” was adopted on 5 December 2007, and included the approval of initially 14 legislative projects and legislative amendment projects, among them also the revision of the EEG (see Section 3.7.2.3). A second package focusing on improved energy efficiency was launched in June 2008. With all of the measures implemented, it is estimated that CO_2 emissions will be reduced down to around 34% by 2020 (BMU 2008a, 18). Critics from the opposition parties and environmental

[106] http://www.bmu.de/pressemitteilungen/... (accessed September 3, 2009).

groups claim that the IEKP measures designed to reach the 40% target do not suffice and point to a number of relevant expert reports (e.g. Kleßmann 2008; EUTech 2007) to substantiate their opinion. In their view the IEKP measures are half-hearted and do not fully exhaust the climate protection potentials in various areas. Critics therefore call for additional measures, e.g. increasing incentives for heat insulation in old buildings, enhancing energy effectiveness and reducing power consumption, especially by replacing night storage heaters. They also propose improved monitoring of the Energy Saving Ordinance (EnEV), an upgrade of the heat-power cogeneration act, the expansion of the Renewable Energy Sources Act to cover housing stock as well, and ambitious measures in the traffic sector.

3.8 Environmental and Planning Law for Renewable Energy Projects

Facilities generating energy from renewable sources have to undergo a licensing procedure, just like any other physical building. In the early 1990s the existing legal framework was not sufficient to meet the challenge of adequately dealing with the new types of facilities and their effects on the environment. In particular, wind turbines were still unfamiliar in terms of appearance and dimension.

The remuneration after StrEG and EEG caused a large expansion in the number of installed renewable facilities, especially of wind turbines. To meet the challenges of a strong and uncontrolled growth, the legal regulation had to be adapted.

The objective was to minimize possible conflicts between wind power generation and other uses sensitive toward the effects of wind turbines by carefully choosing suitable sites. It was also hoped that planning law and other relevant regulations would bring about special provisions designed to create specific facilitation and incentives for RE and thus effectively support the set of eco-economic instruments (Klinski 2005, 7).

The sector-specific approval requirements and their role in a technology's expansion as part of the innovation process are outlined in the relevant chapters. At this point we will only discuss the amendments to the most important and cross-sectoral legal framework which supported the implementation of renewable energy.

3.8.1 Amendment of Regional Planning Law

Regional planning law serves the development, structuring and safeguarding of supra-local plans. Up to the 1990s, it was only large power generation units that were subject to regional or state planning. From the mid-1990s, the regional planning authorities became concerned with coordinating the expansion of wind power use. Finally, the 1998 amendment of the building law also contained an amendment on regional planning legislation.

A new zoning category, the "appropriate area" (Eignungsgebiet)[107] was introduced for wind power. This created the basis for controlling wind power use by determining areas eligible for the sitting of wind farms. After corresponding amendments to the state regional planning acts[108] at the end of the 1990s, areas suitable for wind power use started to be formally designated. At the regional planning level it seemed possible to control plant locations and minimize undesirable effects by concentrating turbines in the appropriate areas. Restricting wind farm areas on the regional planning level compensated to some extent for the licensing privileges (Privilegierung)[109] at the municipal level (see Section 3.8.2).[110]

However, the preparation of regional plans including zones for large-scale wind use turned out to be excessively time-consuming due to rising protests against wind farms. The first regional plans, which supported the installation of wind farms by disentangling incompatible usages, were finished in 2003.

Regional planning was up to that time only to be performed on land and within the 12-seamile-zone offshore. In 2004 it was extended to the Exclusive Economic Zone (EEZ). Being recognized as a promising concept, it was established in order to coordinate competition between offshore wind power use and other marine utilization claims,[111] and in order to define priorities. The first EEZ land-use plan was adopted in 2009.

3.8.2 Zoning Law/Planning Permission Law

3.8.2.1 Amendment of the BauGB 1996/1997

In 1997 the German Federal Building Code (BauGB) was amended. The amendment had been preceded by a long and controversial discussion on the extent to which licensing privileges for projects in non-urbanized areas should also be

[107] The zoning category of "appropriate areas" was introduced by the BauROG 1998 (cf. Index of Legal Sources). The appropriate wind use areas were identified by overlaying criteria indicating high wind yield with minimal clearance criteria. The latter were meant to avoid conflicts with other land uses (like settlement, recreation) and protection needs (e.g. bird protection, cultural heritage, visual landscape).

[108] This opportunity was grasped in particular by the northern German federal states.

[109] Projects with a licensing privilege in non-urbanized areas have to be given approval, unless they are not compatible with public interests (see Section 35 of the Federal Building Act).

[110] In Brandenburg and Mecklenburg-Western Pomerania, the regional plans became more important as a means of regulation than in the old federal states due to the lack of local land use plans in the new federal states.

[111] E.g., shipping, construction of storage sites (sand and gravel quarrying), fishing, aquacultures, military use, communications (subsea cabling), tourism.

applied to wind turbines. Efforts to grant privileges to wind turbines had already failed twice before. Opponents feared that the granting of privileges would almost create a “license to disfigure the countryside”. On the other hand, the wind power sector declared the introduction of a privileged status for wind turbines, implying simplified permission procedures, as indispensable for the sector’s survival. In spite of considerable opposition among its own ranks[112] the Federal Environment Ministry ultimately made a strong case for simplified permit requirements, especially for wind turbines, which spurred the amendment process.[113]

The amendment of the relevant section (Section 35 BauGB) was finally enacted in 1996, which was half a year earlier than the amendment of the BauGB. The revision entered into force as early as 1 January 1997. Among the renewable energies, hydropower and wind power benefited from the stipulated privilege.

The privileged status of wind turbines was simultaneously flanked by what was defined as “planning reservations”, which gave municipalities a right to reserve areas eligible for wind turbines in their local development plans. Thus the construction of wind turbines was permitted in specifically designated areas[114] only. This regulation was expected to bring about spatial concentration of the turbines. The aim was to integrate wind turbines into the existing land-use paradigm in an environmentally and socially sustainable manner. The privilege regulation significantly contributed to clearing the permit backlog that had built up by this time.

Ground-mounted photovoltaic systems are not affected by this privilege regulation. Similarly, biogas plants did not yet benefit from the permission privilege in 1996/1997.

3.8.2.2 EAG-Bau 2004

The adoption of the European Law Adaptation Act for the Construction Sector (EAG-Bau) in 2004 sparked the discussion about extending privileges for plants generating renewable energy in non-urbanized areas anew. An omnibus bill adapting the Federal Building Code to European law extended existing privileges to biogas plants with a capacity of up to 500 kW. From that time on, biogas plants were no longer only permitted as secondary systems for farming businesses.

In addition, planning principles were introduced into the BauGB which were intended to further promote the use of renewable energy within the scope of local responsibility. Ground-mounted photovoltaic systems had once again not been considered in these revisions.

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[112] Supported by the Federal Agency for Nature Conservation, the Federal Environment Ministry’s department for nature conservation initially rejected the privileged status for landscape protection reasons.

[113] The Federal Environment Ministry prepared a draft formulation for the privileged status for the Bundestag’s Environment Committee (Dürrschmidt 2007, pers. comm.).

[114] At the level of regional planning: “Eignungsgebiete” (appropriate areas); at the level of local development planning: “Konzentrationszonen” (concentration zones).

3.8.3 Legal Basis for Grid Connection and Grid Expansion

The Act for the Acceleration of Infrastructural Planning and the Energy Line Extension Act were accompanying legal foundations that were intended to improve the grid integration for offshore plants, eliminate grid bottlenecks and guarantee the improved integration of a growing share of renewable energy.

3.8.3.1 Act for the Acceleration of Infrastructural Planning 2006

The Acts for the Acceleration of Infrastructural Planning (EnWG, EnLAG and ARegV) committed grid operators to bear the costs of offshore facilities grid connection.[115] This regulation implied considerable financial relief for future offshore wind park operators and was intended to reduce the obstacles for offshore implementation.

3.8.3.2 Energy Line Extension Act 2008

The power grid represents a technical and financial bottleneck especially for electricity to be generated offshore. In 2008 the federal cabinet initiated the draft bill of the Federal Economics Ministry for the acceleration of the expansion of extra-high voltage transmission networks. Article 1 of this Act contains the Energy Line Extension Act, as well as amendments to the Energy Industry Act (EnWG), the Rules of the Administrative Courts (VwGO) and the Incentive Regulation Ordinance (AregV). On 7 May 2009 the Bundestag enacted the Energy Line Extension Act (EnLAG). The Act is designed to accelerate permission procedures among other things, by ascertaining the economic necessity of implementing currently 24 urgent power-line construction projects. The planning and approval authorities are now legally required to see to the planning and permission of projects on the regional planning level (determination of power lines) and subsequent planning approvals (approval of singular line sections).[116]

Priority is placed on six line sections for 380 kV lines determined within the context of the dena Grid Study (dena 2005), the extension of which is expected to eliminate bottlenecks and provide for supply reliability and power grid stability. Moreover, projects of European interest are regarded as having priority since they are of paramount importance for the functioning of the European common market or have considerable impact on cross-border transmission capacities and on long-distance capacities.

[115] Article 7 of the Act for the Acceleration of Infrastructural Planning amended the German Energy Industry Act (EnWG) by inserting § 17a, which commits transmission system operators, in whose supply area offshore wind turbines are operated, to establish and maintain a connection to the grid at their own expense.

[116] Article 2 of the Energy Line Extension Act effects changes to the German Energy Industry Act. A planning approval procedure with a concentrating effect is introduced for grid connection of offshore turbines. It replaces the previously necessary time-consuming individual approvals.

Environmental organizations and affected citizens frequently demand underground cabling of extra-high voltage lines so as to reduce burdens on the environment. On the other hand, the energy industry argues that underground construction work has a considerable impact on the environment, too, and that cabling causes significant cost and line losses. The Act defined four pilot routes for cabling amounting to a total length of 500 km. The intention was to gather and evaluate experience with this line technology along these sections.

3.9 Overall Parameters of the Electricity Sector

The energy sector in Germany is firmly embedded in the European electricity industry, especially since the liberalization of its electricity market (Section 3.9.1). It is characterized by a close-knit, centralized structure of power generation and distribution. The market situation is dominated by an oligopolistic structure of a few energy providers. To this date the traditional path of conventional electricity generation has been maintained[117] despite a number of crises and debates (see Section 3.1). It features centralized structures of generation and transmission as well as the predominant use of fossil fuels and nuclear energy as a cornerstone of energy supply (see Section 3.9.2).

3.9.1 Integration of the Electricity Industry in Europe – Actors and Influencing Factors

3.9.1.1 Effects of Liberalization

The liberalization of the German electricity market is the result of the EU Committee's efforts to create a common European energy market. The opening up of the German energy market in the last decade followed a number of European directives (see Section 3.3.1) that leave the actual implementation up to the member states. Implementation of this liberalization, however, proved to be very difficult at the national level, since the European specifications were met with massive resistance from the dominant actors of the German power supply system.

As a result of domestic market liberalization, there is now a range of numerous power suppliers on the German market as well as on the electricity markets of other member states. Unlike private electricity clients, about half of the industrial enterprises and small businesses make use of this choice (Winje 2008b, 19, also Krisp 2007, 169). The rate of changing the supplier differs a lot between member states, with Germany ranging among the top quarter of all of its European neighbors

[117] Hirschl (2008) ascribes the German electricity sector a great deal of inertia in view of attempts at liberalizing and restructuring the supply structures.

(Winje 2008b, 20). Along with creating a free choice of power suppliers, the liberalization of the European electricity market also affected grid access and the conditions of grid expansion. However, so far this has not had the desired effects of greater competition in the electricity market and lower electricity prices (see Section 3.9.3).

3.9.1.2 Businesses in the Conventional Energy Sector

The German electricity market is oligopolistic in nature: ca. 80% of its generating capacities are owned by the "big four" (see Section 3.9.2). It was only recently that an association of municipal energy suppliers emerged as a potential fifth pillar.[118]

The European market is more diversified, yet large-scale enterprises are found here as well. Eight major suppliers transact 53% of Europe's electricity trade, while the remaining 47% is covered by small power generators (Winje 2008b, 17; 2008a, 13). Within the EU's electricity generating market, which records an annual trading volume of around 3,000 TWh, Germany's power utilities rank among the ten largest electricity generating enterprises.[119] These figures indicate that it is still the large power utilities that dominate the market.

3.9.1.3 Electricity Stock Exchanges in the European Electricity Market

Electricity stock exchanges are taking on an important role in commercial transactions in the electricity market. The Leipzig European Energy Exchange (EEX) has considerable impact on pricing in the European market. With its 218 market participants from 19 countries, the EEX is the largest electricity exchange in continental Europe. On the spot market alone, where business is transacted immediately (as opposed to the derivatives market), the amount of electricity traded (154 TWh) corresponds to 25% of Germany's net electricity generation. This suffices to provide clear price signals even outside of the EEX (Winje 2008b, 6–7; EEX 2009). The EEX is also trying to become established on the gas market and on the emissions trading market (Winje 2008b, 13).

3.9.1.4 Structures of the Integrated Grid System

Over the years, formerly local or national electricity grids have evolved to form a European integrated grid featuring an overall synchronous AC voltage of 50 Hz.

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118 In August 2009 E.on and a municipal buying pool agreed to purchase Thüga. Thüga is the core of Germany's largest network of local and regional energy suppliers (http://www.thuega.de/… accessed September 2, 2009). When carried out, the transaction will found Germany's fifth-largest independent energy and water supplier. The association of municipal businesses (VKU) hopes that the sale will create greater competition within the electricity market (Süddeutsche Zeitung of 12 August 2009).

119 The largest power generating company is Electricité de France (EdF), with sales figures amounting to 633 TWh per year. E.ON is second, selling 435 TWh per year, and REW comes third. EnBW ranks tenth, selling 140 TWh per year.

Europe's largest integrated network is the Union for the Co-ordination of Transmission of Electricity (UCTE), which unites the networks of a total of 23 European countries. The members of the UCTE network have agreed on common standards and rules, which are set out in the "Operation Handbook" and also contractually codified in a multilateral agreement between the participating grid operators. The association allows for greater supply safety, as blackouts are mitigated and compensated for collectively by all of Europe's power stations. The significance of network associations and their compensating function increases as the share of volatile renewable energy generation rises. In 1999 ETSO (European Transmission System Operators) was founded as a merger of the four existing grid operator organizations (UCTE, NORDEL, ATSOI and UKTSOA) in Europe. It was intended to help meet the new challenges that had arisen in the context of cross-border cooperation after the market had opened up. Irrespective of this, the UCTE, founded in 1951, remains the main contact for all general technical matters of coordination.

3.9.1.5 Expansion of the European Network Association

An important cornerstone of the electricity industry's integration in Europe is the expansion of European electricity markets in terms of grids – an aspect necessitated by the increase in electricity trade and the need for a more sweeping counterbalancing of regionally fluctuating renewable energy feed-in rates. Yet, an integrated grid is still in its beginnings, with the capacity of existing inter-state coupling points being far too low. In the case of Germany, as little as just under 3% of the domestic power demand can be transmitted through these couplings, as up until now these points have served predominantly to stabilize grid operation.

The expansion of these coupling points' capacity would enable the operation of a European network, but this would initially also be linked to high investment costs. The advantages of such as system would include compensation for regional peak demands and avoiding blackouts in the event of power plant failures, implying greater supply safety and reduced generating costs (Winje 2008a, 30.)

3.9.2 Structure of the German Electricity Supply Sector

Germany's electricity industry is a historically grown system with federal structures existing alongside private and public utilities (Saretzki 2001, 198). It has developed into a three-tier electricity supply system consisting of supra-regional associations, regional utilities and municipal power suppliers (Schiffer 1999, 159 sqq.).

The electric utilities concluded demarcation agreements among each other, which defined their respective supply areas (Mez 1997, 433 sqq.). Within these they signed concession agreements with the municipalities. The tremendous power of these regional monopolies also impacted the price of electricity and gas.

The strongly centralized structure of energy supply was claimed to be indispensable for safety, efficiency and supply reliability: in the context of nuclear power it was argued that reactor safety could only be guaranteed for centralized, large power stations. With regard to coal-fired power plants it was argued that modern, economical pollution control was only possible with large-scale power stations. High capital expenditures and the infrastructural nature of the technology were also used as justifications for monopolization. The main arguments in favor of centralized energy technologies, however, were the inescapable increase in the energy demand and the lack of an economical decentralized alternative. The arguments of growing energy demand and lower costs as a result of the power plant's size were regarded as undisputed trends that were hardly challenged (von Weizsäcker 2001, 77; Nitsch 2007, pers. comm.).

The structures that had emerged proved to be rigid to the extent that the German energy market remained almost entirely shielded from the competition before the EU Committee launched its initiative in the 1980s. German politics reinforced the rigidity of those structures and so did the fact that all the parties involved silently accepted the reasons for monopolization.

Liberalization of the energy markets as demanded by the EU (see Section 3.3.1) effected the revision of the German Energy Industry Act in 1998 (EnWG) (see Section 3.9.3). The purpose of this revision was to open up the electricity market to the competition and in doing so to meet the declared objective of lowering the electricity and gas prices that were perceived as inflated. The energy industry had become expensive and inefficient as a result of its protection, and greater competition was viewed as a means of correcting this development (von Weizsäcker 2001, 78).

In the wake of liberalization, from 1998 onward, the energy market went through consolidation processes (see Section 3.9.3) that led to the emergence of four large power utilities – RWE, E.ON, EnBW and Vattenfall – which created an oligopolistic market situation.

3.9.3 Liberalization of the Energy Market – The German Energy Industry Act

3.9.3.1 The Amended German Energy Industry Act of 1998

The German Energy Industry Act (EnWG) is regarded as the energy industry's "Constitution" (Hirschl 2008, 197). With no changes since 1935, its revision was long overdue. So far a strong coalition of actors from the conventional energy industry[120] had persistently protected their interests in a monopolized energy market. The Federal Economics Ministry, which was in charge of the revision, thwarted attempts at modernizing and liberalizing the German energy law.

[120] Even at the time of adopting the EU directive in 1995, it aimed to save German utilities from being subjected to a regulating authority.

It was only the EU common market directive, which exerted the necessary pressure for member states to take action. Under the protest of the energy industry and related associations, a broad pro-regulation coalition was formed (Hirschl 2008, 571).[121] After lengthy struggles, the Federal Economics Ministry finally came up with a bill for the liberalization of line-bound energy supply (EnWG amendment) as specified by the 96/92/EC single market directive for the electricity market (see Section 3.3.1). The Act was adopted in 1998 and entered into force in the same year.

The new EnWG committed transmission and distribution network operators to grant access to their grids (Monstadt 2004, 164) (see Section 3.9.3.3). This also implied clearly improved prospects for grid access for renewable energy providers. According to the new regulations, denying access to the grid was only possible if the grid lacked the required transmission capacities. Supervision of compliance with the competition regulations was assigned to the Federal Cartel Authority.

Furthermore, the EnWG entitled electricity and gas customers to freely choose their power suppliers. This resulted in the formation of a market of electricity and gas suppliers as well as a market for "green electricity", which is based on customers voluntarily paying surcharges for environmentally friendly electricity. Yet despite the market of suppliers having developed considerably as a result of this, the demand lagged far behind expectations.

The first EnWG amendment was followed only by a brief phase of competition and price drops. Electricity costs declined temporarily, especially for clients with special contracts (industry and trade). Households in fact experienced a rise in electricity prices. For renewable energy, the initially lower prices brought about a decrease in the minimum remuneration, which, as per the StrEG, was coupled to the electricity price.

Fears of economic risks in a liberalized market increased the tendency toward concentration of the utility industry, which ultimately paralyzed the burgeoning competition. Four large energy companies emerged in the electricity market, which controlled 80% of the generating capacities, all of the transmission networks, and the majority of the distribution networks (see Section 3.9.2).

3.9.3.2 Amendment of the German Energy Industry Act in 2005

Since the competition had not developed as intended, the Energy Industry Act was amended a second time in 2005. This, too, was only accomplished after lengthy negotiations and a great deal of pressure from the European Committee,[122] and as a consequence of the Acceleration Directive 2003/54/EC.

In spite of being unpopular with the economics portfolio in charge, the amendment process was expedited by a number of factors at the national level[123]; the Federal Environment Ministry, for instance, had gained a great deal of negotiating power due to

[121] This coalition was made up of proponents of renewable energy, consumer associations, and even the conservative opposition or states under conservative governments and industrial energy consumers. The EnBW played a special role in that it stepped out of the otherwise closed ranks of the conventional power supply industry and spoke up in favor of regulation.

[122] Threatening infringement proceedings.

[123] See Hirschl (2008, 242).

its growing expertise and the increasingly important role it played in the process of shaping Germany's energy policy. However, the EnWG amendment of 2005 was again strongly influenced by the established power supply sector, i.e. its associations, while representatives of the renewable energy sector had difficulties in asserting their interests.

The EnWG 2005 stipulated that grid access, which hitherto had been negotiated (via association agreements), should be replaced with the principle of regulated grid access. The EnWG 2005 therefore specified the establishment of the Federal Network Agency as a regulating authority (see Section 3.9.3.3), despite resistance from the Federal Economics Ministry under Wolfgang Clement.

However, even after this latest amendment of the EnWG, the renewable energy sector did not benefit from its liberalization regulations to any appreciable extent, since the utility's market dominance had remained unchanged. The representatives of renewable energy had managed to protect the EEG from being eroded by the EnWG, but they had not managed to encourage decentralized structures, such as energy management systems, storage or integrated generation, through the EnWG, which would, however, have been necessary in order to promote decentralized energy generation (Hirschl 2008, 433, 571). The development on the electricity market still suggests that there have been no great changes to the competitive situation or the price development even after the adoption of the second EnWG amendment.

3.9.3.3 Grid Access Requirements

The EnWG of 1998 stipulated that a statutory order would regulate the design of grid conditions and payments. Germany thereby became the only EU member state to have chosen to implement the EU common market directive using "negotiated grid access" (see Section 3.3.1), thereby initially doing without the adoption of a regulatory authority with the power to determine tariffs and conditions for grid access. It was hence left to the businesses which were feeding power into the grid – some of which were new arrivals on the market – to negotiate access rights and fees with grid operators. The negotiation of tariffs and conditions for grid use took place in the context of association agreements for the electricity and gas sectors.

Protection of the status quo for regional, closed supply monopolies was abandoned. Now, independent grid operator associations needed to be established whose task it was to guarantee reliable grid operation, allow for interregional cooperation of the grids and permit grid access for third parties. Operators of the transmission and distribution networks were committed to granting access to their grids.

This improved the market access opportunities for providers of electricity generated from renewable energy – the overall prospects of grid access were now good (Ziesing et al. 2001, 147). Existing transmission networks, however, remained in the possession of the power utilities. In practical terms, therefore, access to the power grid or transmission of electricity was not always entirely uncomplicated. Electricity providers were rarely discriminated explicitly when it came to grid access,[124] yet access was

[124] If a grid operator violates the order demanding discrimination-free access to the grid and fair remuneration, the state's competition authority (antitrust authority) can act retroactively.

and is in part impeded by extremely restrictive transmission regulations and fees which rank among the highest in Europe (Monstadt 2004, 170).

The 2005 amendment of the EnWG (see Section 3.9.3) finally stipulated the necessity of establishing a regulating authority, which led to the founding of the German Federal Network Agency. This agency is designed to ensure fair access and use of the energy supply grid for all users.[125] It is under supervision of the Federal Economics Ministry.[126] Whether the agency can fulfill its tasks independently while under the influence of the energy industry and that of the Federal Economics Ministry remains questionable, though. According to Leprich (2004, 198) in (Hirschl 2008, 271), the Federal Network Agency is threatening to become a "subcontractor to the Ministry of Economics".

The Federal Network Agency is entrusted with the unbundling and regulation of the electricity and gas supply networks, so as to separate the grid's monopolistic section from its competitive sections within the energy industry (Leprich et al. 2007). By the time of going to press, however, unbundling of the power utilities was still incomplete. All of the participants in upstream and downstream markets continue to be dependent on the grids. Operators of transport and distribution networks are still benefiting from their monopolistic position by demanding excessive prices and discriminating against network users outside of the utility by delaying grid connection. Complete ownership unbundling is heavily disputed in the energy industry, since this would imply a complete separation of the generation and transport network.

Currently, however, changes in the field of grid ownership are beginning to come up. E.ON and Vattenfall surprisingly announced they would sell their electricity networks, EnBW and RWE, however, are still insisting on keeping theirs. The decision to sell the networks was the result of massive pressure from the EU Competition Authority.[127] It is still open whether or when the electricity network should pass into the ownership of the state or an investor who is subject to state control.

3.9.4 Current Courses Set in the Energy Sector

The current objectives and strategies of the Federal Environment Ministry are based on the results of in-house pilot studies (Nitsch 2007, 2008): the stipulation of both the pilot scenarios developed in the context of these studies is to achieve the Federal

[125] Its tasks also include granting approval for grid remuneration for transmission of electricity and gas, preventing or eliminating obstacles blocking access to the energy supply grid for suppliers and consumers, standardizing supplier change processes, and improving grid connection conditions for new power stations. Cf. http://www.bundesnetzagentur.de/... (accessed September 9, 2009).

[126] Only in individual cases can the Consumer Protection Ministry and the Federal Environment Ministry be consulted (on general prices for private clients and on renewable energies, respectively).

[127] The accusation of having violated competition law and the threat of a possible penalty by the European Commission.

Government's medium- and long-term CO_2 reduction targets[128] while at the same time continuing nuclear phaseout. According to Nitsch (2007, 3 and 2008, 3) the following three partial strategies need to be embarked on in order to meet the emission reduction targets:

- Raised efficiency in all of the sectors
- Expansion of heat-power cogeneration
- Pronounced expansion of renewable energies

These three points reaffirm the political course taken by the Federal Environment Ministry. Furthermore, a study on renewable energy integration in the domain of electricity (BMU 2008c) suggested a variety of factors to be crucial to achieving a large share of renewables in the energy mix: the ability to regulate the generating facilities, the possibility of temporary energy storage, and an active demand-side approach (load management). The study also points to the indispensability of an optimized use of existing grid capacities in conjunction with a demand-based expansion of the power networks (BMU 2008c).

3.9.4.1 Reconstruction of the Power Generation Systems

So far the growth of renewable energies had been spurred mainly by the EEG's incentive scheme, which focuses on the generation technologies. With the share of renewable energy rising, however, fluctuating energy sources in particular, such as wind and photovoltaics, come up against increasing limitations of system compatibility if the power station structure, which is designed to cover base load, is maintained. This incompatibility is due to the fact that production of electricity in large power stations is variable only to a certain extent and characterized by an inability to adjust to varying amounts of power generated and by an inability to adjust to varying demands.[129] The Federal Government is in the process of making some fundamental decisions on whether to maintain power stations as they are or whether to retrofit them. The task of the years to come, which is to "renew the power station fleet", is gradually turning into the general question of which system to use.

Generation Management

The integration of large shares of renewable energy requires enhanced power management on the part of the generating companies. One prerequisite for this is

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[128] With the adoption of the Meseberg resolutions in August 2007, the Federal Government reiterated the decision to reduce greenhouse gas emissions by 40% by 2020 compared to 1990. Moreover, the Federal Government advocates a commitment of the international community of nations (developed countries) to reduce greenhouse gas emissions by 80% by 2050.

[129] In technical and economic terms, nuclear and lignite-fired power plants are designed to generate a steady amount of electricity to cover the base load.

the use of conventional power stations that can be regulated.[130] Another prerequisite for the integration of large shares of RE would be to amalgamate the energy quantities generated in semi- or decentralized power generating plants. This would necessitate linking various power plants to form what is referred to as combined power plants.[131] This in turn would require the power suppliers to communicate with each other as well as enhanced communication between the power utilities and the consumers.

Power Station Structure

The power utilities aim to prolong the power stations' run times and also to speed up modernization of the coal-fired power station fleet. They argue that the energy supply would not be safe if the share of nuclear and coal-fired power plants were cut (see Section 3.9.2). If, by contrast, the current power station structure were maintained and reinforced in the long run, the share of renewable energy sources would, according to the energy industry, need to be restricted, otherwise operating the base-load power stations[132] would no longer make economic sense.[133]

Modernization of the power station structure based on lignite-fired power stations is designed to be accompanied by the concept of CO_2-capture (CCS)[134]. This technology is propagated by power station operators as an effective concept for CO_2 reduction.[135] It conflicts directly with the expansion of renewable energy though, as the continued use of coal and base-load power stations, which are relatively inflexible, is incompatible with a large share of renewable energy. Moreover, the captured CO_2 must be stored in underground sites. The application of CCS and the resulting storage of CO_2 would imply blocking the limited number of underground storage sites permanently. In future, however, these sites will also be needed to store gas in the context of renewable

[130] Nuclear power stations and CCS coal-fired power plants are regarded as inflexible, i.e., not capable of being regulated – it takes more than 20 h to start up a power station.

[131] These are "virtual" power plants with a regional focus which use control technologies to combine decentralized power conversion plants for solar power, wind, biogas and water located in various regions, in a way that allows for continual on-demand power supply. The linking of the power plants permits controlling the decentralized plants in the same way as a conventional large power plant.

[132] New large coal-fired power stations can only be operated economically if their capacity utilization is high. This holds true in particular for lignite-fired power plants that require a very high number of operating hours in order to be economical. The electricity produced must be sold on a continuous basis, even in times of low demand (at night or at weekends). The production rate of other generators must be decreased during this phase.

[133] In addition, the electricity stock exchange frequently saw situations that led to zero or negative prices, which result from the fact that there is an excess amount of base load while the distribution of electricity generated from renewable sources must be prioritized.

[134] CCS = carbon (dioxide) capture and storage.

[135] Arguments for the development and application of the CO_2 capture technology include the possibility of exporting it to countries such as China or India, where coal will remain an important source of energy for some time.

energy expansion (SRU 2009). Similarly, the use of underground storage sites may also conflict with the harnessing of geothermal energy (see Section 6.3.3). The securing of these underground storage sites still requires extensive exploration as well as measures for legal protection.[136] At this stage, the potential and limits of the CCS technology are still in the trial phase.

Critics have warned of hurriedly setting the course by erecting new power stations. Expanding base-load power plants, they argued, was only possible when dispensing with a substantial further expansion of renewable wind and solar power, since large shares of wind power and solar energy could not be sensibly combined with base-load power generation. The decision to build a considerable number of new base-load power plants, as is being discussed, would therefore imply rejecting the idea of further expanding the use of renewable energies. Among the public, the construction of new power stations is controversial. According to an opinion poll (forsa 2007) 67% of the interviewees voiced opposition against the construction of new lignite-fired or coal-burning power stations.

The limits of integration become apparent with an increasing share of renewable energies in the power supply. The issue is increasingly one of transforming the energy supply systems – a project that is proving to be much more expensive and ambitious than the question of integration dealt with so far.

3.9.4.2 Modernization and Expansion of the Transmission Infrastructure

Another prerequisite for the integration of larger shares of RE is that the capacity of the electricity grids meets higher technical demands. Grid capacities, mostly those in certain northern German regions with large proportions of wind power, are already coming up against limitations. Existing grid capacities must therefore be utilized as efficiently as possible, and electricity grids should be expanded according to the market's demand.

Along with expanding capacities, the concept of "smart grids", i.e. modernizing existing grids, is being discussed. "Smart grids" are characterized by power generation management, intelligently designed routes, effective load management (demand-side management) and transmission line temperature monitoring, which would improve grid load control, and by the ability to adjust their output in accordance with demand, which would significantly improve the existing power grid's capacity. It is largely unclear, however, to what extent the capacity could be improved as a result of such activities and to what extent this would render additional expansion of the transmission networks superfluous.

Looking beyond national borders, the creation of a European "super grid" based on high voltage direct current transmission (HVDC) is being discussed.

[136] At the time of going to press, a controversially debated bill on CO_2 storage was in the course of being legislated to explore this (see SRU 2009).

The benefit of such a network would be low-loss, long-distance transmission of electricity, which is not possible with alternating current. It is hoped that temporarily and regionally high renewable power generation, e.g. from offshore wind farms or solar thermal power stations in southern Europe and northern Africa, would be more evenly distributed within Europe. The high costs of expanding a future-capable network infrastructure are regarded as the greatest obstacle in this context, one that has so far been avoided by grid operators as well. This type of network requires a new European cooperation of grid operators that would plan and construct the relevant lines. The linking of international energy markets is still in its early stages, but the process is making dynamic progress.

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Chapter 4
Innovation Framework for Generating Biogas and Electricity from Biogas

Abstract In the pioneering phase of the development, biogas generation was associated with low-tech applications. The technology was regarded as a marginal topic in the German research landscape of the 1970s and 1980s, drawing attention only from a small circle of scientists from agricultural research institutes, non-university research institutions and a few universities. So far the innovation process has undergone six phases. Transition from the pioneering phase to the inception phase was initiated by the Electricity Feed-in Act of 1990. The adoption of the Renewable Energy Sources Act in 2000 spurred on the innovation process. Its revision in 2004 allowed for a great increase in the number of plants constructed, which ultimately led to the sector's boom phase. After 2006 the process of biomass innovation exhibited a changing dynamic.

Generating electricity from biogas is still expensive, since the efficiency rates of converting biogas into electricity are limited. A cost degression effect similar to that in the wind power sector has not set in to date because of the heavy dependence on substrate prices. The biogas sector is occasionally faced with conflict at the local and regional level. Unlike in the other energy sectors, these conflicts are not only caused by the increasing concentration of biogas plants, but also by the fact that substrate production (especially corn cultivation) requires large expanses of land.

Keywords Biogas • Energy crops • Fermentation technology • CHP technology • Bonus system

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4.1 Preliminary Remarks

This analysis is primarily of the technologies involved in the generation of biogas using the process of anaerobic fermentation[1] and the subsequent use of such gas as a fuel for Combined Heat and Power (CHP) plants or Organic Rankine Cycle (ORC) plants. In the past 20 years, these have been through a remarkable process of innovation.

In comparison, no significant innovations have occurred in the burning of solid matter in wood-fired power stations. This more or less corresponds to the technology used in power plants running on black coal and lignite. The situation is similar in the case of electricity generation using plant oil in CHP plants. Here, heating oil or diesel is replaced by plant oils such as rapeseed oil, soya oil or palm oil, without any need for innovations in power generation technology. Other processes, such as the thermochemical gasification of biomass are not considered, since they are still in the research stages and not yet of any practical relevance.

In Germany, the development of biogas generation and the use of biogas to generate electricity can be divided into the phases shown in Fig. 4.1. The constellations of central actors and influencing factors assigned to the phases are explained in more detail in Section 4.2.

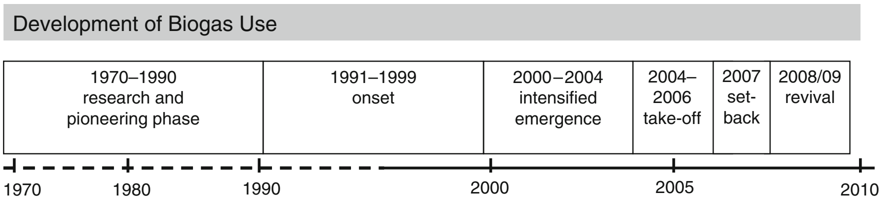

Fig. 4.1 Phases of the development of biogas use in Germany

4.2 Phase-Based Analysis of the Innovation Process

4.2.1 Historical Retrospective

As early as the end of the nineteenth century, sewage gas was generated by the decomposition of sludge in sewage plants. However, at the beginning, the gas could only be used in exceptional cases like for instance in the city of Exeter (UK) where

[1] Biogas is produced in oxygen-free (anaerobic) conditions when biomass breaks down into its component building blocks. For the decomposition of organic materials to take place, certain bacteria are needed which exist in anaerobic conditions, at temperatures between 30°C and 37°C and which generate methane (CH_4). Biogas consists of about two thirds methane and one third carbon dioxide. The gas also contains limited quantities of hydrogen, hydrogen sulfide, ammonia and other trace elements (FNR 2006b, 25–26).

it was used for street lighting. In Germany, it took until the 1920s for sewage gas to be captured and put to use in city gas distribution systems and in vehicle fleets. In the 1920s, Imhoff[2] developed special digesters for the decomposition of sludge. This system allowed sewage gas to be used in the early stages of heat and electricity production in urban areas.

Between 1935 and 1955, when oil and coal were scarce in Germany, biogas partly replaced liquid fuels in road vehicles with petrol engines. By 1937, several cities had already converted their municipal fleets to biogas.[3] A hindrance here was that the gas had to be compressed and carried around in heavy steel cylinders. Biogas had a comparably high methane content and therefore also a higher calorific value. To increase the yield of sewage gas, operators experimentally added plant matter to the slurry. At the time, the biogas potential of sewage sludge was judged to be limited, as was the potential of organic municipal waste (Reinhold & Vollmer 2003, 244).

It was only following the war that agriculture was discovered as a potential source of biogas (Reinhold & Vollmer 2003, 245). Small agricultural biogas plants were seen as potentially providing farms with a convenient source of power. In 1948, the first agricultural biogas plant was constructed in Odenwald (BMU 2006, 97). In the 1950s, biogas generation experienced only a moderate upswing (Jäkel 2003, 6). The total number of agricultural biogas plants in the former West Germany and East Germany were estimated at between 50 and 70 (Reinhold & Vollmer 2003, 245). In France, England and Italy the use of agricultural biogas digesters spread, too. In these countries the Ducellier-Isermann System prevailed. Germany, in contrast, mostly made use of either the "fermentation canal method" (Darmstadt System) developed at Darmstadt University of Technology or of the Schmidt-Eggersglueß System, based on interchangeable containers (Reinhold & Vollmer 2003, 245). It was only in 1967 that the central role of acid-producing bacteria in the fermentation process was recognized. This was required in order to take the first steps in engineering the process. Because the supply of coal and oil in Germany started improving from 1950 onward, and because oil was unrivalled for its low price, agricultural biogas plants were shut down again. It was only with the oil price crisis in the 1970s that there was a revival in the use of biogas technology – as described in the following sections.

4.2.2 Phase 1: Pioneering Phase, 1970–1990

4.2.2.1 Characteristics of the Constellation

Technological elements of different scales, one developed in the former Federal Republic of Germany (FRG) and one developed in the former German Democratic Republic (GDR), constitute the heart of this constellation (Fig. 4.2).

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[2] In the 1920s, Prof. Dr.-Ing. Karl Imhoff, the "father of wastewater treatment", built the first digestion tower for the anaerobic treatment of sewage sludge in Essen.

[3] In the cities of Halle, Pforzheim, Essen, Erfurt, Pößneck, Munich and Heilbronn.

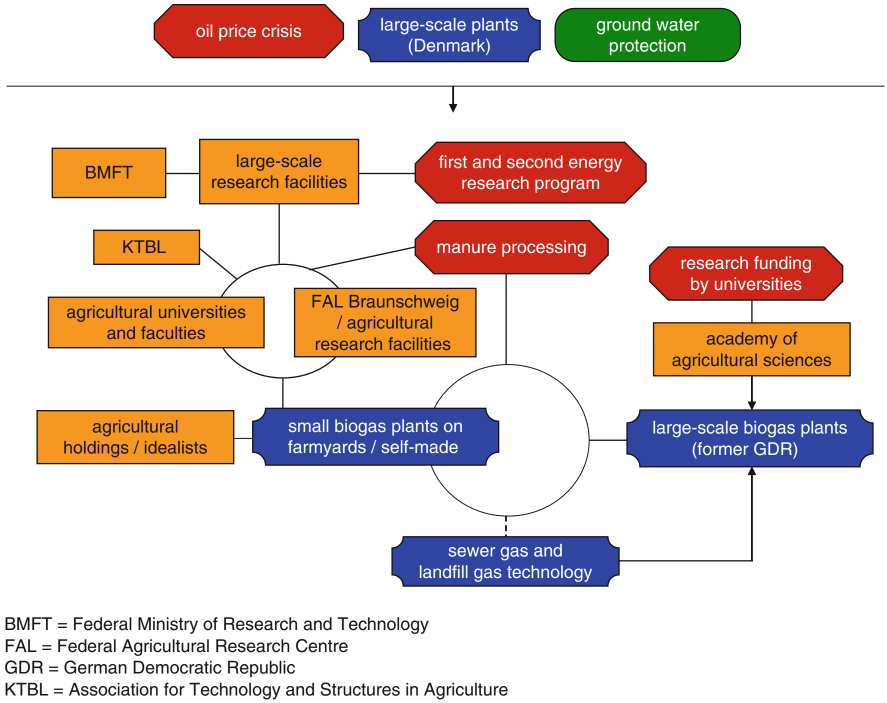

Fig. 4.2 Constellation phase 1: pioneering phase 1970–1990

In the FRG small-scale digesters used in large livestock operations in southern Germany formed the starting point of the biogas movement. Although these plants, predominantly home-built facilities, were primitive, they provided the basis for practical experience and a starting point for agricultural research institutes to achieve further step-by-step improvements at this early stage. In contrast, the GDR already used existing sewage gas and landfill gas technologies to develop biogas plants on a large, industrialized scale.

The prime initial motive in both the GDR and the FRG was the processing of semi-liqid manure[4] into fertilizer by fermentation. The fermentation was meant to reduce undesirable negative environmental impacts resulting from increasingly industrialized livestock production. It promised both to solve problems[5] evoked by the storage and spilling of large amounts of semi-liquid manure and to provide a usable fertilizer product.

On the whole, the agricultural sector in both parts of Germany did not see biogas generation as being part of the energy issue. Gaining heat was considered a by-product, gaining electricity was not in the focus.

[4]The terms semi-liquid manure and slurry are applied synonymously.

[5]For example methane formation, ammonia damage, and nitrogen leaching into the ground water.

As the federal energy research program attributed no great potential for innovation or power generation to biogas development,[6] it did not receive much financial support. The need for research in the procedural problems of the fermentation process was underestimated. The few agricultural research facilities that had taken an interest in biogas made only incremental advancements to the technology.

4.2.2.2 Sector-Specific Context, Influencing Factors and Processes

Oil Price Developments

The second oil crisis of the 1970s and growing concerns about energy security were the main motives for the intensified search for alternative sources of energy (see Section 3.1.2). However, only limited significance was attached to the use of biomass for the generation of biogas and electricity. As a result, this technology did not directly profit from the oil crisis.

Semi-Liquid Manure and its Effects on Groundwater

In order to limit excessive semi-liquid manure production and to prevent the washing of nitrates into the groundwater, the states enacted the so-called slurry regulations[7] in the mid-1980s. These had the effect of increasing interest in less environmentally damaging, wiser ways of making use of sewage. As a consequence of this, fermentation technologies came to be seen as a possibility for improving on the negative environmental effects of sewage production by limiting the mineralization of organic nitrogen whilst simultaneously increasing the value of sewage as agricultural fertilizer.

4.2.2.3 Governmental Guidance and Economic Context

In the 1970s, West Germany, in its search for alternatives to fossil fuels, concerned itself with large-scale and high-tech technologies. The support for research into these technologies was provided by the Federal Ministry of Research and Technology (Bundesministerium für Forschung und Technologie – BMFT) (see Section 3.6.2).

[6]See Mutert (2000, 31 sqq.) for innovation research and innovation policy in the 1970s.

[7]Slurry regulations (based on the power vested in the Federal Water Act to issue statutory instruments) regulate the conditions (time periods, minimum areas per livestock unit) under which semi-liquid manure can be introduced to areas of land in an effort to reduce the contamination of groundwater by nitrates.

Federal Research Strategies

Compared to the 1970s, the research paradigms underwent a gradual shift in the 1980s: it was not only large, technical systems, but also smaller, decentralized production units that were considered to be capable of securing the energy supply. However, according to Eisenbeiß (2007, pers. comm.), the Federal Ministry for Education and Research saw no reason to expand technological research on biogas technologies. In their view technologies for sewage and semi-liquid manure fermentation were sufficiently known. The federal energy research programs[8] limited the support to the implementation of a few pilot plants,[9] which did not help develop any momentum. In addition, the comparably primitive biogas technology was not an attractive field of research (Nitsch 2007, pers. comm.). Researchers lacked in opportunities to gain prestige and recognition. As a result, research for the energetic use of biomass remained a comparatively neglected branch.

Support from Agricultural Sector

From 1990 onward, renewable energies indirectly benefited from the launch of the "renewable resources program"[10] in the agricultural sector. For example, the Federal Ministry of Agriculture (now: Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz – BMELV) supported pilot projects to demonstrate how cultivated plants could be used for industrial and energetic purposes. Still, support of this program was not directed at generating energy. Up until 1995, support for biogas technology had mainly been focusing on the utilization of semi-liquid manure and other organic agricultural residues. The main concerns were about the handling of excess quantities of organic waste and finding an additional "outlet" for them by using them as fertilizers (Schütte 2008, pers. comm.).

[8]Full title: "Energieforschung und Energietechnologien", period of operation: 1977–1980 and 1981–1990. The second energy research program (1981–1990) focused on topics such as the further development of incineration/gasification/pyrolysis plants, testing/adaptation of biogas plants for various waste materials and plant sizes, optimization of processing techniques of fermentation substrates, testing of largely energy self-sufficient systems in agriculture as well as first investigations into combined energy and food plant use.

[9]At the Federal Agricultural Research Center, Braunschweig (FAL) a 100 m^3 volume "bihugas plant" (see Section 4.2.1.5) was being built at the time. The plant was equipped with adequate measurement technologies and was run in order to investigate questions that were largely still concerned with composting or fertilizer production. However, according to Weiland (2008, pers. comm.) the "bihugas plant" was also the starting signal for considerations in terms of the use of semi-liquid manure for generating power.

[10]This program supports research and pilot projects for the cultivation and use of renewable resources. The thematic orientation of the support program is determined in the "Gülzower Fachgespräche" (*Gülzow Expert Talks*) that have been taking place since 1993.

Despite research and development into biogas technology having made progress, significant chemical and biological process engineering problems occurred in practice. Controlling the fermentation process appeared to be more challenging than expected (Nitsch 2007, pers. comm.) and reliable solutions for the average operator were still missing, which made introduction to the market difficult. Operators and researchers experienced backlashes, which often resulted in disappointment and frustration. To overcome this stage, more process related research and scientific monitoring of operation data was needed.

Biogas Research in the Former GDR

Biogas research in the former GDR followed its own individual track. Research on biogas technologies was initiated by research teams at the Academy of Agricultural Sciences (Akademie der Landwirtschaftswissenschaften). At the beginning of the 1980s a series of biogas demonstration and pilot plants were implemented at six large livestock farming locations. The testing as well as the scientific monitoring were co-ordinated as part of a state-funded research program. The aim was to develop models for a GDR-biogas plant, which were then to be produced in larger quantities (Reinhold & Vollmer 2003, 245–246). This program was the driving force for large-scale biogas research. Private individual operators were not involved.

4.2.2.4 Technology and Market Developments

Knowledge Transfer from Sewage Gas Generation

The technology for the extraction of sewage gas was regarded as fully developed at the end of the 1980s. Due to their size, the pilot plants in the former GDR were able to take advantage of this knowledge.[11] For the small-scale plants, which were predominant in West Germany, however, this knowledge could only be applied to a limited extent. Failures occurred[12] when companies from the fields of landfill and sewage gas technology tried to establish their technology in the domains of small-scale agriculture (Weiland 2008, pers. comm.). Due to the high technological standards already established, the sewage gas technology also proved too expensive for agricultural use.

[11] A plant with closed silos was built in Nordhausen. These silos were also used in conventional sewage treatment plants (Linke 2008, pers. comm.).

[12] The plants used for the treatment of semi-liquid manure were not adjusted to run on solid manure or substrates such as straw. The consequences were blockages and insufficient mixing of the substrate (Weiland 2008, pers. comm.).

Digester Technologies in Former West Germany

The first agricultural biogas plants were small- and extremely small-scale plants. They were predominantly constructed by farmers and agricultural machinery engineers as purpose built units for operation under the conditions of an individual farm. The pioneering work was carried out by farmers and agricultural machinery engineers, which were predominantly situated in intensive stock farming areas of Bavaria and Baden-Württemberg. There, intensive stock farming created a large amount of semi-liquid manure and thus high pressure to use it. Moreover, farms near residential areas needed to reduce odor problems.

Until the end of the 1980s many different designs were tried out within the context of the pioneering work.[13] According to Weiland (2008, pers. comm.) by the beginning of the 1990s only a few operators knew how the fermentation process actually worked and how it was controlled. The gas production was a matter of "trial and error", which often resulted in failures. Research had only little relation to the agricultural practical applications during this phase because the exchange and networking between the two was insufficient.

With regard to the gas yields it became clear even at these early stages that fermentation of sewage alone only produces small gas yields. Gas yields could be increased by adding plant biomass (e.g. silage), solid dung or other organic waste from the farm. The first biogas plants with such admixtures did not, however, advance beyond the experimental stages. From the very beginning, the lack of knowledge concerning the process of digestion and how to control it, imposed a major restraint on the co-digestion of other organic substrates at a larger scale. In the initial stages, there was a lack of technology for loading and efficient stirred tank reactors that were capable of ensuring sufficient mixing of the substrate.

Fermentation Technology in the Former GDR

As early as the 1980s, relatively large pilot installations for the anaerobic processing of semi-liquid manure were set up in some of the industrial animal production sites[14] in the GDR. In this case, it was semi-liquid manure *processing* which was at the centre of operations, rather than power production. The warmth produced as a by-product of the digestion process was regarded to be a waste product. The trial of various procedures and systems was aimed at developing systems for the treatment of semi-liquid manure generated by various forms of intensive stock rearing.

[13] Only beginning in the mid 1990s the development concentrated on a few new building types and technical versions, which are today regarded as technologically mature and well proven.

[14] In the former GDR, animal production was centralized. Large facilities for the fattening and breeding of swine and cattle kept up to 190,000 animals in one place in so-called combined fattening and breeding facilities.

Availability and Developmental Situation of Conversion Technologies

In the former GDR, energy production was not the main motivation. Conversion technologies such as gas motors and generators[15] for the conversion of power were not available to the research facilities.

In West Germany, in the mid-1980s, individual farmers began to produce electricity using "homemade generators". They would install a gas engine and attach a generator to it (Holz 2008, pers. comm.). However, the homemade motors often experienced problems, as they were not able to cope with the high sulphur content of the gas. CHP plants had not yet come onto the market as a finished product.

Cost and Market Development

When the biogas in small agricultural plants was produced almost exclusively from slurry, substrate costs did not matter. The energy return – mostly heat– was an additional internal benefit, allowing power savings for the farmer. Generally, living areas and stables were heated, at least during the winter. Biogas generation and conversion plants were to a large extent unique purpose-built constructions. Data concerning investment costs and cost-effectiveness are only available in a very few cases.

In the former GDR, substrate costs were insignificant. The costs of processing semi-liquid manure by digestion were lower than the synthetic production of nitrogen fertilizers (Linke 2008, pers. comm.). However, precise calculations of cost effectiveness, which included the energy yield, were not carried out.

4.2.2.5 Actors in the Pioneering Phase

The important actors during this phase were the farmers who made practical use of the technology and, starting around the beginning of the 1980s, agricultural research facilities and a few agricultural faculties.

Farming Operations

In the West German states, farmers were the pioneers of the gas sector. Together with others committed to the cause of the economical and practical aims of utilizing semi-liquid manure (Mautz & Byzio 2005, 45), biogas farmers who were associated

[15] In the 1980s, Fiat produced a small CHP plant in small batches (Fiat TOTEM), which could be run on biogas. The alternative biogas scene in West Germany knew of these power plants, but demand was low since oil only cost 10 pfennigs per liter. Fiat therefore stopped the production of the TOTEM-motor after a short while.

with the environmental movement and organic farming, formed the core of a niche in which they then largely focused on experimenting with practical knowledge.

Do-it-yourself skills were required in order to construct biogas plants. Small operations in Bavaria and Baden-Württemberg formed the nuclei of agricultural plant construction. They were largely produced by farmers themselves (who also helped each-other) who ran livestock-based operations. For example, in the mid-1980s, members of the Bundschuh-Biogasgruppe[16] in Hohenloher Land (Baden-Württemberg) implemented a series of cooperative homebuilt projects. The "expert knowledge" was passed on amongst the cooperating farmers. Their personal contribution, combined with a variety of technical and manual challenges resulted in individual adaptations being made to the components installed. However, beyond solving the problems of individual operations and beyond the decentralized and primarily horizontally organized network structures, the farmers developed only limited momentum for the sector as a whole.

Federal Ministry of Agriculture

In the 1970s the intensification of agricultural production led to surpluses on the agricultural markets. As a consequence, the Federal Ministry of Agriculture's policy at the time was focused on the stabilization of agricultural markets: measures to enhance export as well as the provision of storage capacities, financed by means of a heavy subsidy, were meant to prevent a collapse in prices. The establishment of the first department for renewable resources in 1985/86 was a side effect of these efforts. Originally, the focus was on the cultivation and use of plants such as flax and hemp, the fibers of which could be used for *material* applications. However, within the Ministry, the department was not held in high regard. Active organization in the subject area did not occur and stimuli continued to consist mainly of subsidies aimed at market stabilization. It was only from around 1993 and in connection with the EU-supported cultivation of rape that energy-based uses for the fuel market came into focus.

Agricultural Research Institutes

In the former GDR, it was the research institutes that took the lead in the state's research into large-scale digesters. The Institute for Fertilizer Research (Institut für Düngungsforschung) at the The Academy of Agricultural Science (Akademie der Landwirtschaftswissenschaften) in Potsdam, the Institut für Energetik in Leipzig (now: IE Leipzig) and the Institut für Mechanisierung der Landwirtschaft in

[16]The "Bundschuh-Biogasgruppe" developed from a (successful) protest movement against a planned Daimler-Benz test track in Baden-Württemberg.

Potsdam-Bornim (now: the Leibniz Institute for Agricultural Engineering Potsdam-Bornim) were the key actors that explored biogas generation.

In the states of former West Germany, agricultural research institutes formed the core of an embryonic "innovation network". In addition to the Federal Agricultural Research Center (Bundesforschungsanstalt für Landwirtschaft in Braunschweig – FAL), this also included the State Institute of Farm machinery and Farm structures (Landesanstalt für Landwirtschaftliches Maschinen- und Bauwesen – now the State Institute of Agricultural Engineering and Bioenergy) at the Universität Hohenheim and the Bavarian State Research Center for Agriculture (Bayerische Landesanstalt für Landwirtschaft – LfL) in Freising-Weihenstephan with its biogas research focus. The former leader of the Environment and Energy Technology Department of the Bavarian State Research Center for Agriculture, Heinz Schulz,[17] made a point of getting involved in technologies designed for use on individual farms. The State Institute of Farm machinery and Farm structures at Universität Hohenheim was also involved with research and trials of biogas generation techniques. At the Technische Universität Darmstadt, the "Darmstadt system" was developed.

Still, the commercial interest in biogas generation was very limited. It was only a small community that had a focal interest in the generation of biogas. The Association for Technology and Structures in Agriculture (KTBL)[18] helped the sector to bridge these "lean times" by supporting small demonstration plants, thus ensuring the survival of the "delicate seedling of biogas" (Döhler 2008, pers. comm.).

Manufacturers and Plant Builders

Prior to 1990, there had been no significant biogas producer sector or plant construction sector. Suppliers of sewage gas plants and waste utilization plants[19] only offered components that were too large and too expensive for use for the agricultural scale. In the absence of appropriate components farmers bought individual parts such as containers and stirrers and assembled them themselves, or with the help of local agricultural machine mechanics. In the GDR, there were, according to Linke (2008, pers. comm.), various specialists and others with backgrounds in chemical plant construction that contributed existing knowledge of vessel construction and the installation of stirrer technology.

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[17] Dr. Heinz Schulz was the co-founder of the Fachverband Biogas e.V. in 1992.

[18] The KTBL is an institution in the operational division of the Federal Ministry of Agriculture (BMVELV), which is responsible for the transfer of technologies into agricultural practice. See http://www.ktbl.de/index.php?id=9 (accessed August 21, 2009).

[19] For example Haase Energietechnik GmbH, which has worked in the area of mechanical-biological treatment of municipal waste (MBT), landfill engineering (landfill gas, leachate) and energy systems since 1981. See http://www.haase-energietechnik.de (accessed August 17, 2009).

4.2.2.6 Interpretation of the Constellation: Driving Forces and Constraints

The pioneering phase was characterized by the search for alternative energy-efficient systems. In the search for alternative options for energy supply, biogas technology initially had limited significance in the research supported by the BMBF. In the context of the research support, a manageable agricultural research network established itself, which concerned itself with biogas technology from the perspective of the utilization of sewage. The process of innovation was defined by its limited momentum. Social and institutional regulatory mechanisms for driving on the process of innovation were limited in their impact. There was no network linking research actors and users. The pioneers in practical applications were idealistic farmers and amateurs who were part of the environmental movement. Apart from the advantages of waste heat recovery, there was no economic incentive to generate biogas. Biogas generation took place with limited efficiency and at a low technical level (trial and error). Despite many failures, farmers were the protagonists of development, and in successful cases they would lower the threshold for others who sought to emulate their example.

The development and adaptation of technology in practice took place via incremental innovation. Technical applications and incidences of adaptation were strongly decentralized – in other words set up primarily for self-reliance. Networking between the supporters was based on personal contacts and focused on their local or regional areas. Individuals, partly with backgrounds in science acted as "change agents" in that they contributed expert knowledge within the groups of users and implemented projects together.

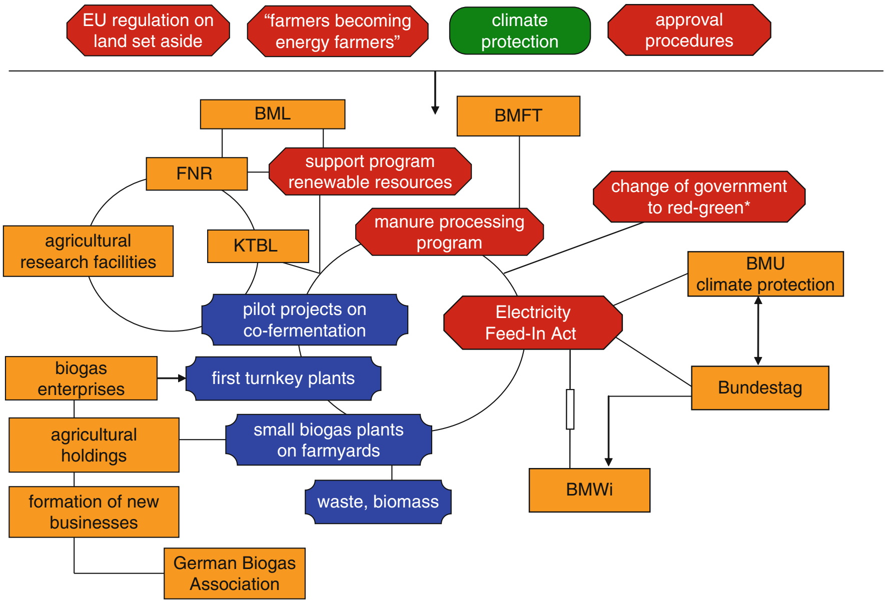
4.2.3 Phase 2: First Phase of Emergence From 1990 to 1999

4.2.3.1 Characteristics of the Constellation

The constellation is split into two sub-constellations[20] whose aims and focuses relating to biogas generation are not entirely congruent. The sub-constellation on the left side of Fig. 4.3 consists primarily of research actors from the agricultural sector. They continue to concern themselves with biogas generation, primarily in the context of utilizing semi-liquid manure. From the mid-1990s on, the sub-constellation is supplemented by elements that put more emphasis on the cultivation of energy crops and renewable energy.

The Agency for Renewable Resources (Fachagentur Nachwachsende Rohstoffe - FNR), which was founded in order to act as project coordinator for the BMELV's departmental research in the area of renewable resources, began to expand its focus to include questions concerning the generation of power from biogas.

[20] Indicated by the two circles in Fig. 4.3.



BMFT = Federal Ministry of Research and Technology
BML = Federal Ministry of Food, Agriculture and Consumer Protection
BMU = Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BMWi = Federal Ministry of Economics

Fig. 4.3 Constellation phase 2: first phase of emergence between 1990 and 1999

At the heart of the newly established sub-constellation, on the right side of Fig. 4.3, is the Electricity Feed-In Act (Stromeinspeisungsgesetz – StrEG[21]). Its coming into force in 1991 demonstrated that public policy was supporting the renewable electricity sector. The tariff specified for electricity generated from biogas in the StrEG of 1991 at first only had a signaling effect. The increase in plant numbers was very limited. It was only with the increased tariff rates specified in the StrEG amendment of 1994 that an appreciable expansion of plant construction finally took place. This resulted in a first emergence of a significant market.[22]

Other technical elements, which constituted part of the core of the constellation were the small and medium-sized farm-based biogas plants, which were primarily fed with semi-liquid manure and, toward the end of this phase, with additional organic waste and energy crops. The availability of ready-to-use plants from the mid 1990s on was a milestone on the road to the professionalization of the sector.

The spectrum of digester substrates then expanded to incluce, besides semi-liquid manure, organic waste materials to enhance the biogas yield. Digestion of organic waste in co-fermentation plants brought actors from the waste industry into play. Due to their needs for organic waste disposal, co-fermentation in biogas plants

[21] The sources for the legal information used in this chapter are given in the Index of Legal Sources.

[22] The StrEG amendments of 1996 and 1998 did not develop momentum within the constellation.

presented a welcome opportunity. As that was also a lucrative venture for the business sector this led to a significant increase in the number of plants by the end of the 1990s.

Of all the political actors, it was the Bundestag that managed to develop the momentum for biogas. With the findings of the Commission of Inquiry[23] as a background, enthusiastic representatives reinforced the goal of climate-friendly energy generation. The Bundestag supported the StrEG amendments and took care of the corresponding amendments to the rates of remuneration.

The change to a Social Democrat-Green government ultimately resulted in a situation of upheaval in which more extensive opportunities for renewable energy opened up.

4.2.3.2 Sector-Specific Context, Influencing Factors and Processes

At the beginning of the 1990s, climate protection became an important context for government actions, especially for the remuneration for electricity from renewable sources.

In 1993, the EU approved a specification of the set-aside regulation.[24] Since then farmers have been permitted to grow energy crops on designated set-aside areas. For these areas, the farmers continued to receive set-aside payments if they stuck to certain conditions and demonstrated that the crop was then being used in energy production or an industrial process. The cultivation of rape in order to harvest biofuels profited from this ruling. These income opportunities caught the attention of farmers in the bioenergy sector. The slogan “Vom Landwirt zum Energiewirt” (“from food farmer to energy farmer”) defined the beginning of a change in consciousness: farmers and their representatives recognized the increasing economic relevance of energy production from biomass (as a second source of income). However, in comparison with biofuels, the generation of electricity from biomass still played a minor role.

4.2.3.3 Governmental Guidance and Economic Context

The Electricity Feed-In Act 1991 and 1994

The enactment of the StrEG in 1991[25] marked the beginning of state support for the generation of power from biogas. According to Weiland (2008, pers. comm.) this

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[23] For more details on the role of the Committee of Inquiry, see Section 3.4.2.2.

[24] Commission Regulation (EEC) No 334/93 of 15 February 1993, last modified by Regulation (EC) No 2991/95. These directives contain detailed procedural specifications for the cultivation of energy crops on set-aside land.

[25] For the origin of the StrEG and its aims, see Section 3.7.1.

was the deciding factor for more acceptance and the subsequent widespread impact on farming practices.

By guaranteeing a minimum compensation rate the intention was to provide an economic incentive. However, the specified payment rate of 75% of the customers' electricity tariff (around 14 pfennigs/kWh) was too low. The increase of the payment rate in the following StrEG amendment (1994) to 80% of the electricity tariff (around 15 pfennigs/kWh) improved profitability slightly. It stimulated plant operators to devise more effective ways of producing gas and generating electricity.

For co-fermentation plant operators, the use of organic residues was particularly lucrative. In addition to the feed-in tariff, they received money, e.g. from food producers in return for accepting organic residues.[26]

The 100 Million Program

Parallel to the updating of the StrEG, the Federal Research Ministry launched a "100 million program" through which facilities utilizing renewable energy were subsidized through investment grants. The aim was to increase demand for relevant technologies as well as to achieve a reduction in production and investment costs. In the period between 1995 and 1999, the Federal Research Ministry launched subsidized biogas plants with a total of around 14 million German Marks (Staiß 2000, II-31). The program supplemented the increased feed-in tariffs in the StrEG and lead to improved economic conditions.

Support for Research into "Environmentally Friendly Processing and Utilization of Semi-Liquid Manure"

After the reunification of the two parts of Germany, support for the third energy research program (1991–1998) of the Federal Research Ministry concentrated on exploring the environmentally friendly disposal of residues and waste materials. In order to deal with the enormous problem of semi-liquid manure disposal[27] in the former GDR, the Federal Research Ministry brought into being the funding priority of the "environmentally friendly processing and utilization of semi-liquid manure". It ran over 7 years, during which approximately 20 R&D-proposals were investigated, at a cost of 40 million Deutsche Marks. The Association for Technology and Structures in Agriculture (Kuratorium für Technik und Bauwesen in der

[26]Even as early as at this point, it became clear that there was a need for readjustments, as the digestion of organic waste was associated with the release of pollutants and the question of the disposal of contaminated digester residues needed to be resolved. See Section 4.2.3.3 concerning the enactment of the Biomass Ordinance.

[27]The media also reported on the environmental problem of the production and storage of large quantities of slurry in slurry lagoons.

Landwirtschaft e. V. – KTBL) oversaw the demonstration plants from 1990 to 1997 and produced documentation of the results (KTBL 1999). According to Döhler (2008, per. comm.) these large-scale projects achieved a quantum leap. It could now be demonstrated that plant technology also worked in the capacity range of 300–500 kW. The Federal Research Ministry program thus caused a significant stimulus to innovation in the development of the technology on a larger scale.

Research Program "Renewable Resources"

The founding of the The Agency for Renewable Resources (FNR) in 1993 (see Section 4.2.2.5) was accompanied by the initiation of the "Renewable Resources" research program. In terms of research support from the Federal Agricultural Ministry bioenergy production slowly started to gain significance as a pillar of rural development. The growing significance was also recognized by the portfolio of the Federal Building Ministry (cf. BBR 2006). At this point, bioenergy support mechnishms aimed at making a wide spectrum of competing bioenergy technologies capable of entering on the market (WBA 2007, 174). Within this spectrum, compared to research into the generation of biofuels, only a small proportion of research concerned biogas. Although the "Renewable Resources" research program started from 1995 onward to focuse more strongly on biogas (Schütte 2008, pers. comm.), this program's main focus remained the biofuels sector.

Meanwhile, agricultural research institutions considered a systematic evaluation of the practices to be overdue (Weiland 2008, pers. comm.). However, they were unable to gain the required support and focus from the FNR's subsidy program. Instead, only a small scale evaluation of biogas plants in Lower Saxony carried out via the FAL was financed by the German Federal Environment Foundation (Deutsche Bundesstiftung Umwelt – DBU). From the view of the operators, the results, however, could not be communicated widely enough, which meant that ultimately "everybody had to learn from their own experiences after all" (Holz 2008, pers. comm.).

4.2.3.4 Technology and Market Developments

Increasing the Gas Yield with Co-Fermentation

Gas yields generated solely by semi-liquid manure digestion were too low. While the initial expert opinion was that the co-fermentation of other vegetative raw materials was not accomplishable (Weiland 2008, pers. comm.), in 1994, the Landesanstalt für Landtechnik (The State institute for Agricultural Engineering) in Triesdorf carried out successful attempts at digesting fresh grass and silage. Based on these findings, other waste materials were increasingly used. Staff at the Weihenstephan University of Applied Sciences (FH Weihenstephan) as well as various north German biogas farmers continued experimentation with the co-fermentation of biogenic residues and waste.[28]

With co-fermentation, the gas yield multiplied several times compared to the digestion of pure semi-liquid manure. The opportunity to increase revenues by these means spread quickly among plant operators. The largest private plant[29] of that time, in which semi-liquid manure and waste from the food industry were digested (Weiland 2008, pers. comm.), was set up in Wittmund. The Federal Research Ministry's "environmentally friendly processing and utilization of semi-liquid manure" program (see Section 4.2.2.3) also supported the implementation of individual large-scale co-digestion plants. By the end of the 1990s, however, organic waste had become a scarce commodity. As a consequence of competition with commercial organic waste digestion plants, the remuneration for the service of organic waste disposal decreased, meaning that the economic viability of agricultural organic waste co-digestion plants dropped drastically. It became very clear that new substrates urgently needed to be exploited. As a stopgap, operators shifted to energy crops, but those were not yet accepted by the compensation system.

Conversion Technologies and Heat Usage

In the 1990s, the generation of electricity from biogas took place in small Combined Heat and Power (CHP) plants with gas or dual fuel engines. The electricity generated was fed into the grid and the waste heat from the engine was used locally for the heating of the digester and of buildings. In the vast majority of cases, however, the utilization of heat was mostly limited, because there was rarely a need for year round heating in the case of residential and farm buildings, for example.

Costs and Market Development from 1990 Onward

Due to the StrEG, the feed-in tariff began at around 14 pfennigs/kWh (StrEG 1991) and rose to 15 pfennigs per kWh in the StrEG 1994. Still, in order to keep cost recovery or amortization within a manageable timeframe, investment in technology used to equip the digesters had to be kept low (Holz 2008, pers. comm.). As a result, an acceleration of development could not be achieved. Due to the fact that the technologies for electricity generation were still inefficient, the improved yield of gas did not directly result in a greater amount of electricity being fed into the grid. The development and use of digester technologies – from fermentation,

[28] Slaughterhouse waste, organic waste from industrial kitchens, biogenic industrial waste such as fat from the food industry.

[29] See history of the Wittmund co-fermentation plant on www.biogasanlage-wittmund.de (accessed August 17, 2009).

to the increasing use of gas for generating electricity – was determined by the political and economic conditions that dominated agriculture.

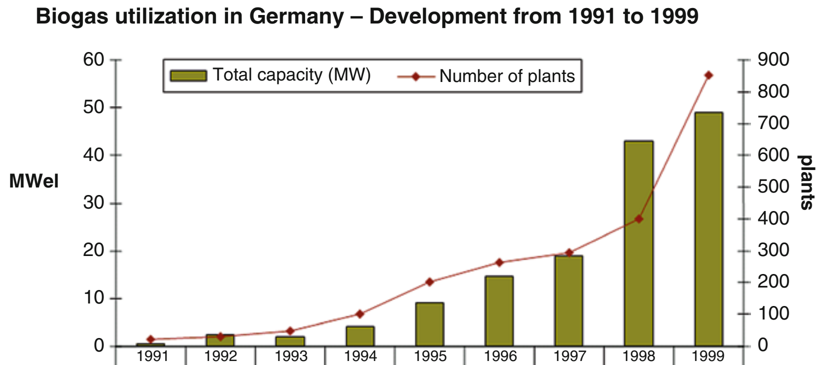
The distinct drop in electricity prices resulting from the liberalization of the electricity market in 1998/1999 led to a reduction of around 1 pfennig/kWh in the feed-in tariff by 2000. This caused an additional reduction in the already limited economic viability of biogas plants. Under the economic pressure, the market for CHP plants momentarily collapsed.[30]

The lack of accessible high-yield fermentation substrates also turned out to be a limiting factor. Renewable resources like energy crops were not (yet) an alternative, as the costs of production and supply were too high to be covered by the feed-in tariffs of that time.

Development of Plant Numbers

In the 1990s, biogas plants were still primarily constructed as farm biogas plants for livestock-based operations (cattle, swine, chickens). They continued to produce biogas and electricity primarily using the farm's own waste, such as semi-liquid manure.

Figure 4.4 shows that, by the end of the phase of emergence in 1999, only around 850 plants of around 50 MW_{el} had been installed. The size of the semi-liquid manure-based plants depended on the availability of substrate as determined by each farm and during this phase was on average 50–60 kW_{el}. Larger biogas plants were only present in the former GDR, since in this part of Germany there were agricultural operations consisting of several 1,000 animals and corresponding quantities of semi-liquid manure.



	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total capacity (MW)	1	2	2	4	9	15	19	43	49
Number of plants	20	30	50	101	200	265	295	401	850

Source: Elektrizitätswirtschaft; Scholvin & Thrän 2008, 35; author's illustration

Fig. 4.4 Total capacity and plant numbers of biogas utilization in Germany until 1999

[30] See http://www.bkwk.de/bkwk/infos/chronik/ (accessed August 17, 2009).

4.2.3.5 Actors in the Constellation

During the described phase of emergence, businesses in the developing biogas sector entered the constellation as actors. The practice of biogas generation continued to be determined by its use in the agricultural context. The research facilities also addressed their questions in this direction. Cooperation between research and practical application was still however limited to individual efforts.[31]

The Bundestag and Participating Departments

During this phase, the Bundestag had become a central driving force as a result of preparing and enacting the StrEG (see Section 3.7.1). It was only with the change of government in 1998 to the Social Democrat-Green coalition (see Section 3.5.2) that a new course was set. In addition to the agricultural innovation network for the investigation of digestion technologies, a new network established itself, which in the following period, concerned itself predominantly with conversion processes and the utilization of energy.

Toward the end of the phase, there was a realization that rural development and support for renewable energies shared similar aims. As a consequence, the Department of Agriculture intensified its promotion of bioenergy.

The Main Users: Farmers

Besides the generation of biogas, agricultural operations offer advantageous conditions for the production of renewable energy (space for wind turbines, ample rooftops for photovoltaics, etc.). This consciousness of being in possession of favorable prerequisites for the production of electricity gradually grew among farmers. Due to restricted financial means, the particular self-image of farmers and their wish for independence the “individual farm-yard style plants” continued to dominate. Co-operative solutions based on sharing did not yet play any role. Farmers exchanged experiences in familiar local user-networks. It was especially those farmers who had successfully implemented plants themselves that became recognized and trusted experts, as they were already considered part of the agricultural community.

Research Institutions in the Phase of Emergence

The emergence phase was shaped by a reorganization of the research landscape. Following reunification, the West German biogas research landscape expanded to

[31]For example in the case of individual scientists from the research facilities who became self-employed plant designers.

include institutes that had gathered experience in the generation and utilization of biogas in the former GDR.[32] In this way, the experience in the large-scale treatment of semi-liquid manure and generation of biogas gained in the GDR was rendered useful. In 1992, the "Institute for Agricultural Engineering" Potsdam-Bornim (ATB)[33] was founded which, together with IE Leipzig, dealt with a large proportion of biogas research.

In 1994, the newly founded Agency for Renewable Resources (Fachagentur für Nachwachsende Rohstoffe – FNR) assumed its duties as the Federal Research Ministry's project administrator. The FNR had an increasing influence on the direction taken by research and the setting of priorities in research support, both for renewable resources and biogas research.

New Businesses – The Origins of the Biogas Sector

The mid-1990s onward saw the establishment of the first businesses offering comprehensive advisory services for potential operators, especially in the field of technical planning. This included locating a sit, the selection of appropriate components, and was complemented by getting the plants up and running and monitoring the operation data.

The motives and processes involved in the establishment of these businesses demonstrated astonishing parallels: following higher education in technology and/or science, and motivated by "environmental concerns" the business founders had turned to biogas technology. All of them had an agricultural background and gained their practical experience through implementing their ideas for plants in their own experiments, which initially took place on their parents' farms. The successful implementation of a functioning "reference project" was what ultimately became the starting point for further contracts. To have commercial success in the agricultural sector, it was crucial to win the trust of farmers. In order to achieve this, it was important for those in the business to provide demonstration plants which could be seen in action, and for the farmers to think of them as "one of us".

The CHP and semi-liquid manure technology produced by well established manufacturers and businesses had hardly gained a foothold at this point. Besides technical planning the new businesses provided essential coordination services: site selection, substrates, biochemical processes, and assistance with planning permission. On top of all this, it was necessary to be able to deal with the mindsets of the farmers. The ability to bring together all of these aspects was what gave these new businesses the advantage (Holz 2008, pers. comm.).

[32]These were the Institut für Düngungsforschung at the Akademie der Landwirtschaftswissenschaften in Potsdam and the Institut für Energetik (Leipzig) (IE Leipzig).

[33]Today known as the Leibniz-Institute for Agricultural Engineering Potsdam-Bornim.

The new businesses worked with components from various suppliers of agriculture and semi-liquid manure technology. The manufacturers reacted to the requirements of the plant builders and adapted components accordingly.

The Founding of Associations: The German Biogas Association and Verband Biogas Union e.V.

Beginning with the operators of farm-based biogas plants in southern Germany, the biogas movement began to organize itself. In 1992, the German Biogas Association[34] was established under the chairmanship of Heinz Schulz[35] as a trade forum of primarily small and medium-sized agricultural operators and businesses, which provided the sector with biogas technology and process engineering. For members of the Biogas Association, the yearly trade association conferences offered the most important forum for professional networking. From the mid-1990s onward, they sought professional exchanges with neighboring Austria and Switzerland. Representatives from other EU member states also gave reports on the state of development and potential for expansion in their own countries.[36] The association thereby encouraged an early orientation toward neighboring European markets.[37]

In contrast, the political representation of the association was less effective. Internal conflicts of interest, engendered by a heterogeneous membership consisting of operators, plant builders and manufacturers hindered the formation of a unified front. Faced with chronic financial shortages, the association had hardly any influence on amendments to the StrEG during the phase of emergence (Schütte 2008, pers. comm.). Following reorganization at the end of the 1990s, the association's administration expanded and, by establishing a branch in Berlin, managed to gain better access to the levels of Government where decisions are made.

In the mid-1990s, a group of large-scale plant operators formed within the association. In 2000, this group institutionalized itself as "Verband Biogas Union e.V" [38] and formed an independent representation for large-scale agricultural, industrial as well as municipal plant operators. This newly founded association took the interests of the new, industrial operators into account.

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[34] Since 1999, the association has been based in Freising, near Munich: See http://www.biogas.org/ (accessed September 29, 2009).

[35] Dr. Heinz Schulz (dec. 1998) was both the leader of the Environment and Energy Technology department of the Bavarian Landesanstalt für Landtechnik (State Institute for Agricultural Technology) as well as director of the Landtechnischer Verein (Association of Agricultural Technology) in Bavaria.

[36] This is documented in the association's conference proceedings from 1997 concerning the main topic of Europe, with reports from Luxembourg, England, Austria und Italy.

[37] During the yearly conference of 2004, the Association expanded its focus area to include EU candidate countries such as the Czech Republic.

[38] http://www.biogasunion.de (accessed August 21, 2009) based in Berlin.

4.2.3.6 Interpretation of the Constellation: Driving Forces and Constraints

The agricultural research facilities formed a primary network of innovation whose priority was the effective and environmentally friendly utilization of agricultural waste, especially semi-liquid manure. With the "Programm Gülleverwertung" (semi-liquid manure utilization program), the Federal Research Ministry reacted to the problems of excess semi-liquid manure produced by factory farming. The "Programm Gülleverwertung" had the effect of advancing the installation of modern large-scale slurry treatment plants. These proved that it was possible to generate biogas on a large scale and that the profitability could be further increased by the co-digestion of biological waste and other solid materials. The results had a positive influence on the assessment of the potential of biogas utilization in terms of energy, as well as with respect to its contribution to climate protection, and as an important component in rural development. There was, however, a lack of interfaces allowing effective knowledge transfer between biogas research (partly research involving large-scale plants) and the operators and builders of farm-based biogas plants.

In practice, farmers experimented with the addition of grass and other plant wastes in order to improve the gas yield and therefore the economic efficiency of the farm-based biogas plants. The founding of the German Biogas Association in 1992 made a broader exchange of specialist experience between the practitioners possible and helped to spur things on. The beginnings of a biogas sector became apparent.

For the first time, the StrEG managed to generate an economic incentive for the generation of biogas and put it in the context of energy production. Despite the payments initially being too low, the operators regarded the StrEG as a sign of things to come. It was increasingly not only the idealists, but also conventional farmers who sought a second income based on biogas generation.

At the center of the process of innovation were the development of more efficient fermentation substrates and the necessary optimization of the digestion process. The use of organic waste in co-digestion plants was economically attractive. Actors in the waste management sector stepped in and it became clear that there was a need to separate substrates that were eligible for payments from those that were not.

4.2.4 Phase 3: Intensified Emergence Between 2000 and Mid-2004

4.2.4.1 Characteristics of the Constellation

The beginning and end of this phase were marked by renewed legal interventions; the enactment of the Renewable Energy Sources Act (EEG) in 2000 as well as its updating in 2004 (Fig. 4.5). Compared to the preceding phase, the complexity of the constellation increased both in terms of the greater number of actors (diversification) as well as in terms of state intervention (readjustments). From a technical standpoint, the availability of fermentation substrates took on greater importance.

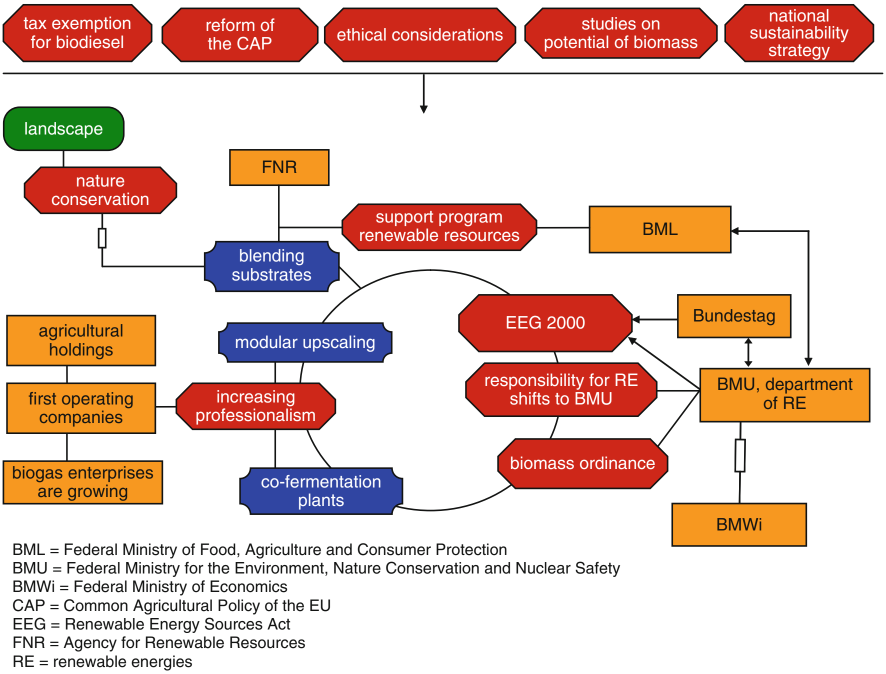

Fig. 4.5 Constellation phase 3: intensified emergence between 2000 and mid-2004

The interest of farmers in renewable resources for the generation of energy increased due to the significant role they saw in it for rural development.

Among the actors, the Federal Environment Ministry (Bundesumweltministerium – BMU) – with the support of the Bundestag – gained in influence, and with the Biomass Ordinance (Biomasseverordnung – BiomasseV) it carried out a readjustment that proved to be an important instrument in securing the aims and intentions of the EEG with regard to an environmentally friendly utilization of biomass. Between 2001 and 2004, the number of plants quadrupled.

4.2.4.2 Sector-Specific Context, Influencing Factors and Processes from 2000

Development was embedded in a complex context of heterogeneous influencing factors. Stimuli at the European level drove on national strategies for the support of renewable energy. In the agricultural sector, the market conditions changed as a consequence of the European reform of the Common Agricultural Policy (CAP reform).

The public discussion concerning the ethics of using food to generate power as well as the cultivation of energy crops instead of food marred the otherwise positive mood.

The EU Directive for the Support of Renewable Energy

The EU directive for the support of renewable energy 2001 (see Section 3.3.2.4) constituted the main reason for the setting of national targets and the implementation and updating of support mechanisms in the area of renewable energy. Regulatory mechanisms at the EU and national levels (e.g. the Federal Government's sustainability strategy; see below) affected each other.

The Federal Government's Sustainability Strategy (2002)

The targets for the generation of electricity from renewable sources were set in the Federal Government's sustainability strategy (see Section 3.5.5). These targets required a massive expansion of bioenergy use. The strategy empowered the political actors to establish more extensive incentives in order to realise the potential of biomass. In this respect, the sustainability strategy formed a context that determined the course of the continued expansion of biogas generation.

European Reform of the Common Agricultural Policy (CAP Reform) 2003

On the 26th of June 2003, the EU Agriculture Ministers enacted a fundamental reform, the CAP reform. It changed the support mechanisms of the common agriculture sector to an area-determined payment scheme.[39] This "decline" on the one side coincided with the support for renewable resources on the other side and caused, in part, a fundamental rethinking among farmers. Fearing a drop in income as a result of the reform of the CAP, farmers became increasingly open to earning their income through energy-based activities, such as increasing their production of renewable resources and their use to produce power.

National Studies of the Potential of Bioenergy/Biogas

In the 1990s, the potential of biomass to generate electricity had not yet been thoroughly investigated.[40] From 2002, the BMU paid more attention to the potential of bioenergy. The extent to which the use of existing potentials would be competing

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[39] The reform of the CAP led to the introduction of a single payment scheme for determining direct payments to farmers. The size of the payment is partly determined by the previously received direct payments and partly by the standardized amounts per hectare of eligible land. The payment is linked to compliance with certain standards (cross compliance). See BMELV (2006, 68 sqq.) and http://ec.europa.eu/agriculture/capreform/index_de.htm (accessed June 13, 2007).

[40] For example Kaltschmitt & Wiese (1993); Nitsch & Langniß (1999).

with other uses, as well as the more general feasibility of making full use of such potentials was also to be investigated at this time. The studies "Ökologisch optimierter Ausbau der Nutzung erneuerbarer Energien in Deutschland" ("Ecologically optimized expansion of the utilization of renewable energies in Germany") (Nitsch et al. 2004) and "Stoffstromanalyse zur nachhaltigen Nutzung von Biomasse" ("Material flow analysis for the sustainable utilization of biomass") (Fritsche et al. 2004) indicated great and as yet untapped potential for the cultivation of energy crops. The studies provided a justification for the EEG's strong support for the use of cultivated biomass.

Ethical Considerations Regarding the Use of Grain to Produce Energy

At this point, market prices for crop had decreased dramatically.[41] As a result, farmers considered the possibility of burning grain to yield power. This triggered an emotionally loaded, extremely controversial discussion, which impaired the image of bioenergy use.

This also affected the biogas sector, even though the crops used for biogas production do not directly influence the food supply. In fact, it is more closely associated with animal fodder. Agricultural associations and churches regarded the burning of rye for the generation of power as unjustifiable, even in the case of low-value waste grain.[42] The symbolic power of grain as a food is most certainly one reason why a sophisticated public discussion weighing up the pros and cons of the use of grain for power generation was barely conceivable (Müller 2004, 6). The ethical doubts were taken so seriously that a motion to allow grain to be used a standard heating fuel was turned down by the Bundestag.[43] The discussion about the burning of grain can be seen as a precursor of the "food or fuel discussion" which came later.

4.2.4.3 Governmental Guidance and Economic Context

In this phase, the use of biomass played a more central role in the Federal Government's energy policy targets. According to Oettel (2001), biomass was assigned an important role in the attainment of CO_2 reduction targets. This was reflected in the sustainability strategy, which set the course for a series of legislative procedures.[44]

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[41] Since 1999, the price of grain was lower that its value as fuel. The price of rye eventually fell to 7 euro/dt (Schütte 2008, pers. comm.).

[42] Interestingly, the use of rapeseed oil – a high quality food product – was not subjected to the same degree of criticism.

[43] Cf. BT-Drs. 16/6418 of October 18, 2007. This was justified by saying that securing food supplies whilst avoiding rising costs had priority and that problems resulting from the release of unwanted emissions during combustion have not been satisfactorily solved yet.

[44] EEG 2000, EEG 2004 (see Index of legal references), BiomasseV 2001, privileges under building law in EAG-Bau 2004.

Improved Tariffs Specified in the EEG (2000) and Supplementary Support

With the tariff regulations in the Renewable Energy Sources Act (EEG[45]) of 2000, the use of biomass for the generation of electricity experienced an improvement in circumstances. The separation of payment from average revenues (unit charge) led to the EEG of 2000, which specified 20 pfennigs/kWh, exceeding the previous payment by 5 pfennigs. By this means, the economic viability of biomass increased considerably. The basic tariff – minus the annual degression[46] of 1% (from 2002) – was now guaranteed for a period of 20 years. The degression rate was intended to increase the incentive to decrease costs (Table 4.1).

Table 4.1 Remuneration for electricity derived from biogas according to § 8 EEG 2000

Capacity	Basic tariff (cents/kWh)
Up to and including 500 kW	10.23
Up to and including 5 MW	9.21
Up to and including 20 MW	8.7

The upper limit of support for biogas plants was increased from 5 to 20 MW of installed electrical capacity. Thus the system of incentives also aligned itself with large-scale plants that were not necessarily based on individual farms.

Alongside the EEG, a subsidy of up to 30% of investment costs was introduced by the German Federal market incentive program. Individual states[47] granted additional subsidies for biomass projects, which originated in the Federal Agriculture Ministry's "Agricultural Investment Program" (Agrarinvestitionsprogramm – AIP). Additionally, there was the support arising from the "Renewable Resources Subsidy Program" (see Section 4.2.2.3). The combined supporting effect of EEG tariffs and investment subsidies developed a powerful momentum.

The German Biogas Association failed in their initiative to introduce a law (Gaseinspeisegesetz – GEG). Like the EEG it was meant to compensate for biogas (biomethane) directly fed into the gas distribution network. As a result, the use of biogas power was limited to the production of on-site electricity in combination with decentralized heating.

Readjustments: The BiomasseV (2001) in the EEG of 2000

During the deliberations for the EEG of 2000, it became clear that the concept of biomass should be more clearly distinguished from organic waste - and residues

[45] For information on the establishment of the Renewable Energy Sources Act (EEG) see Section 3.7.2.

[46] Degression refers to the process of the relative or absolute reduction of one parameter with the rise of a correlated parameter.

[47] See Hoffmann (2002, 73).

as defined by waste- and animal carcass disposal legislation. This was necessary in order to limit the use of environmentally harmful materials for the generation of electricity paid for under the EEG. The Bundestag trusted that the Federal Environment Ministry would be enthusiastic about renewable energy, but that it would also play a well-balanced role when it came to issues concerning the environment and sustainability (Dürrschmidt 2007, pers. comm.). Thus, the Federal Environment Ministry was authorized to develop an interdepartmental draft for the enactment of a Biomass Ordinance (BiomasseV). The creation of the ordinance was considered essential in order to prevent a failure in EEG support, and to steer the adoption of biomass in the right direction. Although the agreement of the Bundestag, the Bundesrat and the Federal Government was required in order to enact the BiomasseV, it came about relatively quickly on the 28th of June 2001. Only a week after its enactment, the Biomass Ordinance came into force and ensured that the EEG served to attain primarily energy and climate policy goals rather than those of waste management.[48] Organic wastes were only to be used for power generation to the extent that they contributed to a reduction in the cost of biomass-derived electricity.

Federal Support for Research

While the Federal Ministry of Research and Technology's fourth energy research program (1996–2005) made no explicit stipulations regarding support for biogas technologies, the Federal Ministry of Agriculture continued with the support of research, development and demonstration projects based on the use of biomass for power production. This was undertaken within the framework of the open-ended "Renewable Resources" research program (Förderprogramm Nachwachsende Rohstoffe).[49] The program was provided with a budget of 27 million euro for the year 2003 (BMVEL 2003, 6). It also covered research on processes based on *anaerobic* digestion for the generation of biogas in agricultural biogas plants. In addition, the palette of usable raw materials was expanded in order to test the limits of the economically viable utilization of organic waste and residues. As a whole, support for research was intended to be more strongly tailored to addressing practical issues.

[48]Within the scope of the EEG, the BiomasseV specifies which materials count as biomass, which procedures for power generation from biomass fall within the scope of the law and which environmental requirements are to be followed when generating power from biomass. For the purposes of this regulation, those things which count as biomass are most significantly plants and parts of plants, plant and animal waste and byproducts, and biological waste, including waste wood.

[49]The support program follows the support framework for the period 1996–2000.

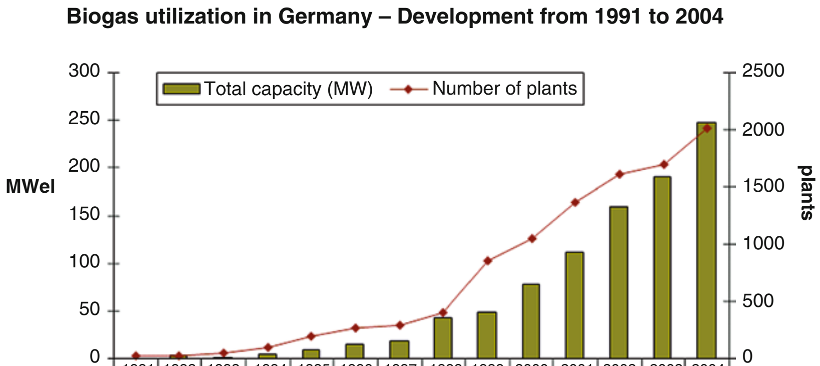
4.2.4.4 Technology and Market Developments

Development in the Number of Plants 2001–2004

At the end of the 1990s and with the implementation of the Renewable Energy Sources Act (EEG) in 2000, the growth in plant numbers accelerated (see Fig. 4.6). The enactment of the EEG was followed by the construction of 600 new plants in 2001, with a total installed capacity of 200 MW.

The average plant capacity had doubled from some 60 kW_{el} at the end of 1999 to around 120 kW_{el} in 2004. This demonstrated the trend toward significantly larger plants of 250 kW_{el} and more in the majority of plants.

In 2004, approximately 2,000 plants were in operation nationally, but the growth rate of plant construction threatened to decline. According the German Biogas Association, the growth rates would only be maintained if energy crops could be mobilized as digester substrates.



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Total capacity (MW)	1	2	2	4	9	15	19	43	49	78	111	160	190	247
Number of plants	20	30	50	101	200	265	295	401	850	1043	1360	1608	1700	2010

Source: Elektrizitätswirtschaft, Scholvin & Thrän 2008, 35; author's illustration

Fig. 4.6 Total capacity and plant numbers of biogas utilization in Germany until 2004

State of Technical Development: Dry Fermentation

A requirement for the utilization of energy crops richer in dry content was dry fermentation. During this phase, the technologies of dry fermentation in continuously and semi-continuously running test plants were in their experimental stages, though a very few were undergoing pilot tests.

Supporters of the digestion of renewable resources emphasized the advantages of developing new crop rotation sequences and the cultivation of new energy crops.

Economically speaking, the methanation of externally sourced biomass – such as from landscaping waste or lawn mowing – could generate new service sectors (energy farms or similar) (Hoffmann & Lutz, o. J.). The higher the proportion of substrates derived from renewable resources, and the lower the proportion of slurry, the less it was the case that such operations were limited to agricultural locations.

Pioneer Projects

Between 2002 and 2005, some biogas pioneer projects serving as "flagships" were implemented to attract public attention. They were intended to demonstrate feasibility on municipal level and to enhance acceptance.

A prominent flagship project in the field of "bioenergy villages" was the village of Jühnde in the south of Lower Saxony. Here, both a biogas plant and a local heating network were implemented. The plant entered operation at the end of 2005; the construction of the heating grid was finished in 2006. Local farmers provide 75% of the necessary biomass, and the rest comes from other farmers within a radius of 35 km. A wood-chip fired power plant supplements the energy supply in periods of peak demand during the winter months.

The biogas plant is operated by a co-operative of 200 local shareholders. Intensive involvement of the locals was regarded as vital for the success of the project. In eight workgroups, local people studied the topics of joint operating companies, biogas, wood-chip fired power plants, local (as opposed to district) heating networks, wood biomass, renewable resources, Heating, Ventilation and Air Conditioning (HVAC) and publicity work (Fangmeier 2008, pers. comm.).

The Development of Costs

The specific investment costs of biogas plants varied between 2,000 and 4,000 euro/ kW_{el}. They were only to a very limited extent dependent of plant *size*. On average, around 45% of costs were spent on construction, 49% for the plant technology and only 6% for the motor generating electricity. There was also great variation in the annual cost of operation, especially in cases where energy crops were used. The specific costs of electricity generation lay between 8 and 13 cents/kWh. Only a small proportion of plants are making a profit. The factor that determined the economic viability of plants running on energy crops was the electrical capacity of the CHP plant. The amortization time for biogas plants was predominantly in the region of 4–12 years.[50]

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[50]Data concerning profitability were collected in a nationwide monitoring program, which included 60 of the 317 biogas plants which were put into operation between 1999 and 2002. For information on the results see FNR (2005a and 2005b).

4.2.4.5 Actors in the Constellation

Agricultural Operations and Investors

In the face of low crop prices and the resulting decline in agricultural income, biogas generation gained increasing significance as a component of rural development. Amongst farmers it gained acceptance as an alternative source of income. Demand for plants rose predominantly among individual farmers. They installed small to medium-sized farm-based biogas plants that were integrated into their agricultural operations. Faced with the increasing investment costs of energy crop-fed biogas plants, farmers began to join forces in so-called operating companies.

In the states of the former GDR, large operators (farming cooperatives with up to 3,000 livestock units and corresponding area) established themselves as biogas plant operators. Having a high slurry output and large cultivation areas at their disposal, they were predestined to construct biogas plants of an "industrial" scale.

Businesses in the Biogas Sector

During the phase of insipient market relevance, the businesses founded in the mid-1990s (see Section 4.2.2.5) experienced a genuine growth spurt. The businesses expanded and within a very short period their employee numbers multiplied. New businesses providing plant planning and operating services with up to 50 employees were founded. The growth in businesses generated regionally significant job and value creation effects.

The first surge of growth in the sector was generated by the entry of new providers into the market. In addition, long-established businesses in related business areas (e.g. the construction of landfill gas plants) expanded their business areas to include the construction of biogas plants. This led to differentiation in the supply structure. While some continued to primarily supply the agricultural market with small and medium-sized plants running on slurry and renewable resources, others sought to enter into the construction of large-scale industrial renewable resource-fed plants. As an exception to the positive trend in the sector, there were also setbacks in that some businesses were unable to keep up with the runaway growth and had to file for insolvency.

Interaction Between the Bundestag and Participating Departments from 2000

During the phase of insipient market relevance, the Federal Environment Ministry, under Minister Jürgen Trittin, was a central driving force. Having already been intensely involved in the preparation and enactment of the EEG at the instigation of the Bundestag, the ministry also managed the formulation and enactment of the Biomass Ordinance (BiomasseV).

From 2002, the departmental responsibility for renewable energy on federal level was completely moved from the Ministry of Economy to the Ministry for the Environment. From this point onward, the Ministry for the Environment became the main contact and executive body in all affairs concerning support for renewable energy. The Ministry for the Environment's policy was shaped by basic energy policy conflicts with the Ministry of Economy concerning the role and significance of renewable energy. In this case, positions of active resistance had to be overcome.[51] Concerning the EEG's support for the biogas sector, there was a coalition of interests between the Ministries for the Environment und Ministry of Agriculture. The agriculture sector profited considerably from the EEG feed-in regulations. Critics regarded the "prioritizing" of the biogas sector as having gone too far, but then described the EEG as "until now, the most effective mechanism for developing rural areas".

4.2.4.6 Administrative Constraints and Conflicts of Aims

The planning of new biogas plants exerted increasing pressure on the authorities responsible for local development planning. Proposals for plant locations concentrated in areas of intensive livestock rearing, were feared to cause cumulative problems due to additional emissions and odor problems. The location of biogas plants in the vicinity of built-up areas was regarded as especially problematic.

Local authorities, faced with a flood of applications and unmanageable requirements for planning approval, saw themselves as having formidable problems finding locations suitable for granting permission. The problems of granting permission for plants increased the pressure to remedy the situation by making legal adjustments.

A further need for readjustments concerning how to handle conflicts of objectives between climate protection and conservation became clear. In the 1990s, the developing bioenergy scene was often closely bound with the ecological and environmental movement. Initially, biogas generation therefore had the support of German conservation and environmental associations as a basic principle.[52] From 2000 onward, there was an increase in criticism of the negative environmental impacts of increased bioenergy production in the context of conferences of specialists and specialist publications.[53] With the increasing growth of the sector, the "ecological coalition" of environmental and conservation associations,

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[51] Between 1998 and 2002 the Ministry of Economy was led by Minister Werner Müller (independent), and from 2002 by "superminister" (Minister for Economics and Labour) Wolfgang Clement (SPD). In both cases the politicians were closely associated with the energy sector and did not support the national renewables strategies.

[52] The management level of the conservation associations, for example, had in principle committed themselves to the aims of climate protection (NABU 1998).

[53] Inter alia Ammermann (2005); Rode et al. (2005).

"green businesses" and "green politics" proved itself not to be free of conflicts and contradictions.

From the perspective of conservation organizations, the negative environmental impacts caused by the unbridled expansion of bioenergy were the most significant issue. Whether in order to grow food or to grow energy crops, the intensification of land use in agriculture would once again lead to an accelerated loss of biodiversity and habitat diversity in agricultural ecosystems. Moreover, the climate neutrality of intensively cultivated energy crops was in question due to the high inputs of artificial fertilizers, pesticides and herbicides, which cause a net release of CO_2 during their production. Criticisms of conservation and environmental organizations were aimed at the Federal Ministry for the Environment and, in the case of the cultivation of energy crops, the Federal Ministry of Agriculture. With this criticism of green energy and their support for the "ecologically sound" expansion of bioenergy, they were faced with the dilemma that they might be playing into the hands of conventional energy providers.

While the Ministry for the Environment and the biogas sector took the criticisms of the conservation and environmental organizations seriously and made efforts to develop strategies for minimizing conflicts, the Ministry of Agriculture was evasive. Negative environmental impacts within agriculture were to be avoided by adhering to the specifications of "good professional practice" ("Gute fachliche Praxis" – GFP).

4.2.4.7 Interpretation of the Constellation: Driving Forces and Constraints

The driving force during this period was the extension of the support for biogas, which had begun with the StrEG by enacting the EEG of 2000. Increased feed-in payments for electricity generated from biogas improved the investment security of plant construction and also meant that biogas generation drew the interest of investors and joint operating companies.

The new increase in feed-in payments simultaneously functioned as a support for the development of agricultural infrastructure. The motives and interests of agricultural policy and renewable energy policy overlapped each other. To the extent to which biogas generation contributed to the stabilization of rural development, the Federal Environment Ministry and the Ministry of Agriculture had a considerable number of aims in common.

The system of agricultural innovation which was supported by the Department of Agriculture became open to renewable energy: besides the utilization of residues, climate protection goals were increasingly taken into consideration and used as justification for the support of bioenergy technologies. The Agency for Renewable Resources (FNR) drove on the implementation and evaluation of numerous projects in the bioenergy sector (cf. Weiland et al. 2004), whereby a process of optimizing capacity and efficiency set in.

The process of the professionalization of the biogas sector continued. The stronger the governments' (institutional) support for the biogas sector, the greater the significance of having effective political representation. The operator structure differentiated further into "large-scale industrial plants" and "farm biogas plants". Diverging interests forced representatives within the sector to undertake restructuring (the founding of new associations, reorganization).

4.2.5 Phase 4: Take-off from Mid-2004 to the End of 2006

4.2.5.1 Characteristics of the Constellation

Combined with the bonus system, the increased feed-in tariffs specified in the EEG of 2004 drove on the construction of biogas plants that ran on renewable resources (Fig. 4.7). These stimuli immediately resulted in growing numbers of plants and increasing capacity and so these stimuli were at the core of the constellation.

The European Law Adaptation Act for the Construction Sector (EAG-Bau)[54] amendment simplified the issuing of planning permission for biogas plants of up

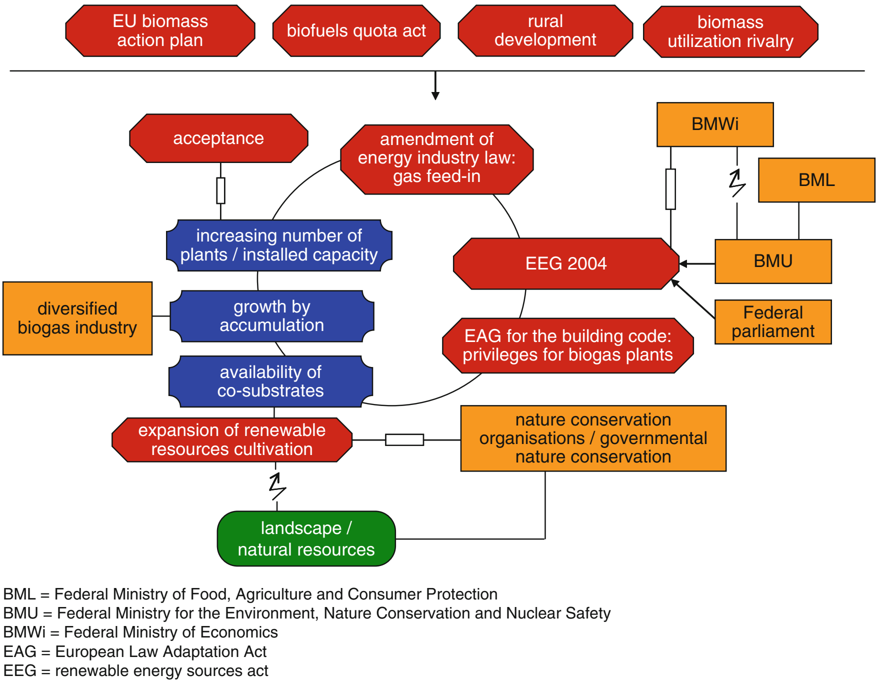

Fig. 4.7 Constellation Phase 4: take-off between mid-2004 and 2006

[54]European Law Adaptation Act (see Index of Legal Sources).

to 500 kW and promoted the construction of more plants by removing the obstacles that had existed until then – this was also an important signal promoting development.

In terms of technology, the increase in size (upscaling) expected during this phase was attained though the accumulation of plants with capacities up to 500 kW; occasionally “biogas parks” were developed. The grading of the feed-in tariffs according to plant capacity had the effect of putting a cap on technological economies of scale, and this effect defined the constellation technologically. The trend toward large-scale plants continued. Lack of substrate could slow down the construction of plants running on renewable resources.

Due to the increased significance of substrate availability for the economical operation of plants, the expanding cultivation of energy crops was classified as a technical element: sensitivity to a lack of substrate could stall the expansion of plant construction.

The diversification of the operator structure was characterized by the appearance of new actors in the form of joint operating companies and commercial providers of energy services. Together with biogas businesses and agricultural operators, the biogas sector gained significance.

At the periphery, there was growing conflict between the production of bioenergy and nature and resource conservation. Protagonists from nature and resource conservation emphasized restrictions that should be observed in the interests of sustainability, like preserving biodiversity. Their influence remained limited, however.

It became apparent that applying for planning permissions brings about conflicts with local people. Effects of increased traffic due to transporting digester substrates and digestion residues, as well as fears associated with the operations themselves (odors, risk of accidents) led to rejections by the public. Because lack of local acceptance produced a restrictive context, the sector had to proceed carefully during location planning.

4.2.5.2 Sector-Specific Context, Influencing Factors and Processes

Strategic Stimulus: The EU Biomass Action Plan (2005)

In directive 2001/77/EC, the EU member states made a commitment to abide by a set of objectives for electricity generation. However, of the renewable energy technologies, only wind power grew rapidly, whilst hydropower stagnated and biomass only exhibited limited growth. In most cases it appeared to be impossible to attain the objectives without an increased utilization of biomass. The European Commission presented a Biomass Action Plan (COM 2005), which called for a greater effort on the part of the member states to increase utilization of biomass for energy production. In national Biomass Action Plans, the member states were supposed to develop concepts at the national level for the increased utilization of biomass for the purposes of energy production. This stimulus from the EU reinforced the significance of the agricultural sector within the German states as producers of biomass and generators of bioenergy.

The Biofuel Quota Act: Legal Codification of Competing Uses

The bioenergy sector benefited from the importance placed on the utilization of biomass for climate protection. In 2006, the Biofuel Quota Act (Biokraftstoffquotengesetz – BioKraftQuG) was adopted. This introduced a quota for the minimum admixture of biofuels to gasoline and diesel starting on 1 January 2007. The purchase of biofuels was thereby guaranteed. With the purchase guarantee, the law considerably strengthened the biofuels sector. Competition was enhanced as the quota specified that a certain minimum area was required for the production of oil-producing crops. This increased the competition over usage and objectives in areas under cultivation. After being passed, the law was subject to increasing criticism, as it supported the least efficient form of bioenergy use in comparison with the other methods of biomass utilization.

Prospects for Agriculture Deriving from Climate Protection

Profiting from the improved economic conditions, the agricultural sector had an increasingly positive attitude toward the production of biofuels. Farmers welcomed the economic prospects afforded by the cultivation of energy crops. With new systems for the cultivation of energy crops and the breeding and patenting of energy plants for the various methods of energy utilization, interest in bioenergy generation took on a momentum of its own. At the same time, the rationale of climate protection and CO_2 reduction was, to an extent, in competition with the aims of achieving financial security through utilization for energy.

Competition Within Agriculture over Utilization and Aims

Following the introduction of the Renewable Resources Bonus (Bonus für Strom aus nachwachsenden Rohstoffen – NawaRo-Bonus) in the EEG of 2004 (see Section 4.2.4.3), the proportion of areas being used for the cultivation of renewable resources jumped dramatically (see Fig. 4.8). This initiated an intense discussion whether there was sufficient land availability for the production of renewable resources – in this case energy crops. In addition, cumulative effects of permanent land claims for other uses were of growing concern.

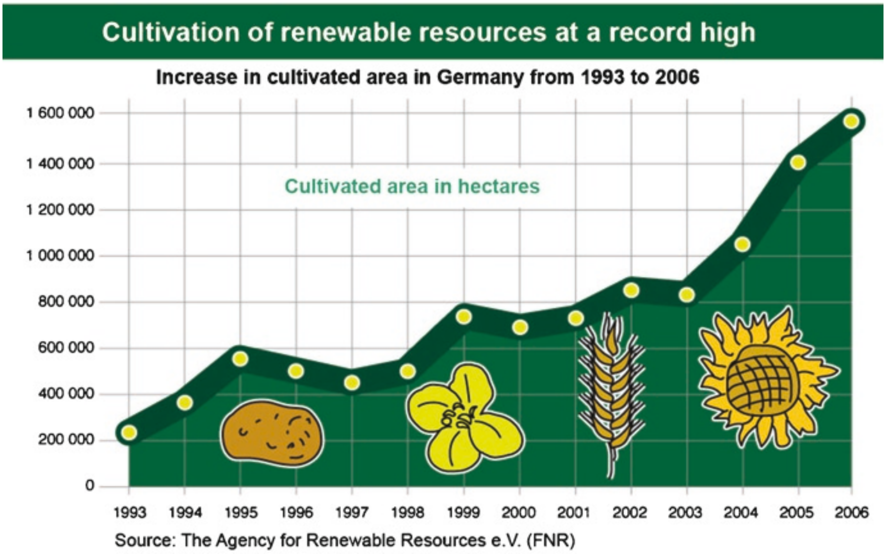

Fig. 4.8 The increase in the area of land in Germany used for cultivating renewable resources

The increasing land needed for the cultivation of energy crops resulted in competition with other agricultural land uses[55] as well as increasingly with the land requirements of conservation[56] and forestry.[57]

Appreciable areas were made available for the cultivation of energy crops by reactivating set-aside and fallow land. This was associated with an intensification of land use. It often took place in those locations that, from an ecological point of view, had only limited suitability for intensive cultivation. In some regions, even grassland was ploughed up. This was especially criticized by nature conservation groups. Faced with these developments, conservationists demanded that climate protection via cultivation of energy crops should not be at the expense of water and soil resources, species conservation or habitat protection.

Competition between the production of food and the generation of biogas from energy crops appeared to be less significant than the competition for land between conventional biomass cultivation for either food or for fuel.[58]

[55] For example the increased requirements of land area in order to make agriculture more extensive and ecologically friendly, as well as areas for the cultivation of fodder and foodstuffs in areas of intensive stock rearing. Within agriculture, further competition also existed in the material utilization of renewable resources.

[56] For example, the entitlement – as enshrined in conservation law – to 10% of the area for the wildlife corridor, the demand for areas of land in order to compensate for ecosystem interference caused by building and infrastructure projects, areas for contractual nature conservation and conservation measures integrated with cultivation.

[57] Such as afforestation, especially in sparsely wooded regions.

[58] For information on the crisis in food supply and food price see Section 3.1.5.

However, agricultural groups perceived no fundamental restrictions on area. Thus, land availability was not a limiting factor for the ambitious bioenergy targets. In their view, competition with food production was buffered by the reactivation of set-aside land. In addition, there was still a food surplus, meaning that no shortages were to be expected as a consequence of a reduction in food production.[59]

Sustainable biomass production and use was also discussed in scientific circles. Among other issues, the CO_2 reduction was under critical review. When taking the entire production cycle into account, the bioenergy contribution to CO_2 reduction and, as a result, to the climate protection aims, appeared to be low.

Apart from regulatory mechanisms, conservationists had no way of combating the increasing extent and intensification of land use. Faced with the economic gains promised by the cultivation of renewable resources, the aims of the Federal Nature Conservation Act (Bundesnaturschutzgesetz – BNatSchG) were no longer attainable. The mechanisms of nature conservation (contractual nature conservation; rewards for rural conservation achievements, compensation for forgone use) proved to be incapable of competing. Regionally differentiated energy crop quotas and so-called "defined areas for the cultivation of energy crops" (see Schultze & Köppel 2007; TU München & TU Berlin 2007) might be able to remedy the situation. At least at an informal level, they offer the opportunity to set in motion a process of coming to an agreement with respect to the acceptable extent of energy crop cultivation.

4.2.5.3 Governmental Guidance and Economic Context

In the face of growing conflicts, the interplay of energy policy, agricultural policy and environmental policy in the regulation of cultivation and the utilization of agricultural biomass for energy production came increasingly into focus. The main mechanism of energy policy continued to be the Renewable Energies Sources Act (EEG, see Section 4.2.4.3), which, through its differentiation of feed-in tariff rates established significant stimuli.

Biogas in the Renewable Energy Sources Act (EEG) of 2004

The fact that the cost for the generation of electricity varies according to the different biomass fractions and processes being used was taken into account by adjusting the minimum feed-in tariff and differentiating according to the biomass used and the plant capacity (see Table 4.2) (Dreher 2005, 394).

In the EEG of 2004, as in the EEG of 2000, the basic tariff per kWh was graded according to plant capacity. With its increased minimum tariff, the EEG of 2004

[59]This argument might have applied on the national level, however, regionally (e.g. in intensive stock-farming areas) shortages and increasing fodder production costs still occurred as a result of increasing lease prices and higher costs of transport for the procurement of fodder.

Table 4.2 Tariffs for electricity produced from biogas according to § 8 EEG 2004 (cents/kWh)

Capacity	Basic tariff[a]	NawaRo bonus	CHP bonus	Technology bonus
Up to and including 150 kW	11.5	6	2	2
Up to and including 500 kW	9.9	6	2	2
Up to and including 5 MW	8.9	4	2	2
Up to and including 20 MW	8.4	0	2	0

[a] Commissioned 2004, 1.5% degression per year on the basic tariff in the subsequent years

aimed to give more support to small-scale plants with capacities of up 150 kW. At the same time, under certain conditions, it was possible to increase the tariff through bonus supplements to the minimum tariff, which were not subject to degression. Up to electrical capacities of 150 kW it was possible to be remunerated with a total of 21.5 cents/kW if all of the heat produced was used (CHP-Bonus) and if the biogas was produced or converted using certain technologies which were eligible for support (Technology Bonus) (FNR & Hartmann 2007, 113).

Bonus System

A new element in the EEG of 2004 was the bonus system for the use of renewable resources, Combined Heat and Power and technological innovation (see Section 3.7.2.2). The bonus system consisted of a renewable resources bonus ("NawaRo-Bonus"), a technology bonus and a CHP bonus.

According to Döhler (2008, pers. comm.), the introduction of the NawaRo bonus[60] had two motivations: one was to reduce the use of waste and polluting substances and promote the use of "environmentally unproblematic" substrates. The other motivation was to create an incentive for farmers whose production costs were no longer covered by the low agricultural prices, to produce energy crops. With 6 cents/kWh, adding up to the basic feed-in tariff, the "NawaRo bonus" was supposed to ensure that the production costs for the digester substrate were covered. In fact, this bonus provided the desired decisive stimulus for the increased utilization of cultivated biomass for the generation of biogas and then electricity (FNR & Hartmann 2007, 113). In connection with the technology bonus, it also supported interest in the implementation of so-called dry-fermentation plants. As in the case of the capacity graded basic tariff, it was intended to benefit small and medium-sized plants more than larger ones.

For electricity produced as specified in the CHP Act (KWK-Gesetz), a new CHP bonus of 2 cents/kWh was paid. This CHP bonus was only paid for that proportion of electricity production where an external utilization of heat took place (no digester heating). This was intended to raise the overall effectiveness by utilization

[60] See § 8, Abs. (2), Nr. 1, (a).

heat produced during electricity production. Plant operators were required to provide an appropriate heat utilization concept.

A third possibility was specified, whereby the use of innovative plant technology was awarded a technology bonus of 2 cents/kWh. It was paid, for instance, in the case of electricity generated from biogas which was itself generated by thermochemical gasification or dry fermentation plants, as well as when the biogas used for electricity generation was processed to the same level of quality as natural gas[61] or if the electricity was produced using fuel cells, gas motors, steam turbines, Organic Rankine Cycle plants (ORC plants), Kalina cycle plants or Stirling engines.

The handling of the technology bonus in order to support methods of dry fermentation turned out to be difficult in practice, as the distinction between dry and wet fermentation is ambiguous. Thus, for example, a plant using a high proportion of energy crops (instead of slurry) was – from a procedural point of view – not necessarily eligible for the bonus on the basis of being an innovative technology for the fermentation of solids. In order to avoid situations where bonuses were being received for actions that would have been undertaken anyway, readjustments were necessary at this point in the form of a guide for the consistent interpretation of the law.[62]

Gas Feed-in Regulation (2005) in the Amended Energy Industry Act

According to the EU Gas Directive (Directive 2003/55/EC), every gas supplier was to be granted access to the gas grid.[63] On the national level, access to the gas grids was subjected to new regulations in the course of the liberalization of the gas market. Thus, the 2005 amendment of the Energy Industry Act (Energiewirtschaftsgesetz – EnWG) from the 7th July 2005, for the first time provided a special regulation for the injection of biogas into the gas grid.[64] The EEG of 2004 had already planned a Gas Exchange Regulation. This opened up the possibility of taking gas from the public supply and feeding electricity generated by the CHP-process into the grid on

[61] The possibility of using the gas grid for biogas was first granted during the parliamentary discussion on the EEG of 2004. The remuneration for power generated from upgraded biogas is paid whether the power is produced locally or – having been injected into the gas grid – somewhere else.

[62] The Federal Environment Ministry published a guide for interpretation in March 2007 under http://www.umweltministerium.de/erneuerbare_energien/downloads/doc/39019.php (accessed August 21, 2009).

[63] Item (24) of the preamble obliges member states to ensure "that biogas and gas from biomass or other types of gas are granted non-discriminatory access to the gas system". In the previous directive 98/30/EC, which was replaced by the new directive 2003/55/EC, biogas feed-in had not been explicitly considered.

[64] If there is any free capacity, biogas is to be given priority in the local distribution network level. When net capacities are insufficient, however, the grid operator may refuse gas injection.

the basis of tariffs specified in the EEG, provided that an energetically equivalent quantity of gas is generated elsewhere from biomass and injected into the public supply. The injection of gas was thus to continue to be profitable under the tariff rates specified in the EEG for the generation of electricity. This opened up a new method for utilizing gas[65] whereby it now became worthwhile to transport biogas over longer distances in order to be used for more efficient heating in larger CHP plants.

The new option of this semi-centralized form of utilization affected the size of plants, the operating structure and the parameters of their location: Production and processing as well as the injection of the biogas produced were only economical above a certain minimum plant size (>1,000 m^3/h raw gas) (FNR 2006a). Economies of scale, which were financially necessary, forced the construction of larger plant units. Not least because of the increased investment needs, it was mainly larger companies (energy suppliers, plant manufacturers, public services) that became operators of biogas plants (see also Section 4.2.4.4). While it had previously been sufficient to use local supplies of substrate, which had been a factor determining plant location, there was now an additional factor of having the possibility of connecting to an efficient regional gas network with an adequate uptake capacity.[66]

The supporters[67] of an independent Gas Feed-in Act along the lines of the EEG, with their requests for support for the production and grid supply of biogas with a resulting opening up of new markets were unable to achieve their aims.[68]

Adaptation of the Legal Requirements for Approval

Depending on the size of the digester and its thermal output, biogas plants are granted approval under building law or the Federal Immission Control Act (Bundesimmissionsschutzgesetz – BImSchG)[69] In addition, the respective approval processes have to pay attention to federal and states' water law, which is complemented

[65] See also research project on the conditions of gas injection cf. Fraunhofer UMSICHT; Projekthomepage, http://www.biogaseinspeisung.de (accessed August 21, 2009).

[66] The minimum injection volume, up to 500 m^3/h biomethane, can only be fed into grids with a high flow-rate. Local grids (usually < 1 bar) are not adequate for this.

[67] This included, amongst others, the German Biogas Association and the political party BÜNDNIS 90/Die GRÜNEN http://gaseinspeisegesetz.de/CorneliaBehm_MdB_B90Gruenen.pdf (accessed August 21, 2009).

[68] In a statement on the EU Biomass action plan, the Federal Government declared that, given the successes achieved so far, there was no need for a biogas feed-in law along the lines of the EEG. The Federal Network Agency also objected to it.

[69] An operator survey showed that, so far, more than half (approximately 55%) of the plants had been approved according to BImSchG and approximately 44% according to building legislation (Scholwin & Thrän 2008, 44).

by the requirements of waste law (e.g. hygiene requirements) as well as pertinent specifications concerning how digester residues are to be dealt with. For plant operators, the legal requirements were not and are not clear (Klinski 2005, 115). The responsible authorities within the federal states administered the various statutory regulations in different ways. In this respect, there was a need to simplify and unify the legal situation. In the case of approvals under building law, the EAG-Bau 2004 simplified and clarified the situation for biogas plants up to 500 kW.[70] Since then, given certain requirements,[71] such plants are preferentially given approval in non urban areas (*Außenbereich*).[72] In order to unify the extremely divergent enforcement practices in the various German states, further secondary legislation[73] was agreed upon. With the introduction of an obligation to dismantle power plants in the non-urban areas, one of the requirements made by conservation and environmental organizations – the avoidance of adverse visual impacts on the landscape caused by old plants – was fulfilled. This requirement was also in the interests of local authorities.[74]

Regulation of Biomass Utilization at the Municipal Level

The increase in plant construction, which began in 2004, presented local authorities with problems concerning local location regulations. Analogously to the designation of concentration zones for wind turbines, some local authorities sought to limit the preferential approval of biogas plants by designating special zones in the land-use plan. However, it is hardly possible to draw on any criteria for objectively differentiating between suitable locations and exclusion zones for this type of plant. In this respect, the regulatory effect proved to be limited.

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[70] Up to the amendment of 2004, biogas plants in the outer zone were only considered privileged in compliance with Section 35 BauGB if they were either mainly fed with materials from their own agricultural operations or if the energy generated by them was mainly used by the farmer himself.

[71] Thus, there must be a spatial and functional connection with a farm or a stockfarm and more than 50% of the biomass must originate on this farm or similar farms nearby. Privileged status is restricted to one plant per farm or operating location.

[72] The term *Außenbereich* comes from German zoning law and describes a category of areas which are not within the area designated by a binding land-use plan and which are not part of the already built-up area (*Innenbereich*); see Section 35 (3) of the Federal Building Code (Baugesetzbuch – BauGB).

[73] On the basis of a model ordinance of the technical commission for urban development of ARGEBAU of 22 March 2006.

[74] The federal state of Brandenburg manifested the restoration obligation in the form of an ordinance. (Erlass des Ministeriums für Infrastruktur und Raumordnung zur Rückbauverpflichtung und Sicherheitsleistung as per § 35 Abs. 5 Satz 2 and 3 BauGB in combination with § 67 Abs. 3 Brandenburgische Bauordnung of 28 March 2006).

4.2.5.4 Technology and Market Developments

Studies of the Potential of Biomass

The potential for the cultivation of biomass and the power derived from it was determined to a significant extent by the areas available for this purpose (Fritsche & Wiegmann 2005, 396).[75] The controversial issue was which proportion of the agriculturally productive area needed to be used in order to secure the food supply, and which proportion would be available for energy production. Between 2002 and 2006, various studies were carried out with the aim of estimating the potential for the expansion of biomass utilization.[76] Among other things, they differed with respect to the assumptions on which they based their existing restrictions for energy-based uses. The predominantly positive estimates of potential served to justify the NawaRo bonus contained in the EEG, which was intended to increase the extent to which the biogas sector made use of renewable resources.

A retrospective evaluation (SRU 2007), however, came to the conclusion that the scenarios on which the studies had been based had over-estimated the technically achievable potential of energy crop production. According to the SRU (2007), even in the relevant environmental scenarios of the studies, restrictions necessitated by nature conservation requirements had not been sufficiently taken into account. In addition, at that time, the demand for biomass products for material and industrial uses was underestimated.

Increase in Plant Size

From 2004 onward there was a clear trend toward ever-larger biogas plants to be observed. At the end of 2007, the average capacity of the German biogas inventory came to 290 kW_{el}. The inventory also showed significant regional differences in plant capacity. Bavaria and Baden-Württemberg were “overtaken”: while the average plant sizes in Baden-Württemberg and Bavaria were 200 and 190 kW_{el}, respectively in Lower Saxony and the eastern states (Brandenburg,

[75] Land is a very scarce commodity in Germany nowadays. The continued removal of agricultural land for the realization of other land-use demands (e.g. transport, urban development) is continuously reducing the potential for cultivation (Reinhardt & Gärtner 2005, 400 sqq.). Opinions differ on the question of to what extent these losses can be compensated for, or even more than compensated for, by improving production methods. According to Reinhardt & Gärtner (2005, 401), the significant sustainability goals could only be implemented through a reduction in the degree of self-sufficiency (food production) to 80%.

[76] Assessments of the potential of biomass: Fritsche et al. (2004): Stoffstromanalyse zur nachhaltigen energetischen Nutzung von Biomasse; Nitsch et al. (2004): Ökologisch optimierter Ausbau der Nutzung erneuerbarer Energien in Deutschland; IE Leipzig (2005): Nachhaltige Biomassenutzungsstrategien im europäischen Kontext. EEA (2006): How much biomass can Europe produce without harming the environment.

Thuringia, Saxony-Anhalt and Mecklenburg-Western Pomerania) the average was around 500 kW_{el}. This development meant that Lower Saxony, with 27.4% of installed biogas capacity, now had first place among the states, although in terms of numbers, Bavaria still had the greatest number of biogas plants in operation (41%).

Between 2004 and 2008, the higher feed-in tariff for small-scale plants[77] as well as the priority given to plants of up to 500 kW within the context of approval under building law led to the practice of "plant splitting". By stringing together modules of 500 kW_{el}, large-scale plants of industrial dimensions were created. One example of this procedure is the biogas park in Penkun. According to Schütte (2008, pers. comm.), the accumulation of single 500 kW_{el} modules was an undesired application of the law. The operator took advantage of the 500 kW_{el} rule and classified the individual modules in the biogas park as stand-alone plants. As a result, this led to a significantly higher tariff.[78] In order to correct this, the 2009 amendment of the EEG changed the definition of "plant" and thereby reduced the tariff rates applicable to plants accumulated in biogas parks. Now, all spatially contiguous modules are classed as large-scale plants and thus get a lower tariff. Operators of biogas parks saw this as a threat to their park's existence. A case brought to the Federal Constitutional Court concerning the retroactive application of the specifications of the EEG of 2009 was, however, rejected.

The Level of Technological Development

Biogas technology was now regarded as mature. Quite apart from the substrates being used and their economic integration into their locations, there is a great variety of technical designs. The supply of standardized complete solutions, the so-called turnkey plants, reflects the increasing professionalization of the sector. In the area of process control (acceleration of digestion, gas yield) and the conversion of biogas into electricity, the view was that there was still potential for optimization.

In combination with the Renewable Resources Bonus, the Technology Bonus stipulated in the EEG of 2004 was intended to promote advances in the development of dry fermentation plants. It had only a limited effect. "All in all, dry fermentation was seen as a process technology which was *ancillary* to the standard practice of wet fermentation and used for special areas of application" (Schüsseler & Daebeler 2004, 114, emphasis added).

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[77] Power from the 500 kW plants running on renewable resources in the biogas park was remunerated at a rate of 16 cents/kWh (instead of 9.3 cents/kWh for a 20 MW large-scale plant) until the end of 2008.

[78] Over a period of 20 years, the plant would have had higher revenues of around 200 million euro due to the increased tariff rates (own calculations).

The Upgrading and Injection of Gas into the Gas Grid

From 2005 onward, the Energy Industry Act (EnWG), complemented by the Gas Network Access Ordinance (Verordnung über den Zugang zu Gasversorgungsnetzen – GasNZV, see Section 4.2.4.3), and the Gas Network Tariffs Ordinance (Gasnetzentgeltverordnung – GasNEV) provided the legal framework for the injection of gas into the gas grid. Since then, it has been possible to feed gas into the gas supply network (see Gas Exchange Regulation in Section 4.2.4.3). However, for the large-scale injection of gas, a number of legal obstructions needed to be removed and regulations concerning responsibility for costs needed to be found (Fraunhofer UMSICHT & Partner 2007).

From the technical perspective, it is necessary to subject the raw gas to an upgrading process[79] in order to bring its quality up to the same standard as that of natural gas.[80] By the end of 2006, only a few German companies were offering market-ready gas upgrading technologies. A significant obstacle is presented by the high costs of upgrading. Upgrading is therefore only economical in plants with high gas yields (>1,000 m^3). At the end of 2006, the first large-scale biogas plants for the injection of biogas went into operation.[81]

Cost and Market Development

Following the amendment of the EEG in 2004, there was a genuine explosion in the market. Between 2004 an 2005, annual growth, which had in previous years been relatively constant and in the region of 30–60 MW_{el}, increased to 420 MW_{el}, and was accompanied by a noticeable tendency in the direction of larger plants. A few new installations had plant capacities of 800 kW_{el}, but the average was around 500 kW_{el}. In this phase alone, the number of biogas plants rose by an additional 800 plants. Between 2004 and 2007, the installed electrical capacity more than quadrupled from 247–1.270 MW_{el}. A decisive factor in this powerful growth was the introduction of the NawaRo bonus in the EEG amendment of 2004. High demand fueled the process of diffusion.

In 2006, 60% of all biogas plants made use of the NawaRo bonus. In 2007, this rose to over 83% (Scholwin & Thrän 2008, 45). This occurred primarily through

[79] Various scrubbing methods (high-pressure water scrubbing, non-pressurized amine wash, organic wash) as well as Pressure Swing Adsorption (PSA) are available for this purpose.

[80] In order to attain natural gas quality, the raw gas has to be dried and pollutant gases (e.g. hydrogen sulphide) as well as carbon dioxide have to be washed off.

[81] One example is the biogas plant in Pliening, Bavaria. With a capacity of 3.9 million m^3 the plant produces biomethane and feeds 485 m^3/h into the gas grid. E.ON Bayern is the buyer. The project was implemented by Schmack Biogas AG together with Renewable Energy Systems GmbH. http://www.biogas-netzeinspeisung.at/anlagenbeispiele/pliening.html (accessed August 21, 2009).

the construction of new plants, but also through the conversion of older plants. The use of renewable resources reduced inputs of industrial and agricultural wastes (in this case primarily slurry) in agricultural biogas plants.

Utilization of heat continued to increase as a result of the CHP Bonus. Fifty-eight percent of the plant operators who were questioned stated that they made use of the incidental heat. The spectrum of usage added up to between 5% and 100% of incidental heat. On average, half of the incidental heat was utilized. Forty-three percent of operators stated that they had implemented CHP systems following the EEG amendment of 2004, which was seen as evidence of the impact of the CHP Bonus. In many cases it was difficult to find locations for biogas plants that were close to larger heat sinks. In order to still receive the CHP Bonus, operators use waste heat in order to dry out digester residues. From the perspective of the Federal Ministry for the Environment, this form of heat utilization was not particularly desirable.

The EEG specified an increased remuneration rate for the generation of electricity from biomass (see Section 4.2.4.3). In practice, however, the maximum possible feed-in tariff was only achieved in a few cases. Commercially available plant sizes of between 400 and 500 kW_{el}, which ran on renewable resources exclusively, received an average feed-in tariff in the region of 16–17 cents/kWh. The precise level of the feed-in tariff was above all dependent on the proportion of heat utilized (CHP operation).

The number of plants running on energy crops increased steadily. As a rule, substrates needed were not produced by the operators themselves, but had to be bought from local farmers. Substrate and transportation costs had an increasing influence on the economic viability of the biogas plant. In regions with increasing demand, increasing prices, could very rapidly end up threatening the profitability of a biogas plant.

As a result of the possibility of being able to feed biogas into the gas system which came about in 2005 there was a prospect of there being further possibilities for the selling of biogas. It was expected that semi-centralized power conversion units would be more efficient and therefore more economical.

4.2.5.5 Actors in the Constellation

Federal Environment Ministry – Lead Management Under the Amended EEG of 2004

For the BMU, the attaining of the self-imposed climate protection targets was a major motive for action. In order to increase the proportion of renewable power, the continuation of targeted regulatory mechanisms was intended to support development. On the basis of the progress report on the EEG of 2000, the Federal Environment Ministry developed sector-specific feed-in tariffs and degression rates as well as a bonus system,[82] in order to allow fine-tuning. Besides the differentiation within the feed-in tariff system, the Federal Environment Ministry continued to pin its hopes on the strategy of making businesses economical for operators even if this meant rising feed-in tariffs as a result of the continuously high costs of power production within the biogas sector. This strategy found support in the Department of Agriculture because it also helped to ensure the survival of agricultural businesses. In contrast to the Federal Ministry of Economics and the conventional energy suppliers and despite not being in complete agreement in terms of their aims, the Federal Ministry of Agriculture was an important ally in the asserting interests during this phase.

The Biogas Sector: Rapid Growth and Orientation Toward Export

The biogas plant construction and supply sector experienced its greatest and most rapid increase in growth during this phase. The evidence for this was that some of the newly founded businesses experienced an annual doubling in employee numbers as a result of rising demand.

Starting in 2004, there was a substantial change in the nature of the operators (Staiß 2007, 65). Though agricultural biogas plants with individual operators dominated for a long time, in 2006, they were in the minority, adding up to only one third of the total. The largest proportion was run by cooperatives and private companies (GbR, KG, GmbH & Co. KG).[83]

Besides sales on the German market, manufacturers (suppliers) and, above all, plant construction firms oriented themselves toward the export markets. According to Holz (2008, pers. comm.), it became apparent that German businesses were dependent on foreign sales in order to maintain their size. The "younger" plant construction firms also started branches and subsidiary companies abroad. Preference was given to countries in which EEG-like feed-in regulations or even higher feed-in tariffs were stipulated, as in the case of Italy.

Biogas Injection Brings in New Actors

In Germany, several businesses spurred on the development of the biogas sector with their own entrepreneurial involvement[84]: The option of being able to inject gas into the

[82] The bonus system was supposed to make it possible to set specific incentives for the achievement of certain developments. So, for example, the NawaRo bonus was supposed to make other, hitherto unused, potentials accessible. The strengthening of CHP generation, as well as progress in terms of technological development, also formed a part of the explicit aims. In particular, the CHP bonus and the technology bonus were intended to provide incentives for increasing efficiency.

[83] Corporate enterprises (public and private limited companies) constitute about a quarter of the plant operators (ibid.). GmbH & Co. KG (limited partnership with a limited liability company as general partner) is particularly attractive in the case of revenue sharing models.

[84] For example, Schmack Biogas AG together with E.ON Ruhrgas and E.ON Bayern, built a 10 MW biogas plant on their own premises for injection into the natural gas grid. www.schmack-biogas.com/wDeutsch/pdfpresse/2006_07_19.pdf (accessed August 21, 2009).

gas grid, as well as the efficient conversion into electricity possible with centralized CHP plants, awakened interest in biogas production on the part of local municipal utilities as well as national power companies. The power companies were able to mobilize the capital required for large-scale plants and add to the spectrum of industrial biogas operators. For municipal utilities, the option of biogas generation and upgrading is especially attractive if they operate municipal CHP plants.

4.2.5.6 Undesired Side-Effects and the Need for Readjustments

Increasing Competition over Land and Use

Reinhardt & Gärtner (2005, 401) have calculated that in order to implement the essential sustainability targets of the Federal Government, 4.5 million hectares of land for the cultivation of biomass for energy purposes would be needed.[85] In the face of growing biomass markets there was, however, persistent and considerable internal competition concerning the use of land for the cultivation of food or animal feed on the one hand, or for the cultivation of crops for material or energy purposes on the other. This kind of competition occurred at many levels and was closely connected with market conditions. It was not only the securing of the food supply, but also the rising demand for the material, or rather industrial utilization of renewable resources, which limited the potential area to be used for the cultivation of energy crops.[86] Amongst energy-based uses there was, in turn, competition in the field of energy crops between the production of liquid fuels (biofuels), gaseous fuels (biogas) or solid fuels (e.g. wood).

The issue of the availability of land for the cultivation of energy crops increasingly came to be a location-determining factor. In some intensive stock rearing regions, the scarcity of areas for cultivation became perceptible. The area required for energy crops caused the cost of leases for farmland to rise. Digester substrate prices rose. Fodder for meat and dairy farms became expensive because the use of biomass for energy production presented an increasingly attractive alternative in comparison with fodder and food production.

Rising Conflict with Nature Conservation and Environmental Protection

The boom in plant construction together with the rising demand for substrates intensified the environmental impacts already mentioned. The increase in the

[85] From the point of view of nature conservation, the usable area for the environmentally sound cultivation of energy crops is an estimated 2–2.5 million hectares. This is equivalent to around 10–13% of the area used for agriculture today (NABU Positionspapier n.d.).

[86] Examples of this are the substitution of synthetics by using plant fibers such as hemp. According to Döhler (2008, pers. comm.), the car industry is developing an increasing demand for this. A significant demand for cellulose fibers will develop in the future for the production of packaging material and adhesives.

cultivation of energy crops (corn) was connected with a perceptible increase in intensification. In the context of this re-intensification, set-aside land was reactivated and changes in use were carried out. Former cereal fields and grasslands came to be used for the cultivation of corn.

In the year 2008, the area of land under cultivation for corn reached a new all-time high at more than two million hectares (see Fig. 4.9). Conservation organizations such as NABU summarized the side effects as "a monocultural overload resulting in a loss of biodiversity and an additional strain on soils and water as a consequence of intensive tillage, fertilizer use and, as the case may be, pesticide use" [87] In order to minimize these negative effects, the system used for cultivating energy crops had to integrate many more of the concepts of ecological agriculture and forestry, or at least the concepts of "integrated production" (Graß & Scheffer 2005). In terms of nature conservation, there was a focus on the issue of increased demand intensifying competition for land: The conditions for the re-designation of wildlife corridors[88] and protected areas worsened. Ongoing agri-environmental and nature conservation programs, which were aimed at making cultivation more extensive, lost their attractiveness.[89] Organic farming also came under pressure as a result of the spread of biomass cultivation.

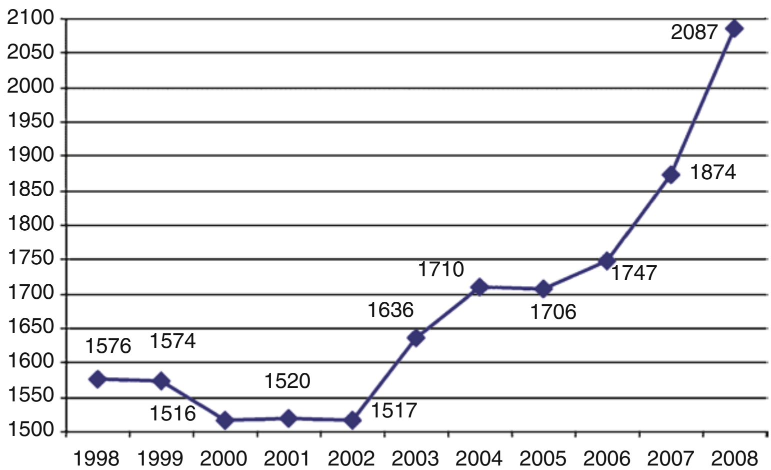

Fig. 4.9 Area under corn cultivation in thousands of hectare as of May 2009 (Dt. Maiskomitee; authors illustration)

[87] See NABU (2007). In addition, it was feared that the cultivation of energy crops could be a gateway for the use of genetically modified plants – with consequences for wild animals and plants which, as yet, remain unknown.

[88] In the Federal Nature Conservation Act an area of 10% is designated as wildlife corridor.

[89] The indemnities paid within the context of these programs were not competitive in view of the new market opportunities.

The rise of monotonous landscapes subjected to intensive corn cultivation[90] was noticed by local populations. Resistance against large-scale biogas plants was directed at the undesired effects of odor, pollution, noise pollution caused by the transportation of digester substrate and incalculable risks associated with plant operation as well as with the effects of energy crop cultivation.

The need to readjust in order to maintain acceptance also became a point of focus on the political level (SRU et al. 2007). Support for renewable energy, including the production and utilization of biomass, had to be consistent with the principles of ecological and environmental sustainability (ibid.). The approaches required in order to achieve such control had not yet been decided upon.

Approaches to Conflict Minimization

Given the various environmental regulations and the obligation to comply with "good professional practice", agricultural representatives have been regarding the environmental impact of energy crop cultivation as less serious. As some kind of sign of openness to cooperation, however, "ecologically sustainable biomass production" approaches were sought for. Here, the development of ecologically sustainable cultivation systems for energy crops played an important role. A further approach to the reduction of conflicts was the investigation of existing competition between solid, liquid and gaseous biofuels and to allow proposed strategies for the sustainable utilization of biomass to be developed (IE Leipzig Institut für Energetik und Umwelt gGmbH 2005).

4.2.5.7 Interpretation of the Constellation: Driving Forces and Constraints

The studies of future potential, which indicated that there was, in national terms, sufficient area for the production of biogas, encouraged state regulation in continuing with the support policies for biogas which were set in the amended EEG. Those involved in biogas production were, however, to take ecological and environmental aspects more seriously in the future.

With a view to ensuring the development of rural areas the Department of Agriculture gave the Ministry for the Environment its support. They prioritized the survival of agricultural businesses and committed themselves to the highest tariff possible. The negative side effects of re-intensification as a result of intensified cultivation of energy crops were not taken into consideration.

The regulatory mechanism of raising the tariff rates and introducing a NawaRo bonus with the intention of mobilizing cultivated biomass as digester substrate had an immediate effect. Plant construction rose sharply. In addition to farm-based biogas plants, which, not exceeding around 150 kW, continued to remain in the

[90] Also referred to as "Vermaisung" ("maizification").

lower range in terms of capacity, larger, industrial biogas plants were also being built. These were operated by joint operating companies or so-called “energy service providers”. The new tariff meant that biogas generation also became attractive for investors. The connection between agriculture and biogas generation, which had been predominant until then, dissolved and the operator structure diversified.

The biogas sector – manufacturers and plant builders – immediately profited from the take-off in demand. In 2006 in particular, the rate of construction shot upwards once again. The businesses that had been founded in the previous phase experienced a sudden increase in growth. Other businesses started up during this phase. Business was brisk.

The grading in feed-in tariffs which was undertaken (the highest tariff being paid for plants up to 500 kW) as well as the licensing privilege for plants of this very capacity class led to the accumulation of numerous plant modules of small size. As a result, biogas parks came into existence. For these, the availability of sufficient quantities of digester substrate was the most important factor in deciding their location.

Corn, which is intensively farmed and then ensiled, was the most important energy crop due to it high yield of gas. Environmental and conservation organizations criticized the strain on natural resources (soil, water) caused by the increasing cultivation of corn, the growing pressure on areas of importance for conservation as well as the spread of monotonous landscapes dominated by corn cultivation. However, the critical voices were unable to stall the boom, especially since nature conservation organizations do not have the financial incentives for ecologically sustainable production at their disposal in order to be able to compete with the potential profits to be made through conventional or energy crop farming. Already decades old, the conflict between nature conservation and agriculture reignited.

With respect to the areas being used, the biogas sector came into increasing competition with other kinds of bioenergy (biofuels market) as well as with food production.

4.2.6 Phase 5: Setback in Development 2007/2008

4.2.6.1 Characteristics of the Constellation

This constellation was characterized by increasing complexity (Fig. 4.10). The enactment of the GasNZV opened up more marketing opportunities for the biogas sector, but had not developed any momentum at this point. The major obstacle at the core of the constellation was the development of substrate prices. As in the case of the internal competition in the energy sector, the market competition between the energy and the food sectors, had the effect of increasing prices. The availability of cheap substrates derived from renewable resources developed into a limiting factor. High prices had an inhibiting effect on the rate at which plants were constructed. As a consequence, many businesses experienced a collapse in sales.

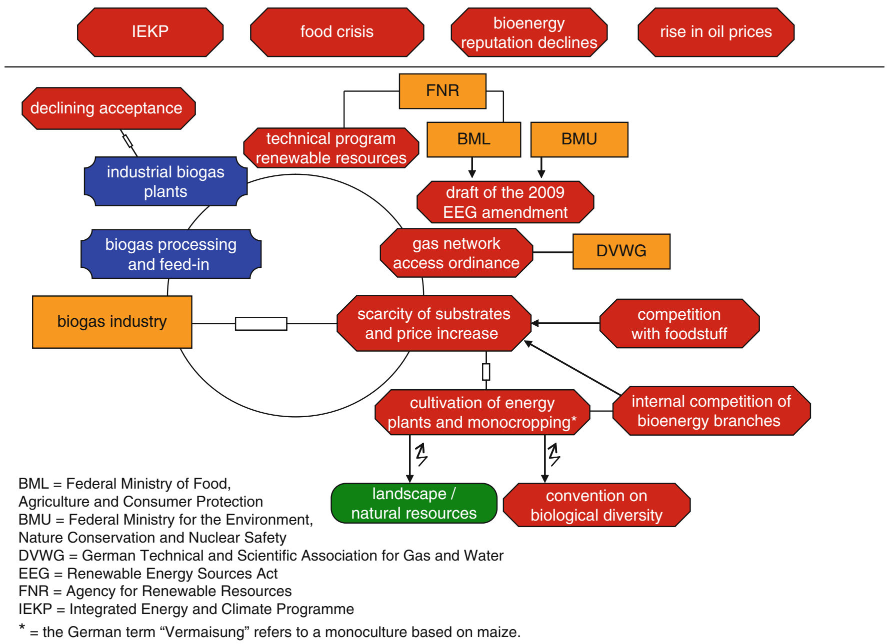

Fig. 4.10 Constellation phase 5: setback in development 2007/2008

As a result of the complexity of the sector, the criticism of bioenergy in the media and in public (loss of image) caused a further reduction in acceptance of biogas. In particular, resistance to large biogas plants with high substrate requirements grew. Support for the cultivation of energy crops on the one hand, and the goals of landscape preservation and resource conservation on the other meant that there was a conflict. Faced with the concern within agriculture to maintain production, for which the cultivation of energy crops had become an important component, there was intensification in especially those environmental and resource conservation problems associated with the "maizification" of the landscape. The national implementation of the aims of the biodiversity convention contradicted the massive re-intensification of agriculture.

4.2.6.2 Sector-Specific Context, Influencing Factors and Processes

At this time there were inconsistent signals: On the one hand, the preparation of the Integrated Energy and Climate Programme (Integriertes Energie- und Klimapaket – IEKP) maintained a certain momentum – the renewable energy sector was able to rely on positive stimuli. The rise of oil prices to unprecedented heights also left no doubt as to the necessity of supporting renewable energy. On the other hand, economic factors had a counteracting effect on the established system of incentives, above all, the increase of prices in the food sector. Media reports criticizing the undesired side effects of bioenergy dampened the euphoria over bioenergy.

The Integrated Energy and Climate Programme (IEKP) and Preparations for the Amendment of the EEG

2007 was defined by the implementation of the The Meseberg Resolutions.[91] For the biogas sector, the resolution sent out positive signals, as goals for the expansion of the injection of biogas[92] into the gas grid were established.

During the updating of the EEG, it became clear that the combination of minimum tariffs and a bonus system for the production of electricity from biogas was to be retained. However, drastic increases in substrate prices and rising costs of operation within the sector unsettled operators and caused worries as to whether the cost-covering feed-in tariffs would continue to be safeguarded. In the preparatory stages of the updating of the act, there was a lack of agreement concerning whether it should be small, medium-sized or large plants which should benefit from the payment system. The legal debate was therefore the object of tense observation.

Food Crisis: Critical Media Response and Bioenergy's Loss of Image

Food shortages and increases in food prices,[93] among other things, were traced back to the increasing use of agricultural products and areas for the production of bioenergy products. The production and subsidizing of biofuels came in for particularly strong criticism. Representatives of the biogas sector contrasted the advantages of biogas technologies with the production of biofuels by focusing on its higher efficiency and lower net output of CO_2. Should there be food shortages and a lack of land for cultivation, changes should take place in the use of energy crops for biofuel production, they argued.

While the discussion about the national and global effects of bioenergy was initially carried out primarily in the relevant specialist circles (e.g. Bringezu et al. 2007), from the end of 2007, reports in the public media which criticized the competition between food production and biofuels production increased. The effects of the use of corn in the USA for energy purposes on Latin American food prices (e.g. "tortilla war") were challenged, as were the stifling effects of palm oil production carried out in order to satisfy the increasing demand for palm oil imports for local CHP plants.

The reports depicted both the environmental and the social effects of the growing hunger for energy in industrialized countries. Thereafter, the use of imported liquid biomass (e.g. palm oil, soya oil) no longer had a positive public image per se.

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[91] In 2007 the Federal Cabinet held a closed conference in Meseberg, for the final passage of the IEKP (see Section 3.7.3.1).

[92] The resolution says that 6% of the present consumption of natural gas in Germany is supposed to be substituted with biogas by 2020 and 10% of it by 2030. cf. http://www.dena.de/de/themen/thema-reg/projekte/projekt/biogaspartner/ (accessed August 21, 2009).

[93] For information on this fundamental problem see Section 3.1.5. Only those aspects relevant to the bioenergy sector will be addressed here.

Moreover, it became clear that, both in terms of efficiency and undesirable side effects, bioenergy was not a front-runner in comparison with other forms of renewable energy generation. The production of first and second generation biofuels came in for particular scrutiny. Although the conversion of biogas into electricity had a better energy yield per unit area and produced less CO_2 than the production of biofuels, the loss of image also has indirect effects on the biogas sector, especially since, in the public perception, no distinction was made between these two sectors within bioenergy. For the biogas sector, the lack of heat utilization concepts became a point of weakness. In the face of an increasing need for energy efficiency, improvements needed to be made.

Rise in Oil Prices

After the price of crude oil had almost doubled during the course of 2007, at the beginning of March 2008, it exceeded 100 dollars/barrel, and then shortly thereafter reached a new high of 135 dollars/barrel. The costs of operating biogas CHP plants (with dual fuel engines) increased significantly. Moreover, the dramatic developments in oil prices encouraged the possibility of the increased adoption of oil substitutes such as biogas in the heating and transport sectors to be considered. The German gas supply companies were increasingly open toward injecting biogas into the gas distribution network.

4.2.6.3 Governmental Guidance and Economic Context

A Change in Strategy in the Amended EEG?

At the beginning of the phase, and prior to the updating of the EEG, a change in strategy[94] was under discussion: Were small and medium capacities[95] to continue to receive incentives or should larger plants profit more? In the former case, less effective, local power generation units and uses of heat would predominate. In contrast, a shift toward larger generation units would improve the profitability of biogas injection and help in opening up new sales markets. The latter option was, above all, in the interests of the large-scale power industry, who would thereby be able to use existing structures.

From the point of view of environmental protection and the structure of agriculture, it had already become clear that large-scale plants with operators who did not have rural roots would have negative consequences for the regions

[94] For efficiency reasons, should the EEG set stronger incentives for large-scale plants or should the focus continue to be on small and medium-sized plants?

[95] The majority of the biogas sector, especially agriculturally related firms specializing in the production of biogas plants, would thus keep a significant fraction of their clientele.

affected as well as for the environment. Because the EEG's support for decentralized (and thereby smaller) generation was also an aspect of the issue, the position of small to medium-sized plants was strengthened by the increased tariff rates in the EEG of 2009 and through the clarification of plant definitions. The technology bonus for upgrading and injecting biogas continued unchanged. The major improvement for the injection of biogas was the Gas Network Access Ordinance (GasNZV).

The Gas Network Access Ordinance: Improved Conditions for Biogas Injection

Simultaneous with the amendment of the EEG, on 12 March 2008, the Federal Cabinet approved the GasNZV, which had been developed by the Federal Ministry of Economics, by which the conditions for gas injection were considerably improved,[96] in comparison with the previous regulations (see Section 4.2.4.3). The improved financial conditions for those injecting gas into the distribution system were supposed to promote the opening up of new sales markets. Biogas can be passed through the gas distribution system to larger CHP plants situated closer to the point of need (heat sinks) and be used to generate electricity. While the Federal Ministry for the Environment also favors this option on the grounds of its efficiency characteristics, market participants and gas supply companies were more interested in merely substituting natural gas and delivering biomethane to their clients – most of all households operating primarily small heating units.

Gas supply companies and businesses in the biogas sector which specialized in large-scale plants[97] welcomed the new ordinance, which constituted a basic requirement for the implementation of the ambitious aims formulated in the IEKP for the substitution of natural gas. The implementation of these aims requires the construction of newer, more efficient biogas plants to a considerable degree, as well as the expansion of the gas distribution system, whose availability and uptake capacity is still to present an important restriction for the injection of biogas.

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[96] According to the new GasNZV, processed biogas is to be prioritized. The grid operator is responsible for the adjustment of the biomethane to the calibration legislation guidelines and the pressure conditions in the gas grid. The grid operator pays the operating costs, whilst resulting investment costs are split into two. The general gas costs of the grid operators are to be transferred onto general grid fees. The biogas injector receives a flat-rate of 0.7 cents/kWh for avoided grid fees (not to be confused with feed-in tariff).

[97] Orientation toward the biomethane or natural gas market offered the biogas companies who suffered under the sales slump new economic prospects. Schmack Biogas AG, for example, subsequently focused more strongly on biogas treatment and sought co-operation with large power suppliers: See http://isht.comdirect.de/html/audio/detail/main.html?ID=12330 (accessed August 21, 2009).

Rising Digester Substrate Prices

Since the end of 2006, corn and wheat prices had more than doubled. Global agricultural prices thereby rose to a level such that the utilization of agricultural areas became profitable even in the absence of political support (WBA 2007, 204). Possibilities for regulating usage through the use of subsidies were thus rendered void. Farmers marketed their crops wherever they were able to return the greatest profit. This also caused a rise in the price of digester substrates derived from renewable resources.[98] According to Thrän & Kaltschmitt (2007, 61), this was a "quantity-price problem", in other words, the desired quantities were not available on the market for the anticipated price (ibid.). It was, above all, those plant operators who were dependent on the buying in of substrate and who had not negotiated long-term fixed-price supply contracts with farmers who strayed closest to the limits of economic viability. The demand-driven developments in prices caused new construction to stagnate, above all in the case of plants running on renewable resources, since it was in this sector that the rise in prices had the greatest impact.

4.2.6.4 Technology and Market Developments

Collapse in Demand

In 2007, the graph of plant construction began to level out. Only around 450 new plants of around 300 MW were added to the gas distribution system. In 2008, it was even fewer, with only around 300 plants[99] (Thrän et al. 2009, 17). From mid-2007 onward, plant builders noticed a collapse in demand in the sector consisting of plants running on renewable resources, which was mainly attributed to the extreme increase in substrate costs (see Section 4.2.5.4).

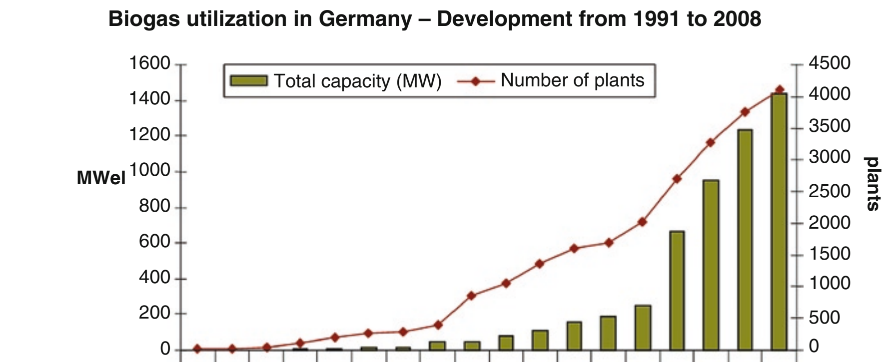
Additionally, rising energy prices drove up the costs of operating plants run on renewable resources such that it was no longer possible to run them profitably. Following the accelerated growth of the previous years, the drop in new orders meant a serious slump for suppliers of plants. Large companies within the biogas sector also went into the red and the share price of those businesses quoted on the stock exchange collapsed. Despite the collapse in demand, Fig. 4.11 shows a growth in capacity for the years 2007 and 2008. This arose from the construction of plants that had already been commissioned before the rise in substrate prices.

Technology for the Upgrading and Injection of Gas

The positive assessment of the potential of biogas, the targets set in the IEKP regarding substitutes for natural gas and the new Gas Network Access Ordinance

[98] Usually entire corn plants but also parts of plants.

[99] For comparison: in 2005, it was 700 new plants that were built, with a capacity of around 420 MW.



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total capacity (MW)	1	2	2	4	9	15	19	43	49	78	111	160	190	247	665	949	1232	1435
Number of plants	20	30	50	101	200	265	295	401	850	1043	1360	1608	1700	2010	2690	3279	3764	4100

Source: Elektrizitätswirtschaft, Scholvin & Thrän 2008, 35; author's illustration

Fig. 4.11 Total capacity and number of plants utilizing biogas in Germany up to 2008

empowered the sector to take up biogas upgrading (see Section 4.2.4.4) as an important area of innovation. In pilot projects, various gas upgrading techniques[100] were tested. Which of these techniques was going to establish itself in the long term remained, and remains, to be seen.

Because the upgrading of gas presents an additional cost factor, upgrading is only worth doing in the case of plants with a certain minimum yield of biogas.[101] In contrast to industrial plant operators, operators of individual agricultural plants have so far hardly derived any benefit from the possibility of being able to feed in biogas, resulting in further fragmentation within the sector between industrial and agricultural producers, with specific interests and coalitions of actors in each case.

The financial viability of industrial biogas gas-grid injection plants remained dependent on developments in the price of gas and the further definition of subsidy conditions.

Innovative Technologies for Electricity Generation in Pilot Applications

While gas engine CHP plants and dual fuel CHP plants for the generation of electricity from biogas are state of the art, microturbine, ORC technology, Stirling engines and fuel cells are still in the test phase.

[100] This includes the high-pressure water scrubbing, amine washing as well as the pressure swing adsorption.

[101] With increasing plant size, processing costs decrease. With a flow-rate of more than 250 m³/h, processing costs come down to about 2 cents/kWh, whilst they can be double or triple that for small plants of 50m³/h (4.5–6 cents/kWh). From an economical point of view, biogas injection is therefore not particularly attractive for small producers from the agricultural sector.

In the case of microturbines, and despite multiple advantages, high purchase costs have so far stood in the way of market breakthrough (Scholwin & Thrän 2008, 47).[102] Within the biogas sector, ORC technology is still only being used in pilot projects. Technologies such as biogas-fueled Stirling engine plants and fuel cells[103] are, as yet, commercially unavailable (Scholwin & Thrän 2007, 12), nor is their continuous utilization expected in the near future (Scholwin & Thrän 2008, 47).

Development in the Costs of Electricity Generation

Generation of electricity was made significantly more attractive by the bonus system of the EEG 2004. According to Dürrschmidt (2007, pers. comm.), it was not possible to attain the cost reduction targets, despite the substantial growth. The generation of electricity from biogas remained more expensive than expected. The costs were more or less twice that of wind turbines and were therefore the second most expensive category in the EEG after photovoltaic power. In contrast to photovoltaics, an appreciable drop in the costs of biogas power generation costs in the near future is not expected. On the contrary, the increased substrate prices for renewable resources (see Section 4.2.5.4) led to an increase in generation costs. In comparison with other kinds of renewable energy in the power sector, the use of biogas for electricity generation suffered a loss of competitive advantage. The limited potential of reducing the costs of electricity generation is partly the reason why the sector oriented itself toward the injection of gas.

4.2.6.5 Actors in the Constellation

Businesses in a Fight for Survival

Due the collapse in demand resulting from the rise in the price of digester substrates derived from renewable resources, orders for new plants came to a standstill between spring 2007 and mid-2008. The biogas firms – plant manufacturers and plant builders – registered significant declines in profit and remained below the growth rates achieved in the three previous years. The shares of those businesses quoted on the stock markets collapsed dramatically in August 2007. Though the German biogas industry obtained between a quarter (around 150 million euro) and a third of its revenue abroad, the increase in international sales was not able to compensate for the loss of profits at home.

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[102] Some of the advantages are low-maintenance operation combined with functioning gas upgrading (desulphurization and drying), low noise levels, hardly any vibrations as well as a low concentration of nitrogen oxide in the waste gas. Due to the low electrical efficiency of the process it is economically necessary for the high-temperature-heat to be used, for example, for drying processes, greenhouses or heating water.

[103] For information on the application of fuel cells see Kaufmann et al. (2007, 59 f.)

Increasing Involvement of Gas Suppliers

Through the Gas Network Access Ordinance (GasNZV) and the development of injection technologies, gas suppliers came to be included as actors in the process of innovation. They took part in larger generation and injection units and so expanded their own portion of the value chain.[104] The admixture of biogas was welcomed by the gas industry for image reasons. They hoped that the addition of "green gas" would safeguard the chances of natural gas on the markets. In contrast, there was limited interest in functioning purely as distributors of biogas for the generation of electricity in semi-centralized CHP plants.

4.2.6.6 Undesired Side Effects and the Need for Readjustments

Loss of Acceptance

The increasingly negative media coverage of the disadvantageous global consequences of bioenergy use put the biogas sector under pressure. Representatives of the biogas sector made an effort to differentiate between the negative consequences attributable to the cultivation of oil-producing plants for biofuels or the importing of palm oil in order to run CHP plants and those attributable to the biogas sector. Apart from this, the biogas sector was subjected to negative media coverage when local residents saw the extent of biogas plants in their local area as having exceeded what was reasonable. The media coverage concerning the lack of financial viability of biogas plants (which had been caused by the rise in the cost of substrate) also damaged the image of the biogas sector. The introduction of industrial-scale biogas production was openly criticized while "farmyard biogas plants" were regarded as the more acceptable option.

Ecologically Sound Energy Crop Cultivation?

The area under cultivation for renewable resources for material and energy-based uses reached a peak of just over two million hectares.[105] 1,750,000 ha were used for the cultivation of renewable resources for energy purposes[106], of which around 500,000 ha were allotted for the cultivation of biogas crops. At 80%, corn silage

[104] One example for this model is the biogas treatment and injection plant Schwandorf. As a shareholder, E.ON now promotes the advantages of "biomethane".

[105] This means that energy crops and crops grown for raw materials were cultivated on just under 17% of the arable land.

[106] At one million ha, the cultivation of rapeseed for biodiesel takes up just under 60% of cultivated land. Sugar and starch plants for ethanol make up just under 15% with an area of 250,000 ha.

constitutes the greatest proportion of digester substrate. Studies have demonstrated that the rise in the number of biogas plants leads to an increase in area used for the cultivation of corn silage.[107]

Both the Agency for Renewable Resources (FNR) and the Federal Ministry for the Environment provided financial support to research projects concerned with the minimization of the effects of the cultivation of energy crops on the ecosystem. The approaches included were the development of specific systems of cultivation,[108] the development of extensive cultivation methods and crop diversification. In order to provide alternatives to corn, the cultivation of other energy crops was tested; however, their adoption for the generation of biogas is regarded as uneconomical at present and for the foreseeable future.

With the formulation of the criteria for "good professional practice in energy crop cultivation", the negative environmental impacts are supposed to be reduced. These criteria remain ineffective, however, if they are not connected with the conditions for subsidization specified in the EEG.

In order to reduce conflicts in the context of the planning and approval of biogas plants, specific environmental protection and conservation requirements were formulated which were in future to be taken into more serious consideration during the process of site selection as well as the planning and issuing of permission for biogas plants (Peters 2008).

4.2.6.7 Interpretation of the Constellation: Driving Forces and Constraints

With the promotion of the IEKP the course was set for a consolidation and intensification of the approach already being taken. At the same time, however, the food crisis emerged as an inhibiting factor, in conjunction with bioenergy's loss of image and the continued rise in agricultural and oil prices.

In this constellation, unforeseen developments in prices gained influence over the market situation. The steep rise in substrate prices and maintenance of the old tariff rates meant that plants running on renewable resources were, to an extent, no longer economically viable. From spring 2007 onward, growth in the sector slowed down, and from summer onward it practically came to a standstill. The slump in demand sent a series of plant constructors into a sales crisis. The upcoming EEG amendment meant uncertainty as well as the opportunity to take countermeasures.

[107] See Daniel (2007) inter alia; According to Kruska & Emmerling (2008, 69 sqq.), the proportion of silage corn in Rhineland-Palatinate has doubled and tripled in these communities, making silage corn the dominant crop on arable farmland.

[108] For cultivation systems see Scheffer (2005) and Graß & Scheffer (2005, 435 sqq.); see also IFEU, Partner (2008) with recommendations for the sustainable expansion of biogas generation and use.

In the preparation phase, there was uncertainty concerning whether industrial biogas generation and gas-grid injection or agricultural biogas generation was to profit from the support. Within the sector, the separation between large industrial producers and small and medium-sized operators widened.

The development of agricultural prices on the world market revealed the limits of government regulation and intervention. Criticisms of the lack of sustainability of bioenergy generation had an impact on the public perception of the biogas sector. The threatened loss of acceptance led to support mechanisms being initiated in order to ensure sustainable production conditions.

4.2.7 Consolidation from Mid-2008 Onward and Future Prospects

From mid-2008 onward, the price of corn and wheat fell significantly and, by the end of 2008, reached the levels of 2006 again. The adoption of the IEKP in June 2008 (see Section 3.7.3.2), which included an amendment of the EEG of 2009, the amended Gas Network Access Ordinance (GasNZV) and a Renewable Energies Heat Act (Erneuerbare Energien Wärmegesetz – EEWärmeG), gave legislators important stimuli for use in the biogas sector. As early as the second half of 2008, a rise in demand for the services of plant builders and designers was to be observed.

At the time of writing, it is still not possible to make a final judgment as to whether this development represents the beginning of a new phase and – if so – how this phase will be characterized from the point of view of the development of innovations. For this reason, the mapping out of a constellation for this (too short) time period has not been carried out. Instead, those developments that significantly contributed to overcoming the setback will be sketched out with the help of influencing factors and actors.

4.2.7.1 Sector-Specific Context, Influencing Factors and Processes

A “Freeze” on the Biofuels Quota

In October 2008, the cabinet adopted a new legal basis for the support of biofuels. It specified that the increase in the blending quota from 5.25% to 6.25% biofuel scheduled for 2009 was to be rescheduled to 2010. This quota was then to be frozen at a level of 6.25% until 2014. The biogas sector welcomed this cap, since an increase in the quota would have entrenched or intensified competition over land use.

Adoption of the National Biomass Action Plan

In June 2009 – 3 years after the EU Biomass Action Plan – the National Biomass Action Plan was adopted.[109] This was intended to implement the EU's strategic goals for the greater development of bioenergy usage at the national level. The use of measures supporting biofuels and the generation of electricity and heat using biomass was intended to significantly expand the bioenergy sector. In the case of environmental organizations, the fact that the expansion targets were just as high as they had been before was met with criticism. Particularly in the case of the biofuel sector, there was a lack of critical reflection with respect to efficiency, the CO_2 balance and sustainability.

The Biomass Action Plan formulated individual targets for each of the then bioenergy technologies. This resulted in the lack of a *coherent* strategy for the cooperation of the different bioenergy technologies.[110] The internal interaction and competition between the bioenergy technologies over land and resources as well as over opportunities on the market were only partly taken into consideration. There were doubts as to whether the measures proposed for the reducing competition for different uses (see Section 4.2.4.6) and for safeguarding sustainable production would significantly help in regulating the situation. Specialists from the SRU (2007) and the WBGU (2008) regarded a "deceleration" of the development, which had been forced until then, as necessary. This would offer a chance to adjust the strategic goals and test the extent to which the measurements for the minimization of conflict were being effective.

EU Directive 2009/28/EC for the Support of Renewable Energies

The critical debate about the social and environmental justice of the utilization of bioenergy in Germany as well as in those states from which raw materials for the generation of power were being imported made it clear that there was a need for readjustments in the area of sustainability. At the European level, Art. 17 of the directive (see Section 3.3.2.3) for the first time introduced sustainability criteria for the production of liquid fuels.[111] At the national level this resulted in a need for action in order to develop supporting mechanisms to guarantee the sustainable production of the raw materials. Within the framework of the IEKP, Germany already met these requirements. The adoption of a Biomass Electricity Sustainability Ordinance (Biomassestrom-Nachhaltigkeitsverordnung – BioSt-NachV) and a Biofuels Sustainability Ordinance (Biokraftstoff-Nachhaltigkeitsverordnung – Biokraft-NachV) (see Section 4.2.6.3) were already scheduled for 2009.

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[109] The National Biomass Action Plan was created by the BMU together with the BMELV, of which the latter was responsible for coordination www.bmu.de/43839 (accessed August 21, 2009).

[110] See SRU (2009); http://www.umweltrat.de (accessed June 11, 2009).

[111] An expansion into gaseous and solid biofuels is supposed to follow.

4.2.7.2 Governmental Guidance

The Gas Network Access Ordinance and the Gas Network Tariffs Ordinance

Within the framework of the IEKP, in 2008, the Gas Network Access Ordinance of 2005 (see Section 4.2.5.3) was complemented by ambitious targets for the injection of biogas. In addition, prioritized network access for biogas was established. Simultaneously, the Gas Network Tariffs Ordinance (GasNEV) was amended and now stipulated that grid operators pay transport customers a flat-rate fee for avoided grid costs at a rate of 0.7 cents/kWh. The establishing of ambitious injection targets, priority grid access and the improved regulation of costs increased the attractiveness of injecting biogas.

Remuneration for Electricity and Gas in the EEG of 2009

The amendment of the EEG with the reorientation of the tariff regulations and the legislative measures for the improvement of biogas injection were regarded as having been the main regulatory incentive up until that point. The EEG of 2009 was adopted within the framework of the IEKP and entered into force on the 1st of January 2009. For the biogas sector, the new tariff rates have had a consolidating effect (see Table 4.3).

Compared to the tariffs given in the EEG of 2004, the basic tariff was increased by 1 cent for both small-scale plants (<150 kW) as well as for those smaller than 500 kW. Because this improvement cannot be justified in terms of efficiency or the wise heat usage, the increase has to be evaluated as a political and strategic support for the agricultural sector.

The NawaRo bonus was increased by 1 cent/kWh for plants up to 500 kW in order to cover increased production costs. In addition, the principle of exclusivity,

Table 4.3 Tariffs for electricity and gas according to § 27 and Annex 2 EEG 2009 (Cent/kWh)

Capacity	Basic tariff	NawaRo bonus	Landscape conservation material bonus	Slurry bonus	CHP bonus	Technology bonus
Up to 150 kW	11.67 (12.67)	7	2	4	3	3
Up to 500 kW	9.18 (10.18)	7	2	1	3	3
Up to 5 MW	8.25	4	–	–	3	3
Up to 20 MW	7.79	–	–	–	3	–

Values in brackets: Apply when compliance with the threshold values for formaldehyde in TA-Luft is required (generally plants of over 350 kW_{el})

which had been in force until then, was somewhat relaxed. Thus the bonus can in future be claimed for the use of organic waste materials such as brewer's spent grain, rapeseed cake or glycerin from the production of biodiesel. Agricultural interests also prevailed with the increased flexibility of the "principle of exclusivity" when issuing the NawaRo bonus.[112] The bonus payment for renewable resources was not linked with conditions or environmental requirements[113] for their production. The new slurry bonus establishes an incentive to make increased use of slurry as a digester substrate.[114] This takes effect when the digester substrate consists of at least 30% slurry. Operators of smaller plants (up to 150 kW_{el}) should be able to profit from this incentive.

In the class of plants of up to 500 kW, a landscape conservation material bonus of 2 cents/kWh is provided. This new bonus should have the effect of improving the economic viability[115] of using the plants/vegetation generated by landscape management activities. The German Association for Landcare (Deutscher Verband für Landschaftspflege) in particular was committed to creating a financial incentive for care and maintenance measures to be carried out in wooded areas in the open country. Its incorporation into regulation was seen as a concession to environmental and nature conservation organizations.

In line with the recommendations of the EEG progress report (BMU 2007, 98), the CHP bonus was raised from 1 to 3 cents/kWh for new plants and new heating networks for existing plants. Additionally, it is now also paid when the power being produced is used for the drying of digester residues.

In conclusion, it has been determined that it is particularly plants up to 500 kW – i.e. the smaller and medium sized ones – which especially benefit from the new tariff rates. In this range of capacities, the increases in tariffs compensate for the increased costs of raw materials,[116] or at least minimize their impact. In certain ways, the alignment of EEG subsidy policy with agricultural clientele running small and medium-sized biogas plants goes against the stimuli established by the GasNZV (see Section 4.2.5.3). The latter granted a better position to those injecting biogas into the grid by granting reductions in costs,

[112] The aim is to enable the admixture of incidental agricultural residues on farms without reducing the NawaRo bonus.

[113] It would have been conceivable, for example, to have limited the proportion of corn silage in the fermentation substrate.

[114] Since only 10% of the slurry production in agriculture had been used for the production of biogas, the intention is to increase this rate. This improvement is justified by the lower net CO_2 output of slurry fermentation in comparison with the fermentation of energy crops like corn silage.

[115] The plant bonus is supposed to compensate for the higher costs of making the substrate available and the lower yield of gas from this heterogeneous material.

[116] By the end of 2008, substrate prices were falling again. The world market price for wheat fell by half compared to its peak at the beginning of 2008 and ended up at around 140 euro/t. Similar developments occurred in the cases of corn and soya.

meaning that it was essentially the operators of large-scale plants who benefited.[117]

More generally, the increasing complexity of the effects and interdependencies raised the question as to whether the limits of differentiation in the EEG had already been reached or exceeded.

Fine-tuning Sustainable Bioenergy Generation

While a sustainability ordinance for biofuels[118] had already been adopted in the context of the IEKP, this was followed in March 2009 by the drafting of a Biomass Electricity Sustainability Ordinance (BioSt-NachV-E). This readjustment was aimed at devising methods for the more sustainable cultivation of biomass grown for the purposes of energy generation. The corresponding requirements[119] address the generation of *liquid* biomass, whose utilization for the purposes of electricity generation is remunerated according to the EEG (e.g. rapeseed oil, palm oil, soya oil). These requirements are to be adhered to from the 1st of January 2010. Compliance with these requirements will be ensured by an as-yet unestablished monitoring and certification system.[120] Whether such a system would function globally in the foreseeable future is in doubt (Ekardt et al. 2009, 225–226), the more so as its establishment is associated with a level of expenditure that is not feasible in all the world's countries.

At present, however, this regulatory approach does not yet extend to the cultivation and utilization of energy crops that are used as substrates for biogas generation.

From the agricultural perspective, the existing legislation, in combination with compliance with forms of cultivation defined as "good professional practice" had, to date, been sufficient to ensure the sustainable production of energy crops. Additional regulations, which might restrict freedom in operational decision-making, were rejected. In contrast, environmental organizations took the view that

[117] The expenditure required for treatment and injection means that is only profitable for industrial-sized plants.

[118] The sustainability ordinance sets the requirements for the climatic impact of biofuels (a minimum 30% reduction of greenhouse gases compared to fossil fuels over the complete life cycle) and for nature conservation.

[119] Protection of certain natural areas (such as rainforests, moors), reduction of greenhouse gases by at least 35%, obligation to report on social standards, complete proof-of-origin.

[120] Following an EU initiative, evidence for the sustainability of biogenic fuels is supposed to become mandatory in the form of certification. At the end of 2008, the Federal Government and the European Commission began to set the sustainability criteria for this obligatory certification. The affected fuels are biofuels for transportation and power generation or CHP generation.

rulings such as plant protection and fertilizer regulations would not be able to adequately protect precious plant and animal habitat within the agricultural landscape, as they had no influence on the way in which usage was spatially organized. What were missing were specifications of acceptable upper limits of certain types and intensities of use e.g. a “corn quota” for the cultivation of corn. Up until this point, there had been no regulatory or planning mechanism by which such regulation of cultivation systems could be carried out. Only in a few cases did informal concepts result in approaches for an ecologically sustainable limit on land usage and intensity of use.

4.2.7.3 Technology and Market Developments

From mid-2008 onward, corn and wheat prices sank significantly, and by the end of 2008 they had reached the levels of 2006 again. This development reduced the financial pressure on plants running on renewable resources. However, so long as a large proportion of plants were making use of substrates for which there was strong market competition, developments in the prices of these materials would represent an element of uncertainty with respect to financial viability.

According to a current projection (ecoprog & Fraunhofer UMSICHT 2008), growth from around 4,100 plants in 2008 to around 5,900 plants in 2012 is expected.[121] It is intended that the new plants increase the present installed electrical capacity from 1.420 MW_{el} at present to 2.140 MW_{el} by 2012.

Industrial Generation and Injection of Biogas

By mid-2008 there were ten plants injecting biogas into the gas grid and by mid-2009, 17 such plants were in operation. A further 19 plants are either being planned or are presently under construction.[122]

This growth has been fueled by the setting of ambitious injection targets in § 41a of the GasNZV. In addition to this, the technology bonus in the EEG (see Section 4.2.6.2) makes the construction of plants that inject gas into the gas supply network more attractive.

Those in the sector are optimistic that ca. 30 plants that both produce and inject biogas will have entered operation by the end of 2009. These plants consistently take the form of large-scale plants or biogas parks which inject between 500 and 1,000 m^3/h.

[121]For further information on the state and further development of the biogas industry see Stolpp (2009).

[122]Cf. list of projects http://www.biogaspartner.de/index.php?id=10074 (accessed August 21, 2009).

4.2.7.4 Actors in the Constellation

Support from the Bundestag

In the course of the parliamentary consultations, the tariff rates specified in the interdepartmentally agreed-upon Government drafts were revised upwards. The biogas sector benefited from the fact that delegates agitated for a correspondingly high “slurry bonus” as well as a “Landscaping remains bonus”[123] for smaller plants and a special bonus (CHP Bonus) for the drying of digester waste.

Actors in the Gas Industry

With the “biogaspartnership” project, the German Energy Agency (dena) created a platform for supporting the segment of biogas injection. This platform is intended to set in motion an exchange of experience between the gas industry and the primarily industrial biogas producers and substrate suppliers. The gas supply companies support the injection of biogas: the substitution of conventional natural gas with “green gas” creates a positive image. However, the interests of the gas industry are concentrated on the marketing of “green gas” to the end user – whether that turns out to be to households for heating purposes or as fuel for vehicles. A technological system change toward more CHP and centralized district heating was not pursued as this reduced possibilities for making profits from end users. Rather, the gas industry demanded that support for renewable energy be fundamentally “open-minded about technology” and that it should not only be semi-centralized renewable energy technologies and CHP plants which should profit from the system.

The development of the market for the injection of biogas continues to be subject to restrictions regarding the availability of substrate and suitable locations for the injection of biogas into the gas grid. Whether the injection targets set by the Federal Government can be attained under these conditions is questioned by those familiar with the sector.

4.2.7.5 Interpretation of the Constellation and Future Prospects

From mid-2008 onward, falling substrate prices resulted in a relaxing of market conditions whereby the financial viability of those small and medium-sized plants already in operation improved. The improved tariff ruling in the EEG of 2009 led to a revival of demand for plants. However, the generation of electricity from biogas remains the most expensive of all the renewable electricity generation technologies

[123]This term describes the use of plant material which comes up in the course of maintainance and enhancement of grassland, shrubs, forests, hedges, etc.

due to the high operating costs. Existing dependence on substrate prices means that, in the future, operators will continue to have to deal with a more or less irreducible level of risk. Because of this, the EEG continues to be the main support for the sector consisting of small and medium-sized plants. Tariffs covering the costs of electricity generated from biogas are likely to remain of interest to the agricultural sector since they provide income generating opportunities for those in agriculture and support the aims of rural development.

The amendment of the GasNZV sent out positive signals to large-scale industrial plants and the gas injection sector. This marketing opportunity is regarded as a second source of income for the sector, opening up shares in the market in the areas of transport and heat/direct marketing. However, it is rather the "industrial biogas plants" segment, with its previously mentioned unwanted side effects, which benefited from the cultivation of energy crops and substrate transport. In the future, further readjustments will be necessary in order to reduce pressure on land and the environment. The readjustment could, for instance, be aimed at making the use of waste materials as digester substrate more attractive as well as implementing rules (e.g. defined areas, upper limits on cultivation) for the ecologically sustainable cultivation of energy crops.

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Chapter 5
Innovation Conditions in the Case of Solar Power Generation

Abstract The development of photovoltaics since the mid-1970s is divided into six phases. The beginning of the period examined was characterized by the two oil price crises of the 1970s and an awareness of limits to growth. After helping the technology's introduction on the market by means of a broad-scale support program, the municipalities bridged the subsequent critical phase in the development by guaranteeing cost-covering compensation for photovoltaic electricity. The 100,000 Roofs Program was crucial for the photovoltaics breakthrough. The Renewable Energy Sources Act ultimately created long-term security for investment, which led to a boom in the development. Innovative activities in the field of photovoltaics usually rank as high-tech technologies. In addition, photovoltaics is split up into several different technology lines that run in parallel. It is this complexity that sets photovoltaics apart from wind power technology, for example. An additional key factor is the high expectations that commercial and political entities have for this technology, despite photovoltaic electricity generation still being very expensive.

As an alternative to the decentralized use of photovoltaics on buildings, 7–8% of the capacity today is produced in ground-mounted photovoltaic systems – the social acceptance of which is much lower, though. Photovoltaic installations on buildings are more expensive than ground-installed systems, yet they also cause less conflict because they are hardly visible and do not interfere with the appearance of the landscape. Currently there is a very high, unused potential of roof space, the harnessing of which not only requires acceptance but also a more active stance on the part of the actors.

Keywords Photovoltaics • Crystalline and thin film cells • Private operators • Raising efficiency • Cost-covering compensation

5.1 Preliminary Remarks

In addition to passive solar technologies, energy from the sun can also be harnessed using three different types of active solar technologies:

E. Bruns et al., *Renewable Energies in Germany's Electricity Market: A Biography of the Innovation Process*, DOI 10.1007/978-90-481-9905-1_5,

1. Solar thermal energy that uses collectors to produce heat
2. Photovoltaic (PV) systems that make direct use of light energy to generate electricity, using semiconductors. Semiconductors are materials whose conductivity can be enhanced through energy input in the form of heat or light. These materials include silicon (Si) and germanium (Ge) and also organic synthetic materials and dyes. Semiconductors convert light energy into electrical energy
3. Solar thermal power plants that generate heat, which is subsequently converted into electricity using a steam power cycle

Since the use of solar thermal energy to generate electricity is not relevant for solar power production in Germany this chapter will not examine it in any great depth. The construction of solar thermal power plants only makes sense in countries with high levels of global radiation (e.g. in the Mediterranean or in the equatorial region which receive 2,000–3,000 kWh/m² a year). In spite of this, Germany has provided a great deal of funding for research into this technology since the 1980s.

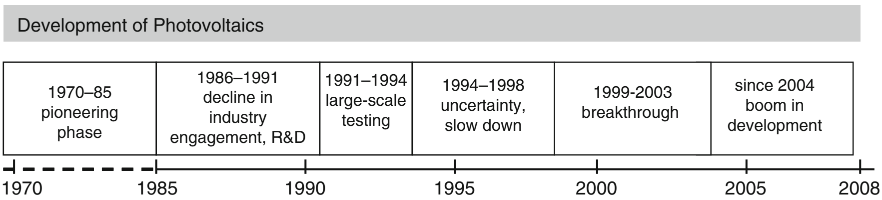

Fig. 5.1 Phases of the development of photovoltaics in Germany

Using an interdisciplinary approach the photovoltaic development process in Germany was divided up into six phases (see Fig. 5.1). Each phase was then examined in greater detail. (see Sect. 5.2). The next section provides a short overview of the history of photovoltaics prior to the actual period of investigation, which starts in 1970.

5.2 Phase-Specific Analysis of the Innovation Process

5.2.1 A Historical Overview

Alexandre-Edmond Becquerel was the first to observe the photoelectric or photovoltaic effect in 1839. The history of photovoltaic electricity generation began in 1873 with Willoughby Smith's discovery that light irradiation increased the conductivity of selenium a thousandfold. Then in 1876 William Grylls Adams and Richard Evans Day demonstrated that selenium produced electricity when exposed to light. A great deal of research was conducted into the photoelectric effect over the next few decades and a basic theory took shape explaining this phenomenon. In 1905 Albert Einstein published his paper on the photoelectric effect, which won him the Nobel Prize in 1921.

Another important step in establishing the foundations of semiconductor technology and photovoltaics was Jan Czochralski's discovery in 1916 of a method of growing single crystals, which was subsequently named after him (the Czochralski process). The technique was refined in the 1940s and put into practice on a wider scale in the 1950s due to increased demand for semiconductor components.

In 1954 Bell Laboratories (USA) unveiled the first silicon solar cell – the USA is thus known as the birthplace of photovoltaics. As a result of the costs involved, the new technology was primarily used in space travel in the 1950s and 1960s. In 1958 the first satellite (Vanguard I) to generate power with solar cells was sent into space. In the 1960s in Germany AEG-Telefunken began to manufacture cells for the space industry. The first satellite with AEG solar cells was AZUR 1 in 1968 (Räuber 2005, 154). AEG-Telefunken and Wacker Chemie researched and produced crystalline solar cells. In the mid 1960s Siemens also became active in this field.

The photovoltaic cells used during this period by the space industry were manufactured exclusively from monocrystalline silicon. Monocrystalline silicon was produced using the complex and expensive Czochralski process. However, the high costs did not have a major impact on the technology's application in the field of space travel and space exploration.

5.2.2 Phase 1: Pioneering Phase, 1970–1985

5.2.2.1 Characteristics of the Constellation

Sparked by the oil price crises in the 1970s (see Sect. 3.1.1), this period was dominated by the search for energy-efficient alternatives and an awareness that growth was limited. The introduction of state research funding into photovoltaics for domestic electricity production signaled the start of government interest in this power generating technology. Research into the various applications of the fledgling photovoltaic technology formed the core of the constellation, supported by the First Energy Research Program launched by the Federal Research Ministry. Research focused above all on improving the base materials. Research was also conducted into all components of the manufacturing chain within the scope of demonstration projects and into using photovoltaic technology in hand-held devices. Established industrial corporations and research institutes were both involved in the research activities. Activities abroad (in the USA and Australia) acted as precursors for activities in Germany. In this phase, however, the constellation only comprised a small number of relevant actors and influencing factors (Fig. 5.2).

5.2.2.2 Sector-Specific Context, Influencing Factors and Processes

Key factors in the development of photovoltaics in Germany during this phase were the oil price shocks of 1973/1974 and 1979/1980, a desire to reduce dependence on imported raw materials, an awareness that fossil fuel reserves were limited, the environmental impacts of conventional energy sources and a lack of acceptance for nuclear energy. A further important factor was a certain fascination for a technology based on an inexhaustible source of energy.

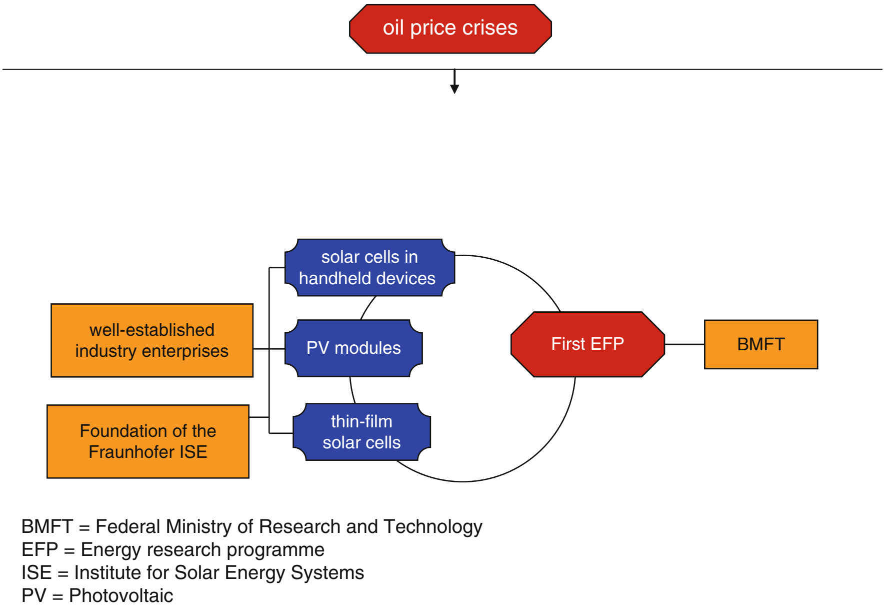

Fig. 5.2 Constellation phase 1: pioneering phase, 1970–1985

Against this backdrop, bold visions and optimistic goals concerning the application of photovoltaic technology emerged. A rapid transformation of the energy system into a "solar powered world" was viewed as a feasible endeavor (Jacobsson et al. 2002). In the 1970s demand for solar cells for domestic applications exceeded that of space travel for the first time.

Events in other countries which stimulated developments in Germany during this phase included the 1973 Cherry Hill Conference organized by the US Department of Energy and the world's first electricity feed-in act for renewable energies, the Public Utility Regulatory Act (PURPA),[1] which came into force in the USA in 1978. Another important practical step was the decision by the Australian government in 1976 to power the outback's entire telecommunications network using battery stations based on photovoltaic technology. The installation and operation were extremely successfully, sparking a surge in interest in photovoltaics across the world.

5.2.2.3 Government Policies: Research and Development Funding

In Germany, political interest in the new technology rose significantly. Already in 1982 research and development expenditure in the field of photovoltaics soared.

[1] The PURPA was passed by the United States Congress as a federal law. Its implementation was left up to the discretion of the states and they applied the law in various ways. The PURPA created a market for electricity producers insofar as energy supply companies were obliged to purchase electricity from other "non-utility producers".

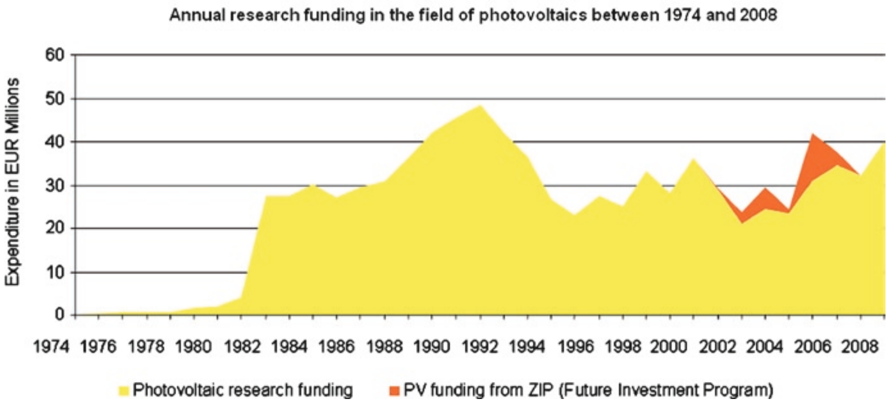

Fig. 5.3 Federal project grants for photovoltaics since 1974 (BMU 2009a, 16)

Grants were allocated not only to industry but also to research institutes. The extent of project funding increased dramatically from 1982 (see Fig. 5.3). Between 1975 and 1985 the Federal Research Ministry allocated a total of 160 million German mark[2] to research and development projects (Lundszien 1997, 36). One such project was the Technologies to Harness Solar Energy program (Technologien zur Nutzung der Sonnenenergie), launched as part of the Federal Government's First Energy Research Program (1977–1980) under the direction of Federal Research Minister Volker Hauff. The First Energy Research Program focused on developing new base materials and cost-effective production processes as well as compiling and evaluating relevant meteorological and technical data.

The research projects fell within the remit of the Federal Research Ministry's department responsible for microelectronics (semiconductor technology and information technology). The Federal Research Ministry held the opinion that photovoltaic technology was best implemented in a decentralized manner in small-scale projects. The government's share of funding for photovoltaic research projects was initially 80% but was later reduced to 50% – the rest of the share had to be raised by the beneficiary.

5.2.2.4 Actors in the Constellation

Important actors in the pioneering phase were those who furthered research into power generation using photovoltaic technology. In addition to the Federal Research Ministry, which provided the funds, these actors included established corporations such as AEG and Siemens, universities and the first non-university-affiliated research institute for solar energy systems, the Fraunhofer ISE.

[2] German mark here refers to the former German currency, Deutsche Mark.

Industrial Photovoltaic Research

Compared with the years before, this phase saw a comparatively significant increase in industry's photovoltaic research activities. Between 1975 and 1985, research contracts were assigned firstly to Wacker (silicon and silicone) and AEG-Telefunken (cells and systems technology) and later also to Siemens (source materials and thin film) and the Siemens subsidiary Interatom (systems and system components) (Räuber 2005, 155). In 1979 the RWE subsidiary, NUKEM, began work to enable industrial-scale production of thin-film solar cells based on copper sulfide (Cu_2S/CdS). In 1980 MBB launched a research project into production of amorphous silicon thin-film solar cells (a-Si). Siemens and AEG conducted similar research activities (Räuber 2005, 155). Energy suppliers also expressed a certain level of interest in photovoltaic technology, provided the undertaking was of a sufficient magnitude: the utility company RWE operated the photovoltaic power plant on the island of Pellworm (see Sect. 5.2.2.5).

Foundation of the Fraunhofer ISE

The Fraunhofer Institute for Solar Energy Systems (ISE) was founded in 1981 in Freiburg. It was the first non-university-affiliated solar energy research institute in Europe.[3] At the time, large industrial companies could not see a function for an institute of this kind (Räuber 2005, 155). Today, however, projects commissioned by industry account for approximately one third of the ISE's revenue and the institute has close working ties with numerous companies in the photovoltaic sector.

5.2.2.5 Technology and Market Developments

Believing that it was possible to bring about rapid cost reductions and increase efficiency rates, thus making solar cells a marketable commodity, NUKEM and MBB followed the example of AEG, Siemens and Wacker Chemie at the end of the 1970s and also started researching and producing crystalline solar cells. Founded in 1914 in Burghausen, Wacker Chemie began research into the field of hyper-pure silicon as early as 1947 and started manufacturing hyper-pure polycrystalline silicon in 1953.[4] In 1978, working together with AEG-Telefunken, Wacker developed the first polysilicon solar cell, which made production many times cheaper than with single crystal silicon. Wacker had, in fact, developed multi-crystalline silicon for application in the field of optical technology. In 1983 Wacker Chemie also

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[3] It was founded by Professor Adolf Goetzberger, see http://www.ise.fraunhofer.de/about-us/history/history?set_language=en&cl=en (accessed June 30, 2009).

[4] http://www.wacker.com/cms/en/wacker_group/wacker_facts/history/history.jsp (accessed 30 June 30, 2009).

began to manufacture wafers, but discontinued production in 1988 due to insufficient demand. Wacker passed on its expertise in this area to Bayer.

The GDR also produced hyper-pure silicon. VEB Spurenmetalle, founded in Freiberg in 1957 and taken over by Bayer Solar and later by SolarWorld after reunification, began production of silicon and wafers for the GDR's semiconductor industry in 1966.[5]

In 1975 thin-film solar cells based on copper indium (di)selenide (CIS) achieved over 12% efficiency in laboratory conditions. In 1978 Wacker Heliotronic and AEG-Telefunken developed a new method to manufacture polycrystalline silicon. It was now possible to mass-produce cast polycrystalline blocks with an initial efficiency of 13% at a fraction of the manufacturing costs for the monocrystalline cells used in space (Wagemann 2004, 21).

Germany's first PV power plant was constructed in 1983 on the island of Pellworm. It was a pilot plant, using cells manufactured by AEG. The plant, which was financed entirely with federal research funding (Jacobsson et al. 2002, 18), was the largest plant in Europe at the time with an output of 300 kW.

All important discoveries that had an impact on photovoltaics today had essentially been made by 1984 (Räuber 2005, 156). This includes monocrystalline silicon solar cells with a lab-efficiency of 18%, which were successfully produced in three laboratories. The same period saw the discovery of three thin-film technologies with the potential to be produced on an industrial scale (amorphous silicon (a-Si), cadmium telluride (CdTe) and copper indium (di)selenide (CIS)). By this point, researchers had also already developed the construction principle for photovoltaic modules, which is still predominantly in use today. Since then, activities to promote the development of technologies to produce solar power have focused on four areas: enhancing solar cells from mono or polycrystalline silicon and thin film, improving inverters and developing industrial-scale production technology.

The production of a photovoltaic module involves a complex value chain from the base material to the finished module. This process brings together a range of different and largely independent branches of production (Räuber 2005, 166):

- Chemistry/metallurgy, required for wafer production
- Semiconductor technology, required to manufacture cells (adaptation of semiconductor-based electronics)
- Glass technology and glass finishing, used in module technology (adaptation of laminated glass technology)
- Plastics technology, also used in module technology
- Microprocessor technology and power electronics, used in inverters

[5] After the end of the GDR, the company operated under the name of Freiberger Elektronikwerkstoffe GmbH from 1990 and was taken over by Bayer Solar in 1994. In 2000 SolarWorld acquired a majority stake in Bayer Solar and renamed the company Deutsche Solar. See http://www.deutschesolar.de/Chronik.236.0.html?L=1 (accessed June 30, 2009); see Fig. 5.9.

Thus in many areas it was possible to build upon existing technologies. However, photovoltaic technology still had to undergo a large number of both minor and major development steps in order to make the leap from the laboratory through workshop production to today's largely automated industrial manufacturing processes.

Due to the low number of units and efficiency rates, the cost of producing photovoltaic cells was extremely high during this phase. It was only economically viable to use this technology to generate electricity in particular niches and for isolated applications that had previously mainly been battery-powered (e.g. buoys, telecommunications devices or wrist watches) (Grober 2004). The combination of battery power supply and solar cells made it possible to significantly cut the operating costs of these isolated applications, meaning that the high cost involved in purchasing the solar cells quickly paid off. However, the comparatively high purchase price prevented the mass-market application of the technology. As a result of the low demand, only very small volumes were produced using costly workshop manufacturing methods. In the absence of economies of scale, it was not possible to achieve significant cost reductions in this way.

5.2.2.6 Interpretation of the Constellation: Driving Forces and Constraints

This phase can be described as a euphoric pioneering phase. When compared with previous years its defining feature is the significant increase in funds provided by both the government (see Fig. 5.3) and industry. The key background motivation was a desire to secure Germany's energy supply, in view of the oil price crises of the 1970s. However, actors from industry in particular had extremely high expectations regarding the immediate potential to use photovoltaics, mistakenly believing that the goal of industrializing this new technology was already within reach. Companies focused on less expensive products, in spite of being aware of their lower efficiency rates (Räuber 2005, 153–155). However, there were very few reliable photovoltaic products on the market. Overall, there was no sign yet in this phase that the situation regarding the costs of photovoltaics would improve. Nevertheless, cost trend graphs provided hope that photovoltaics projects would break even in the long term.

5.2.3 Phase 2: Stagnation of Industry Engagement, R&D, 1986–1991

5.2.3.1 Characteristics of the Constellation

The modified context was one of the factors that gave rise to changes in this phase. The reactor disaster in Chernobyl and the report by the Enquete Commission on Preventive Measures to Protect the Earth's Atmosphere boosted hopes vested in the

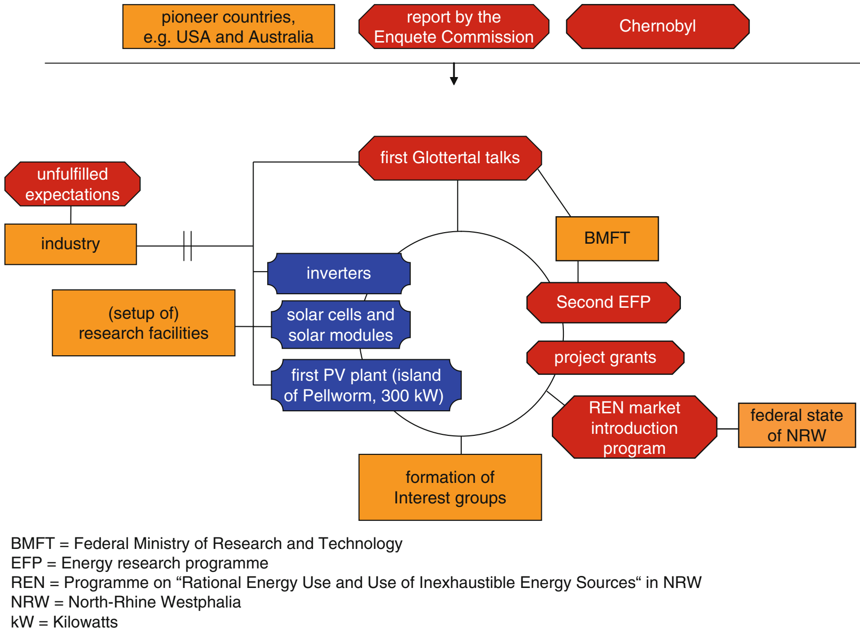

Fig. 5.4 Constellation phase 2: stagnation of industrial engagement, R&D, 1986–1991

technology. The first photovoltaic power plant demonstrated the technology's potential to generate electricity. However, industry's expectations of rapid increases in efficiency were not fulfilled and industry engagement stagnated (Fig. 5.4). There was increasing pressure to act and thus the decision was made to optimize research funding allocation. The aim was to focus the Second Federal Energy Research Program on the promotion of technologies to harness solar energy. The state of North-Rhine Westphalia's REN program[6] played a part in increasing the utilization of photovoltaic systems. The constellation stabilized in spite of industry's declining interest, thanks to intensified and institutionalized cooperation between policy-makers, companies and research institutes (by means of advisory sessions known as the *Glottertal talks*, for example), the establishment of new research institutes and the improvement of the facilities of existing ones. Associations were founded to provide institutional structures for the interests of actors engaged in activities to promote photovoltaics. These associations also helped bolster the foundations of the constellation.

[6] The program "Rational Energy Use and Use of Inexhaustible Energy Sources" provided investment aid for renewable energy facilities. It was initiated by the state government of North-Rhine Westphalia in 1989 and has been revised on a yearly basis ever since (see Sects. 3.6.3 and 5.2.2.3).

5.2.3.2 Sector-Specific Context, Influencing Factors and Processes

Chernobyl, Resource Conservation and Climate Protection

The second phase of the innovation process was set in motion by the shock of the reactor disaster in Chernobyl, which also had a major impact on the development of photovoltaics. The ecological consequences and risks for the energy industry became a topic of public debate that energy policy-makers could no longer ignore. The appointment of and report by the German Bundestag's Enquete Commission on Preventive Measures to Protect the Earth's Atmosphere was also a response to findings concerning global ecological risks (see Sect. 3.1.1 for more detailed information). The actors involved in promoting renewable energies could see a sea change in energy policy emerging on the horizon: an inspiring vision whereby renewable energies, and in particular solar energy, completely covered energy requirements. The sun became the symbol of the movement against nuclear energy and in favor of a change in energy policy.

The European Community: Recognizing Problems and Setting Goals

Climate protection problems featured on the political agenda at international and EU levels in this phase. The first climate protection goals were determined at these levels, which sped up the process of developing measures at national level in Germany. In 1988 the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) established the Intergovernmental Panel on Climate Change (IPCC). As early as 1990 the first IPCC Assessment Report already set out goals concerning climate protection and reduction of CO_2 emissions. However, these were not yet legally binding (see Sect. 3.2).

This coincided with intensified efforts on the part of the EU to liberalize the energy market (see Sect. 3.9.3). In 1988 the EU Commission voiced its opposition to the existing monopolistic structures and exclusive rights on the electricity market (COM 1988). This was followed by two draft directives in which the Commission announced further steps to liberalize the energy market (Matthes 2000, 178–179). This prompted the German Federal Government to amend the Federal Electricity Tariff Regulation, which gave small electricity producers access to compensation payments for the first time. The concurrent efforts to liberalize the market and protect the climate resulted in a context that was extremely conducive to the development of renewable energies in Germany.

Influences from Abroad

From about 1980 onward it became standard practice to use solar modules to operate signaling systems and offshore oil rigs. In the late 1980s solar modules were used to power signaling systems on the coastline and navigation lights. They replaced battery-operated systems and were a more cost-effective alternative that required less maintenance. As a result of these first major commercial activities, the USA had attained a 21% share of the global photovoltaics market by 1983. The USA also led the way at the international level in terms of research, in particular in the area of amorphous silicon. Activities in the USA and those in Australia described in the previous chapter (see Sect. 5.2.2.2) acted as precursors for activities promoting photovoltaics development in Germany.

5.2.3.3 Governmental Guidance and Economic Context

Research Funding from the Mid 1980s

For the first time in the area of public research funding, the Federal Government's First Energy Research Program (1977–1980) comprised its own sub-program entitled Technologies to Harness Solar Energy. The Second Energy Research Program (which ran from 1981 to 1989) significantly expanded this element. With regard to photovoltaics, the Second Energy Research Program focused on:

- Conducting basic research
- Minimizing the costs of thin-film solar cell production
- Conducting research into new materials
- Cutting the costs of production procedures and silicon manufacture, while boosting efficiency rates

At this time photovoltaic cells still had extremely low efficiency rates. The cells were so thick and consequently required such a high materials input that it took 5 years before they had even regenerated the energy consumed in their production. Key aims of research promotion were, therefore, to develop thinner and thus more cost-effective wafers, reduce sawing losses, boost efficiency and simplify processes.

Following the reactor disaster in Chernobyl, the research budget for renewable energies increased significantly. The first increase came in May 1986 and amounted to an annual 50 million German mark. Funding was later increased to 300 million German mark (see Fig. 5.3).[7] Research into renewable energies was suddenly no longer a token gesture. All this enabled the continuation of funding, in particular for thin-film cell research (Siemens and MBB), which was subsidized by 70% (Eisenbeiß 2007, pers. comm.).[8]

In 1985 the Federal Research Ministry launched a demonstration program that involved, inter alia, testing the application of photovoltaics in decentralized sensors, sea buoys, street lamps and signs. This was a joint program carried out in cooperation with the Institute for Solar Energy Supply Technology (ISET) and the Fraunhofer Institute for Solar Energy Systems (ISE) and flanked by a 2-year monitoring program.

[7] Ongoing projects promoting rational energy use and hydrogen and energy storage research could also make use of these funds.

[8] Projects in particular areas (such as solar technology for developing countries) were subsidized by 100%.

These experiments expanded the scope of photovoltaic systems, which had primarily been used in small-scale applications up to that point (Eisenbeiß 2007, pers. comm.). The energy supply companies RWE and Bayernwerk now also provided funding for large-scale demonstration projects.

While installed solar power generation capacity only amounted to 1.5 MW in 1990, by the mid 1990s the demonstration program had facilitated the construction of more than 70 large-scale facilities with various applications. Thus above all, the program had resulted in new knowledge with regard to the application of photovoltaics.

Glottertal Talks

The "Glottertal talks",[9] which were bi-annual strategic talks on research funding between politicians, researchers and industry, took place for the first time in 1987. Representatives from the Federal Ministry for the Environment and the Federal Ministry of Research met with project administrators and leading figures from research institutes and companies to discuss possible key areas for research funding. The research community had the chance to formulate proposals on the future shape of research funding (Prognos AG et al. 2007a, 24, 148, 292; Dürrschmidt 2007, pers. comm.).

The strategic talks also dealt with research into photovoltaics. In view of the decline in industry engagement during this phase, the expert discussions on research funding were of particular importance. The focus was on gearing photovoltaic research toward future requirements in a targeted manner.

State Funding in North-Rhine Westphalia (REN)

1987 saw the launch of the program Rational Energy Use and Use of Inexhaustible Energy Sources (REN) in North-Rhine Westphalia, which is still running today. The broad-based funding within the scope of the REN program supports construction measures that aim to save energy and utilize renewable and inexhaustible energy sources. Grants were specifically allocated to investments that would expedite the introduction of environmentally friendly technologies on the market. Funding was primarily granted to solar panels (up to 2007, ca. 26,000 solar panel systems with a collector surface of ca. 225,000 m^2) and photovoltaic systems (up to 2007, ca. 11,000 photovoltaic systems with an installed capacity of about 65,000 kW).

However, the REN program was dependent on annual budget consultations and could not provide investors with long-term security. Instead, it either promoted or hindered developments, depending on the level of funds available. Nevertheless, the

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[9] The Glottertal talks are representative here of strategic debates overall. Talks were also held in Bad Zwischenahn and there were a number of other expert discussions involving researchers, sector representatives and project administrators to determine the direction of research and development policy.

program did have a wide-ranging impact on the field of photovoltaics in some respects. From 1987 to 2007 the REN program allocated about 260 euro million to a total of some 51,000 projects. The grants prompted private follow-up investment amounting to nearly 1.5 euro billion and resulted in the creation of about 15,000 jobs.[10]

5.2.3.4 Technology and Market Developments

In the mid 1980s there was an air of stagnation and disillusionment in the field of industrial photovoltaic development. It became clear that it was not sufficient for cells to have an efficiency of 10%, even if production was more cost-effective. This realization dashed hopes that high levels of investment in research and development could lead to cost-effective solutions within a very short period of time. Photovoltaic systems in the USA and Japan had ever-increasing efficiency rates, a trend which the German photovoltaics industry was badly prepared for, in spite of numerous warnings from research circles. This led to a complete reorientation from the mid 1980s to the mid 1990s and a number of mergers and takeovers resulting from strategic corporate decisions. The number of industrial companies that withdrew from the photovoltaics business was virtually the same as the number that entered into mergers (Räuber 2005, 156 sqq.).

Crystalline Silicon

In the field of crystalline photovoltaics two predominant lines of industrial activity had developed by the end of the 1990s: one can be traced back to AEG-Telefunken[11] and NUKEM; the other began in 1965 with photovoltaics-related activities at Siemens, which manufactured crystalline silicon (using assembly-line production procedures) and amorphous silicon (a-Si) for thin-film cells. However, following the acquisition of ARCO Solar (USA) in 1990, these activities were largely discontinued in Germany. With the ARCO takeover, Siemens Solar Industries (a joint venture of Siemens and E.ON) had acquired solar cell technologies based on monocrystalline silicon and CIS technology, which were both considered to hold far greater potential than Siemens Solar's own technologies.

Thin-Film Technologies

During both this period and the preceding phase, great hopes were vested in thin-film technology. Many were optimistic that the use of thin film would quickly transform photovoltaics into a profitable technology, and anticipated that production costs would be in the area of 30 cents per watt as early as the 1990s.

[10] These figures come from Internet sources (www.ren-breitenfoerderung.nrw.de/evaluation/index.html) that were no longer available by the time study was concluded.

[11] In 1989 AEG Telefunken's photovoltaic unit was taken over by the company DASA, which was founded by Daimler-Benz.

Since the emergence of thin-film cells in 1980, the following lines of technology have proven to be particularly suitable and are still pursued today (see Fig. 5.5):

- Copper indium (di)selenide (CIS)
- Amorphous silicon (a-Si)
- Cadmium telluride (CdTe)

For a long time, the area of copper indium (di)selenide pursued two lines of development. One line has its origins in a process developed by Stuttgart University and the Centre for Solar Energy and Hydrogen Research (Zentrum für Sonnenenergie und Wasserstoff-Forschung – ZSW), which was later adopted by the company Würth. The second line has its origins in Siemens' thin-film projects and was subsequently adopted by Shell Solar. The beginnings of amorphous silicon (a-Si) technology date back to 1980 at MBB (Putzbrunn), which formed the basis for the spin-off company Phototronics Solartechnik (PST), founded in 1988. Siemens was also involved in research into amorphous silicon. The third line of technology, developed on the basis of cadmium telluride (CdTe), has its origins in Germany at the Battelle Institute in Frankfurt. The development of thin-film cells – initially based on cadmium selenide – began here in 1977 (see Fig. 5.5).

In 1979 developers at the nuclear fuel element manufacturer NUKEM began work on thin-film cells based on cadmium sulfide. After a joint venture with the aerospace company MBB failed to materialize in the mid 1980s, the company moved the focus to crystalline silicon (Iken 2005).

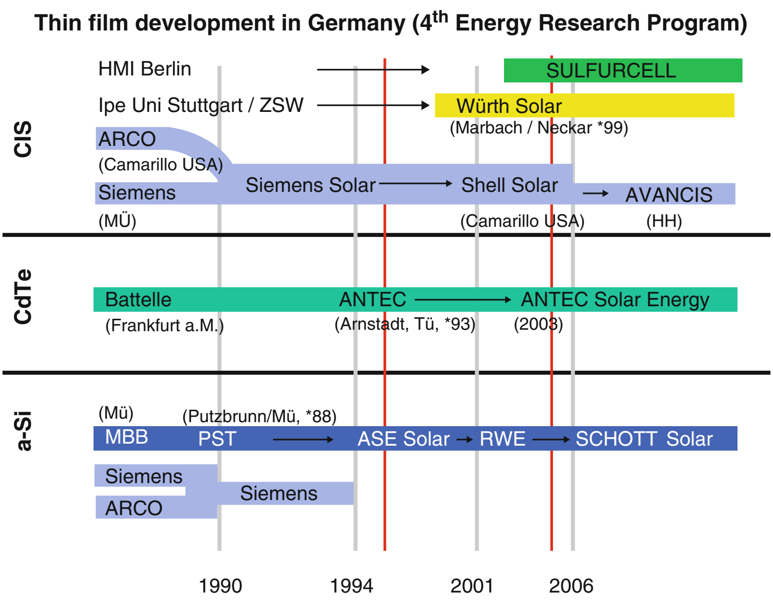


Fig. 5.5 Industry development of thin-film solar cells (Prognos et al. 2007b, 410)

Overall, there were no major advances in technology until the beginning of the 1990s. Photovoltaic systems from this period up until the mid 1990s were also far more likely to suffer from operational failures due to malfunctioning inverters or other electrical defects than systems developed in subsequent years. The 60–70% performance ratio (PR) of these systems was significantly lower than ratios today (as of 2009). The systems also deteriorated over the years, which also further slightly reduced the ratio (BINE 2003, 4).

Connection of First Photovoltaic Systems to the Grid

The first grid-connected photovoltaic systems were installed in the second half of the 1980s, primarily on private residential buildings (Stryi-Hipp 2005, 183). The standard feed-in tariff for solar power ranged from 6 to 10 pfennigs per kilowatt hour. This low tariff was justified on the grounds that reserve capacity should be stored for the winter period. However, some energy supply companies allowed customers to feed in power via reversible electricity meters (net-metering) (ibid). Several municipal utilities even launched support programs for photovoltaics. At the end of the 1980s, the municipal utility company Stadtwerke Gießen offered subsidies to 100 facilities of 1 DEM/W, a maximum of 1,000 German mark, as well as a feed-in payment of 10 pfennigs per kilowatt hour. Stadtwerke Saarbrücken also offered a higher compensation for solar or wind-powered electricity: a feed-in payment of 25 pfennigs per kilowatt hour for a period of 20 years. This was the highest payment in Germany at the time. The VSE Group AG (Vereinigte Saar-Elektrizitäts-AG) was the first company to officially introduce a 1:1 compensation with reversible electricity meters (Stryi-Hipp 2005, 183). It became apparent at the end of 1980s that connecting the systems to the grid was a vital step for the expansion of photovoltaics in Germany.

5.2.3.5 Photovoltaics in the Field of Development Cooperation

At the beginning of the 1980s, photovoltaics assumed a more significant role in development cooperation. Module manufacturers and above all photovoltaic distributors provided developing countries with both power generating facilities and their expertise on these systems. In addition to systems enabling the electrification of homes, solar-powered water pumps were also a significant development (Eisenbeiß 2007, pers. comm.).

Alongside the Federal Research Ministry, the Federal Development Ministry also supported photovoltaics, albeit to a lesser degree. In 1982 it launched a joint project between Germany and the Philippines and thus became a pioneer in the field of rural electrification using photovoltaics (Stryi-Hipp 2005, 183; Eisenbeiß 2007, pers. comm.). The mid 1980s saw the installation of photovoltaic systems in the Philippines, Jordan, Indonesia, Senegal and Peru, primarily to generate electricity in villages and houses. Photovoltaics was viewed as holding great potential in countries with high levels of solar radiation, but less so in Germany.

The funding of demonstration systems abroad improved the market for developments in German photovoltaic technology and thus had a favorable impact on the innovation process.

5.2.3.6 Actors in the Constellation

In addition to actors at international level (see Sect. 5.2.2.2), the Federal Research Ministry (see Sect. 5.2.2.3) and industrial companies (see Sect. 5.2.2.4), a number of newly founded research institutes and several states played an important role in this phase. Among these states, North-Rhine Westphalia was particularly active in the field of photovoltaics with its REN program (by providing investment grants for photovoltaic installations). While it may not have provided security for investors, it nevertheless contributed to the spread of photovoltaic systems (see Sect. 5.2.2.3). In addition, newly founded interest groups also supported the process.

Foundation of Solar Energy Research Institutes

Against the backdrop of an increasing need for research, the 1980s saw the foundation of many of today's leading solar energy research institutes, such as the Fraunhofer ISE in Freiburg (founded in 1981, see Sect. 5.2.2.4), the Institute for Solar Energy Research Hameln in Hameln (ISFH), founded in 1987, the ZSW in Stuttgart founded in 1988 and the ISET in Kassel founded in 1988. During this phase, there was a spirit of optimism in the area of research. Institutes worked closely with industry (e.g. Wacker, Siemens, NUKEM) and conducted numerous successful projects (Räuber 2005, 158).

Foundation of Solar Associations and Organizations

Non-parliamentary associations, organizations and groups deserve their own section in the history of photovoltaic development. They repeatedly drew attention to the potential of photovoltaics and worked with enormous determination to ensure it received greater support. There were three types of organizations that advanced the cause of photovoltaics:

- Associations and societies: one of the first associations to come into existence was the German Society for Solar Energy (DGS),[12] which was founded in 1975 in Munich. Solar energy associations were and are the most influential lobbying force and continue to play a vital role in propagating the cause of solar energy. Their intensive information campaigns conducted over many years helped create a positive image for solar energy and enhanced the framework conditions in this area. In 1986, in the aftermath of the Chernobyl disaster, the German Association for the Promotion of Solar Power (SFV) was founded in Aachen. The SFV was

[12] Since 1989, it has also functioned as the German section of the International Solar Energy Society (ISES).

a pioneer of the solar energy movement and carried out important groundwork in the diffusion of photovoltaic systems and the creation of institutional structures to support solar energy in Germany. It developed, for example, the concept of cost-covering compensation (see Sect. 5.2.4.4).
- Industrial associations: the Association of Solar Energy SMEs (Verband mittelständischer Solarindustrie e.V. – VSI) came into existence in 1979 and changed its name to the German Solar Industry Association (Deutscher Fachverband Solarenergie e.V. – DFS) in 1986. The association is active above all in lobbying campaigns for the photovoltaic industry.
- International associations: EUROSOLAR was founded in August 1988. This non-profit European association for renewable energies is dedicated to replacing nuclear and fossil energy with a system based entirely on renewable energies. Its activities are particularly geared toward developing political and economic concepts to enable the implementation of renewable energies. EUROSOLAR's members include parliamentarians, scientists, companies, associations and citizens from a wide variety of occupation groups.[13]

These three types of organizations demonstrate that photovoltaic technology found advocates at a number of levels; they gradually branched off in different directions and formed networks. During the pioneering phase and during the phase in which industry involvement stagnated, the ground-breaking work of associations and societies provided a particularly firm basis for the development of photovoltaics. Furthermore, the organizations helped shape measures at federal, state and local level and played a major role in conveying the potential of photovoltaics (Mautz & Byzio 2005, 31; Jacobsson et al. 2002, 20).

5.2.3.7 Interpretation of the Constellation: Driving Forces and Constraints

The reactor disaster in Chernobyl and the report by the Enquete Commission resulted in major changes to the context of the photovoltaic constellation in Germany, which increased the scope for action. At the same time, however, a decline in industry involvement slowed down developments. The constellation in this phase is marked by disillusionment on the part of industry. It transpired that the ambitious expectations did not reflect reality; the phase of boundless "solar-power optimism" was over. Development stagnated from the mid 1980s, as companies began to doubt the potential economic viability of photovoltaics.

However, federal and state research funding protected the niche of photovoltaics. The reactor disaster in Chernobyl resulted in a significant increase in research funds. The research community, which generated knowledge about various potential applications of solar cells, received a boost and prospered as a result of state funding and development funding. Many photovoltaic applications underwent comprehensive product development measures. On the one hand, the background motivation for

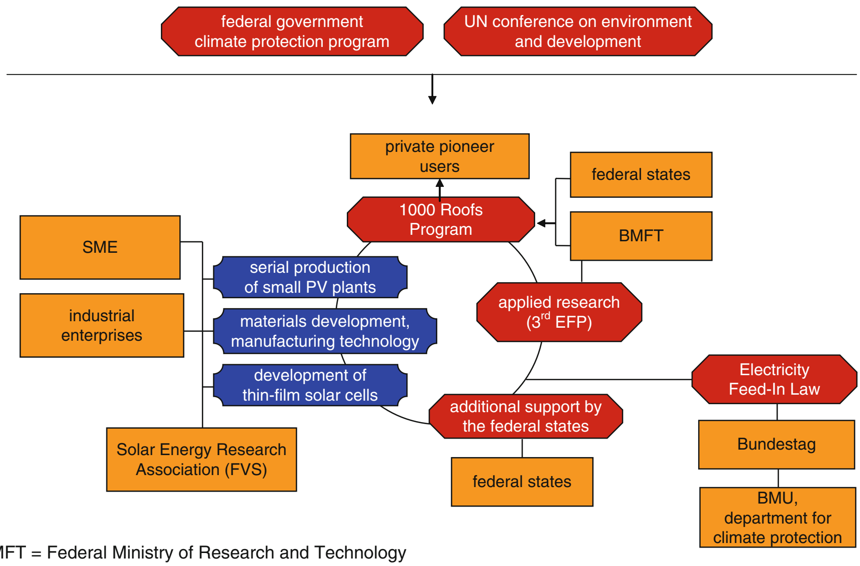
[13] See www.eurosolar.de (accessed July 6, 2009).

providing this support was photovoltaics' image as an environmentally sound and climate-friendly power generating technology. On the other hand, doubts concerning the use of nuclear energy sparked by the reactor incident in Chernobyl were growing and the search for alternatives was becoming ever more pressing. During this phase, grid-connected systems gained in significance for the first time.

5.2.4 Phase 3: Large-scale Testing from 1991 to 1994

5.2.4.1 Characteristics of the Constellation

During this phase, the German Federal Government's climate protection program and the UN Conference on Environment and Development in Rio were important contextual factors, which furthered the development. One of the central elements of the constellation during the 1991–1994 phase was the 1,000 Roofs Program. The program was equivalent to large-scale testing, but was viewed by many as the initial stages of a market launch in Germany. The 1,000 Roofs Program involved private households in the process of power generation. In addition to research within industry, it stimulated research outside the industrial domain, which was investigating a broad range of topics during this phase. Initiatives to forge networks and create institutional structures in the research community led to the amalgamation of all relevant research institutes to form the Solar Energy Research Association (Fig. 5.6).



BMFT = Federal Ministry of Research and Technology
BMU = Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
EFP = Energy research programme
SME = Small and medium-sized enterprises

Fig. 5.6 Constellation phase 3: Large-scale testing from 1991 to 1994

In addition to the 1,000 Roofs Program, successes in the area of incremental technological development and other policy measures spurred on the innovation process. These measures included applied research funded by the Federal Research Ministry and additional support from a number of German states. The feed-in payments for photovoltaics stipulated in the Electricity Feed-in Act (StrEG)[14] which came into force in 1991 were too low in view of the costs involved, which were still extremely high. However, the law was a significant step as it guaranteed connection to the grid, thus establishing an important framework condition for the technology's further development.

5.2.4.2 Sector-Specific Context, Influencing Factors and Processes

This phase is marked by the international climate protection debate and the guiding principle of sustainable development, which was gaining in significance. In 1992 the United Nations declared its commitment to this guiding principle and adopted a global action program, Agenda 21, at the United Nations Conference on Environment and Development in Rio de Janeiro. The Framework Convention on Climate Change, which was signed in 1992 in Rio and came into effect in April 1994, created an internationally binding foundation for international cooperation to prevent global warming and highlighted the necessity for a sea change in energy policy (see Sect. 3.2.2). It was the first international treaty that obliged a group of states[15] to take action, in particular to cut CO_2 emissions. Reunified Germany reviewed the priorities of its energy policy goals. In addition to ecological factors, the integration of Germany's national energy policy into the Single European Market grew in significance.

However, the development of the price of oil during this phase counteracted these contextual circumstances. At the beginning of the 1990s the oil price sank to just under ten dollars a barrel, resulting in a decrease in global interest in renewable energies (see Sect. 3.1.2).

5.2.4.3 Government Policies and Economic Framework Conditions

1,000 Roofs Program

September 1990 saw the launch of the 1,000 Roofs program, which was designed to generate momentum for photovoltaic technology (duration: 1991–1994). The Federal Research Ministry initiated the program, which was financed by the Federal Government and the states.[16] It stemmed from an appeal from the parliament to boost support for research and development in the area of renewable energies against the

[14] The Index of Legal Sources provides information on the sources of all legal documents cited in this report.

[15] 186 states ratified the Framework Convention on Climate Change.

[16] The 1,000 Roofs Program is comparable to the 250-MW Program to promote wind energy, as in both cases the government's research portfolio supported the initial stages of the technology's launch onto the market by boosting demand. Both programs were flanked by a monitoring program and in both cases high demand led to funding increases.

backdrop of the reactor disaster in Chernobyl. The concept behind the program was inspired by both the 250-MW Wind Energy Program and a project in Switzerland between 1989 and 1990, which involved the installation of a total of 333 3-kW roof systems, amounting to a total installed capacity of 1 MW (see Sect. 5.2.5.2).

The demonstration program was an initial attempt to introduce photovoltaics on the market. It was designed to show that decentralized feed-in from photovoltaic systems is unproblematic in technical terms. The Federal Government and the states allocated grants to cover up to 70% of the investment costs.[17] As a result of the high level of interest and the subsequent inclusion of the former East German states, the program was extended to fund a total of 2,250 installations (IEA 1999; Stryi-Hipp 2005, 183). The program allocated funding to grid-connected, rooftop systems with an installed capacity of between 1–5 kW. The total capacity of the subsidized systems amounted to ca. 4 MW (Staiß 2003, I-93-94; Reiche 2004, 161);[18] the grants allocated totaled 50 euro million (Langniß & Ziesing 2005, 214). The program was accompanied by a scientific monitoring program and socio-scientific research (Langniß & Ziesing 2005, 214).

The last system to receive funding as part of this program was installed at the end of 1995. At the time, the 1,000 Roofs Program was the world's most extensive support program – or most extensive trial – for photovoltaic systems and was viewed at international level as highly innovative (Jacobsson et al. 2002, 22). It resulted in the development of new power inverters and the improvement of the technical conditions for photovoltaic installation and network integration.

In spite of the huge success of this support program, it was not immediately followed by the launch of another national support program. The Federal Research Ministry had designed it as a research and development program. It had been earmarked as a research project and it was thus not possible to finance a subsequent market introduction program.

State Support Programs

As a result of the high demand, individual German states launched supplementary programs (Staiß 2003). From 1991 to 1993, for example, the state of Baden-Württemberg helped fund 220 installations, providing grants that covered 35% of the costs. Berlin granted subsidies covering 70% of the costs; Hessen and Saarland provided 50%. Hamburg paid a fixed amount of 11,000 DEM/kW. All of the state programs ran for limited periods and consequently had more of a supportive influence than a key impact on the innovation process.

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[17] Investment costs in the old German states were subsidized by 50%; in the new German states, this figure was 60%. Many states topped up these grants by a further 10% (new states) or 20% (old states) (Langniß and Ziesing 2005, 213).

[18] This figure varies according to the source: according to Langniß & Ziesing (2005, 214), installations receiving funding had a total capacity of 5.8 MWp; according to Stryi-Hipp, this figure was 5.5 MWp (Stryi-Hipp 2005, 183).

Electricity Feed-In Act

The Electricity Feed-in Act (StrEG) was passed in 1990 and came into effect in 1991. However, it had very little impact on the development of photovoltaics because the compensation rate set for this sector – unlike the wind energy sector – was too low in relation to the extremely high production costs to enable a rapid expansion of photovoltaics. Thus the Electricity Feed-in Act did not include cost-covering compensation for photovoltaics. The compensation for solar-powered electricity was set to at least 90% of the average revenue per kilowatt hour generated from the sale of electricity by utility companies to all final consumers. However, in the 1990s this resulted in payments of less than 10 cents/kWh, while the costs of producing the electricity at that time still amounted to ca. 1 euro/kWh. To make the operation of photovoltaic systems economically viable, it was necessary to combine different supportive measures: in addition to the payments from the StrEG, support was required from the 1,000 Roofs Program and other promotional schemes organized by municipalities, states or the German Federal Foundation for the Environment (DBU) (Dürrschmidt 2007, pers. comm.; Gutermuth 1997). However, the Electricity Feed-in Act had a positive impact on the development in two respects: on the one hand, the StrEG secured the connection of decentralized electricity generating systems to the grid. On the other, the law also sent out positive signals that impacted the photovoltaics sector.

Research Funding

This phase is also characterized by the allocation of high levels of research funding for photovoltaics (see Fig. 5.3). At the beginning of the 1990s, Federal Research Ministry funding exceeded levels granted in the USA and Japan (Räuber 2005, 161). The Federal Government's Third Energy Research Program (1990–1995, see Sect. 3.6.2) focused on cutting the production costs of photovoltaic cells, boosting efficiency, developing thin-film technology, optimizing systems and applications engineering and funding pilot installations.

5.2.4.4 Technology and Market Developments

The total installed capacity up to the middle of the 1990s in Germany amounted to just under 12 MW by the end of 1994 (see Table 5.1). The growth that occurred between 1991 and 1994, amounting to ca. 9 MW in installed capacity, can be attributed primarily to the 1,000 Roofs Program. The specific electricity production costs were still extremely high at over 1 euro/kWh. The price of systems ranged from 10,000 to 12,000 euro/kW.

It was not until the introduction of the 1,000 Roofs Program that the serial production of transistor-based inverters became a viable option. In turn, developers of inverter technology were able to build upon the microprocessor technology and power electronics that had emerged in the 1980s and could thus ensure grid connection in spite

Table 5.1 Photovoltaics: installed capacity in Germany from 1990 to 1994 (BMU 2009b)

	1990	1991	1992	1993	1994
Installed capacity (MWp)	1	2	3	5	6
New installations (MWp)		1	1	2	1
Growth on previous year		100%	50%	67%	20%
Market stimulated by:		1,000 Roofs program			

of intermittent power generation. The specific costs of photovoltaic inverters were high, at about 1 euro/W with an efficiency rate of 90%, meaning that in the case of a 3 kW-system the inverter alone already cost 3,000 euro. Frequency conversion resulted in the loss of 10% of the electricity (in 2009 this figure was only 1–2%). In the area of inverters, the 1,000 Roofs Program revealed that in addition to using large central inverters it is also wise to divide photovoltaic systems into a number of electrical strings and to connect inverters to each of these strings. This significantly reduces the risk of system malfunction.

Corporate Developments

At the end of the 1980s and the beginning of the 1990s, it was mostly subsidiaries of major energy and industrial companies (e.g. RWE, Siemens, ARCO, DASA) that set up pilot projects utilizing thin-film technology, purchased stakes in solar energy companies or bought out such companies (Lundszien 1997, 37–38).

In 1994 the solar energy projects initiated in 1979 at NUKEM in Alzenau were consolidated with solar energy activities organized by the aerospace company DASA (which had their origins in projects at AEG and MBB) to form a new company, Applied Solar Energy (ASE). In the same year ASE purchased the solar division of Mobil Tyco Solar Energy Corporation in the USA, thus gaining access to its EFG technology.[19] The merger with ASE brought together earlier crystalline silicon projects conducted at AEG, NUKEM and Mobil Solar. ASE's thin-film activities have their origins in projects launched within MBB. Thus the failed joint venture between MBB and NUKEM in the mid 1980s was realized in another form with the integration of MBB into DASA in 1989 (see Fig. 5.9). From 1994 Siemens focused on CIS technology and discontinued its development of amorphous silicon.

In 1993 scientists from the disbanded Battelle Institute founded the company ANTEC Solar Energy GmbH with the aim of producing thin-film solar cells based on cadmium telluride.

[19] Mobil Tyco Solar Energy began development of the EFG (Edge-defined Film-fed Growth) process in 1973: this process involves floating a graphite body with a narrow opening (edge length 10–12 cm) on the melt. Placing a silicon disc on the melt and pulling it upward creates a ribbon. In practice, octagonal tubes up to eight meters long are pulled from the melt and then cut into wafers with a laser.

Silicon Solar Cells – Corporate Development in Germany from 1990 to 1994

In 1990, within the scope of the Solar-Hydrogen-Bavaria Project, the utilities company Bayernwerk contracted the construction of its first PV plant (total capacity 368 kW) in Neunburg vorm Wald in cooperation with partners Siemens, Linde and BMW (Dietsch 1996, 3–4). The aim of the project was to utilize electricity produced by solar cells to generate hydrogen and subsequently use this hydrogen to create fuel cells. Public funds covered 50% of the costs of the project, which was terminated in 1999/2000. Following this joint venture, Bayernwerk and Siemens founded Siemens Solar, which grew into one of the largest photovoltaic companies in the world. In 1990 Siemens Solar purchased the American company ARCO in order to gain a foothold in the larger USA market and acquire access to a-Si and CIS technologies.

5.2.4.5 Actors in the Constellation

In addition to the Federal Research Ministry and the states, which initiated the 1,000 Roofs Program, the Bundestag and the Federal Environment Ministry also gave the photovoltaics sector a positive boost. By introducing the Electricity Feed-in Act, they secured the connection of PV systems to the grid (see Sect. 5.2.3.3).

Private Pioneering Users

Private users played an important role in the first wide-ranging trials of photovoltaic systems. The 1,000 Roofs Program provided support for the installation of small-scale systems and was thus specifically geared toward private homeowners. For the first time, significant numbers of homeowners became producers of electricity from renewable sources. It was not only the support program's investment grant of 70% that made using a photovoltaic system an attractive option. The ecological image of photovoltaics, which was viewed as a "green technology", also motivated homeowners to install these systems in a clearly visible place on their rooftops. Furthermore, the long-term perspective of those constructing or purchasing their own homes was compatible with the expected lifetime of a photovoltaic system (20 years or more). These factors made it possible to involve private households in the process of generating electricity from renewable sources (Mautz & Byzio 2005, 42–43).

Decline in Industry Involvement

Up until this point, enthusiasm for the field of photovoltaics had primarily come from major industrial corporations, where photovoltaics as a business unit generally only played a relatively minor role. During this phase, strategic considerations and the realization that the photovoltaics market was developing at a much slower rate than had been anticipated prompted a number of industrial corporations to withdraw from the field of photovoltaics and sell their operations to other actors (see Fig. 5.11).

Merging of Research Institutes

In 1990 the non-university-affiliated research institutes founded their own organization in the form of the Solar Energy Research Association (FVS). The goal was to create a united force representing the interests of decentralized photovoltaics research vis-à-vis industry and politics. The association was to function as the central point of contact for research, business and politics and thus gain a similar standing to major research institutes in other branches of research.

5.2.4.6 Interpretation of the Constellation: Driving Forces and Constraints

This phase saw the first significant surge in the development and diffusion of photovoltaic systems. In conjunction with the Electricity Feed-in Act, the 1,000 Roofs Program as a large-scale testing program played a key function in both technological and political developments. It enabled manufacturers, system suppliers and installation companies to offer reliable systems and components. The program illustrated the necessity of follow-up support programs in Germany and inspired many similar projects abroad. It integrated private households into the energy production process and stimulated research activities outside the industrial domain, which was investigating a broad variety of topics during this phase: material development, systems technology, manufacturing technology and at the same time a range of variants of these technologies. Initiatives to forge networks and create institutional structures in the research community led to the amalgamation of all relevant research institutes in 1990 to form the Solar Energy Research Association – a significant milestone in the development of this sector.

5.2.5 Phase 4: Uncertainty and Slowdown, 1994–1998

5.2.5.1 Characteristics of the Constellation

After the promising phase at the beginning of 1990s, the 1,000 Roofs Program was discontinued and a follow-up scheme in the form of a market introduction program failed to materialize. As a result, the photovoltaics sector experienced relatively weak and strongly fluctuating growth from 1994 to 1998 (see Fig. 5.7).
Large corporations significantly reduced their involvement or discontinued their activities entirely, while newly start-up companies saw the future potential of the

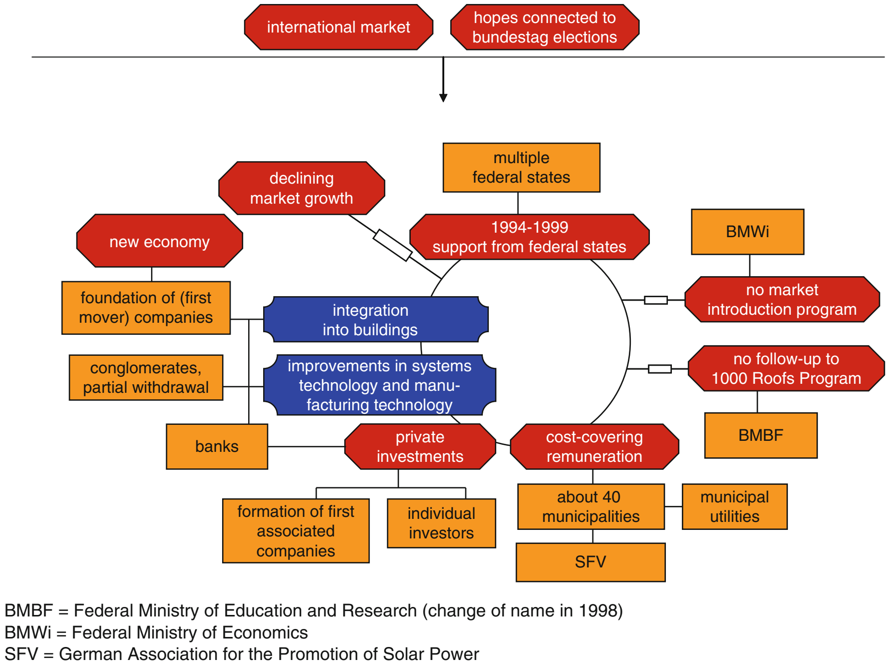

Fig. 5.7 Constellation phase 4: uncertainty and slowdown from 1994 to 1998

technology and entered the market as "first movers". The emerging New Economy eased their path onto the market.[20] The combined impact of initiatives at municipal and state level and private investment strengthened the constellation, which was beset by numerous obstacles, thus bridging this critical phase.

5.2.5.2 Sector-Specific Context, Influencing Factors and Processes

The international market continued to develop independently of the situation in Germany. The global solar energy sector was experiencing growth, while the development in Germany was going through a critical phase. The dynamic of the previous phase was subsiding due to the lack of a follow-up funding program to the 1,000 Roofs Program. The sector hoped that the new coalition Federal Government that came to power following the 1998 election would work to improve the framework conditions.

[20] The term New Economy describes an economic system with the following predominant characteristics: globalization, networking using new means of communication, and new methods of corporate financing.

5.2.5.3 Governmental Guidance and Economic Context

Draft 100,000 Roofs Program

In 1996 the SPD introduced a draft bill into the Bundestag, which aimed to support industrial solar cell technology (the 100,000 Roofs Program). The program, which was initially limited to 5 years, aimed to promote the move to mass production of solar cells. It was an investment grant program and thus geared toward private, small-scale users. Energy supply companies, on the other hand, were excluded from the program. However, the draft was rejected by the CDU/CSU/FDP government and was not passed.

Federal Government Research and Funding Policy

During this phase, German policymakers adopted a reserved approach when compared with the previous phase. The Federal Research Minister Jürgen Rüttgers categorically rejected the concept of subsidizing photovoltaics and in particular the SPD's proposal for the 100,000 Roofs Program. According to the Research Minister there was little prospect of the electricity production costs for a solar power system sinking below 50 cents/kWh and he thus believed that providing state subsidies would be the wrong strategy (Kreutzmann 1997a, 3). Rüttgers voiced his opposition to funding grid-connected photovoltaic systems and put forward proposals to fund installations that operated *independently of the grid*: "The fact of the matter is that, in spite of providing billions of marks in funding over many decades, not a single solar energy system to date […] has achieved electricity production costs of 1 DEM/kWh […] The photovoltaic industry's greatest hope today lies in the area of hand-held devices and small-scale systems that operate independently of power grids, which the Federal Research Ministry has thus made a funding priority within the framework of the Fourth Energy Research and Energy Technology Program" (Rüttgers 1997, 13).

Lack of Funding Concept and Uncertainty After Termination of 1,000 Roofs Program

After the 1,000 Roofs Program came to an end (in the old West German states in 1994; in the new East German states in 1995), there was no adequate follow-up project to support the development of photovoltaics, although the 1,000 Roofs Program had confirmed – in spite of initial technical problems with inverters – that broad-based application of grid-connected photovoltaic systems was possible.

In the field of photovoltaics the Federal Government did not have a coherent expansion strategy at that point in time,[21] as was the case with all other renewable

[21] A coherent strategy did not come into existence until the Federal Ministry for the Environment assumed responsibility for renewable energies in the fall of 2002 and established an independent department for renewable energies and the environment.

energy technologies. No government portfolio felt that it held overall responsibility for the area at this time or systematically took charge of the expanding the renewable energies market.

Subsequent to the Federal Research Ministry's work to promote photovoltaics, the Federal Ministry of Economics should have facilitated its introduction on the market. However, it did not take such action (Stryi-Hipp 2005, 184; Dürrschmidt 2007, pers. comm.). The Federal Ministry of Economics did initiate a program known as the "100-million program", which – among other supports – planned to allocate funds to photovoltaics amounting to 10 euro million over a 4-year period. However, neither this program nor the low compensation rates in the StrEG[22] were able to create the economic prospects required for the manufacture of solar cells in Germany (Langniß & Ziesing 2005, 214).

The photovoltaics sector criticized the lack of an effective market introduction program that would give it a chance to stand up to competition from the USA. One in every five systems manufactured in the USA was exported to Germany. As a result of the difficult situation regarding funding and compensation rates, young companies in Germany had problems gaining a foothold on the market (Kreutzmann 1997a, 3). Due to the discontinuation of funding, the introduction of PV products initiated by the 1,000 Roofs Program ground to a halt in the mid 1990s, before a self-supporting market that went beyond niche applications had emerged.

During this phase the Federal Government barely provided any funding for solar projects in developing countries. As a result, the German photovoltaic industry was deprived of another important market (Schmela 1997, 40 sqq.). In addition, there were plans to discontinue research funding for solar power plants at the end of the 1990s, an area which had received a great deal of research funding since the beginning of the 1980s. However, renewable energies received financial support from interest earnings allocated by the Federal Ministry for the Environment that had been generated by the auction of UMTS licenses.[23] This enabled Germany to continue its support for solar power plant technology (Eisenbeiß 2007, pers. comm.).

5.2.5.4 Municipal and Regional Initiatives Keep the Flag Flying

In spite of the lack of a funding concept at federal level, photovoltaics continued to develop. This was thanks to a range of different regional initiatives, programs and projects that shored up the market. A number of states initiated their own programs to supplement the low level of Federal Government funding and a certain amount of support even came from programs organized by public utilities. One such program was the REN program in North-Rhine Westphalia (see Sect. 5.2.2.3).

[22] The compensation rate set by the StrEG (9 Cent/kWh) only covered ca. one tenth of the imputed costs incurred.

[23] In the year 2000 UMTS (Universal Mobile Telecommunications System) spectrum licenses were sold by auction for use via the mobile telecommunications system. The revenue, which was used above all to repay public debt, amounted to 50.8 billion euro.

The Concept of Cost-Covering Compensation

The introduction of cost-covering compensation and similar funding models in a number of municipalities from 1993 onward was of vital importance. By the end of 1999, these measures had enabled the construction of photovoltaic systems with a capacity of over 10 MW (Staiß 2003, I-93-94). Cost-covering compensation in municipalities – which was more successful than the 1,000 Roofs Program (Welter 1997, 38; see also Table 5.2) – sustained the development of the innovation process after the large-scale testing program came to an end. Similar to a decentralized political strategy, it exerted pressure "from below" on the national level.

Table 5.2 Photovoltaics: installed capacity in Germany from 1990 to 1998 (BMU 2009b)

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Installed capacity (MWp)	1	2	3	5	6	8	11	18	23
New installations (MWp)		1	1	2	1	2	3	7	5
Growth on previous year		100%	50%	67%	20%	33%	38%	64%	28%
Market stimulated by:		1,000 Roofs Program				Municipal cost-covering compensation			

The novel feature of cost-covering compensation was that rather than providing subsidies to support the construction of solar systems, it remunerated the feed-in of solar-powered electricity to the public grid by electricity supply companies. Operators of solar systems received a compensation payment that completely covered their costs from an economic perspective for a contractually-guaranteed period of 20 years. The remuneration was calculated on the basis of the cost of a technically optimized solar system constructed in the same year. The level of compensation per kWh varied between municipalities and was financed by increases in the price of electricity. A favorable legal opinion declared an increase in the price of electricity of about 5% as permissible (v. Fabeck 2008).

The Association for the Promotion of Solar Energy (SFV) played a decisive role in initiating this measure and fought hard for the introduction of cost-covering compensation rates in Aachen in 1993.[24] In spite of considerable opposition from the municipal utility company STAWAG and protracted negotiations in the city council, Aachen introduced cost-covering compensation. The first contract between STAWAG and a solar energy producer feeding in electricity was concluded in 1995. As the idea for this funding model originated in Aachen, it came to be known as the Aachen model.

In the period that followed, some 35 other cities and municipalities[25] (primarily in southern Germany) introduced the compensation model. These included

[24] Following city council resolutions, Aachen, Freising and Hammelburg were the first cities to introduce the cost-covering model in 1993. Due to hesitation on the part of the state of North Rhine Westphalia to grant approval, the FCR came into force in the Bavarian municipalities of Freising and Hammelburg first at a rate of 2 DEM/kWh.

[25] This figure was 25 according to Langniß and Ziesing (2005, 216). According to Stryi-Hipp over 100 cities passed a resolution approving the introduction of cost-covering compensation and over 35 cities subsequently implemented this strategy (Stryi-Hipp 2005, 184). Mußler (2008, 88 and 111) states that 96 cities across Germany introduced cost-covering compensation.

Bonn, Darmstadt and Nuremburg. In some cases, it was only possible to introduce the regulation on the basis of a city council resolution after grueling discussions with municipal energy suppliers. In 1993 Hans-Josef Fell – a city councilor at the time and today a member of the Bundestag in Alliance 90/The Greens – also successfully introduced cost-covering compensation in his hometown of Hammelburg. This would later provide inspiration for the drafting of the EEG, in which Fell played an instrumental role: the obligation to purchase electricity from renewable sources, a compensation rate which covered costs and the obligation to connect renewable energy systems to the grid were all central aspects of the municipal cost-covering compensation schemes which were incorporated into the EEG.

While many municipal and regional energy suppliers did not provide cost-covering compensation, they did increase the rate. In 1994, for example, municipal utility companies in Freiburg introduced a compensation rate for solar-powered electricity amounting to 46.6 pfennigs per kilowatt hour at peak load times and 26.6 pfennigs per kilowatt hour at normal load times. Furthermore, they paid 2 DEM/kWh during the first 2 years of operation (Stryi-Hipp 2005, 184). However, requests for cost-covering or increased compensation for electricity generated by photovoltaic systems were generally (and still are) turned down by municipal utilities that cooperate closely with large energy supply companies or in which energy suppliers are the major stakeholder.

The German states were also involved in designing the model of cost-covering compensation insofar as they oversaw the tariff system: it was their responsibility to authorize the apportionment of costs. Thus the general electricity tariffs absorbed the additional costs resulting from cost-covering compensation, meaning that the energy supply company adopting the cost-covering strategy incurred no additional expense. Within this framework the resourcefulness of municipalities enabled the continued growth of photovoltaic systems (v. Fabeck 2008).

Marketing Initiatives and Demonstration Projects

A number of energy suppliers also showed willingness to become active in the field of photovoltaics. In 1994, for example, the public utility company Bayernwerk introduced a green pricing model for the first time, which subsequently resulted in investment in a 50 kW installation. Shares of ca. 20 pfennigs per kilowatt hour were sold to around 100 people. This inspired other models along similar lines. Around 15,000 people got their electricity supply from solar cells, wind farms and hydro power and paid an eco-tariff which was about twice as expensive as the normal tariff (Jacobsson et al. 2002, 24).

RWE fitted a row housing development in Essen with 25 photovoltaic systems, each with a capacity of 2 kW, with the aim of gathering experience concerning installation, integration and network operation. From 1994 to 1996, as part of the program Solar Energy in Schools (Sonne in der Schule), Bayernwerk provided funding for 544 photovoltaic installations, each with a capacity of 1 kW. The schools assembled and fitted the construction kits themselves.

The energy supply company PreussenElektra also financed 450 school rooftop installations with the same capacity as part of the program Solar Energy Online (Sonne online) in northern Germany. Large-scale projects provided further market opportunities for photovoltaics, such as the system fitted on the roof of the Munich Trade Fair Centre in 1997 and the array integrated into the roof of the further training academy in Herne, each with a capacity of 1 MW (Stryi-Hipp 2005, 184–185).

These initiatives sustained the market even after the 1,000 Roof Program came to an end. While growth was limited in this phase, the large number of cities that introduced local feed-in tariffs and the spread of green pricing models highlighted the widespread interest in photovoltaic technology.

5.2.5.5 Technology and Market Developments

The rise in demand for silicon at international level led to shortages in supply, which created difficulties for cell producers due to subsequent price increases. Production capacity for silicon had mainly been geared toward the needs of the semiconductor industry up to this point. The demand for solar silicon had primarily been covered by silicon that did not possess the quality (purity) required by the semiconductor industry. It took some time before production capacity was expanded to accommodate the rising demand for solar silicon.

While the end of the 1,000 Roofs Program may have created uncertainty in the sector in Germany, *demand* for photovoltaic systems did not fall. The adoption of cost-covering compensation by numerous municipalities prevented the collapse of the market. The period from 1995 to 1998 saw the construction of systems with capacities ranging from 4 to 12 MW annually, i.e. more than during the 1,000 Roofs Program (see Table 5.2).

In 1998 the downward price trend for fully assembled systems came to a halt when a 1-kW installation cost on average 8,000 euro.

1998 was a particularly difficult year for the photovoltaics sector in Germany. While 1997 saw the installation of new photovoltaic systems with a total capacity of 12 MW, in 1998 domestic demand experienced a drop for the first time of 25% on the previous year. Many attribute this to the ineffective funding policy. The "funding jungle" is reported to have become increasingly hard to navigate and the share of municipal funding stagnated or decreased as a result of pre-defined maximum limits (caps), among other reasons. Furthermore, many interested parties had put their investments on hold in anticipation of the Bundestag election and in the hope that it would result in improvements to funding conditions. In 1998, compared with the strong growth of previous years, activities at international level also focused on consolidation (Janzing 1999, 27).

From the mid to the end of the 1990s, in spite of the uncertain situation overall, a number of start-up companies entered the photovoltaics market, motivated by the prospect of improved funding conditions. The SPD's proposal for a 100,000 Roofs Program was one factor that gave rise to this hope.

Silicon Solar Cells – Corporate Developments in Germany from 1990 to 1998

This phase saw the foundation of a number of new companies in the photovoltaics sector (see Fig. 5.5). Solar-Fabrik (founded in 1996), Ersol (founded in 1997) and SOLON (founded in 1997) planned or established production lines for solar cells and modules (Stryi-Hipp 2001). The end of this phase saw the emergence of the companies SolarWorld (founded in 1998), Q-Cells (founded in 1999) and Würth Solar[26] (founded in 1999). The foundation of Würth Solar was closely connected to research into CIS thin film at the Centre for Solar Energy and Hydrogen Research (Zentrum für Sonnenenergie und Wasserstoff-Forschung – ZSW).[27] In addition, the first specialty suppliers emerged on the market, such as PV Silicon from Erfurt (founded in 1997). The company specialized in manufacturing wafers by sawing silicon blocks (ingots).

This remarkable start-up boom, which occurred in spite of the relatively uncertain framework conditions, illustrated that both the 1,000 Roofs Program and the anticipated development at international level (the construction of huge numbers of solar home systems in countries without nationwide electricity supply, for example) had created prospects that triggered a high level of corporate engagement. On the other hand, this start-up boom would probably never have happened had it not been for the emergence of a new phase of corporate financing around that time. It became known as the New Economy. During this phase investors showed great willingness to provide large amounts of venture capital to start up companies. These companies mostly assumed the legal form of a stock corporation to collect capital; the shares were traded on the "Neuer Markt", a special segment of the Frankfurt stock exchange. The excitement surrounding the Neuer Markt was so great that investors often failed to check exactly where they were putting their capital. This phase came to an end as a result of many negative experiences caused by the collapse of numerous companies in 2000/2001. After this period, it was virtually impossible for a start-up company to obtain capital on the stock market.

In addition to solar modules, advances in inverter technology were also of great importance for grid-connected systems. The reliability of inverters continued to rise and tended to be greater than had been the case with systems in the 1980s and early 1990s (1,000 Roofs Program). Assessment of 400 photovoltaic systems from the 1,000 Roofs Program had revealed that it is necessary to replace or overhaul inverters in older systems after 8–10 years to avoid long periods of downtime (BINE 2003, 1–2).

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[26] Würth Solar was founded by a solar cell dealer who wanted to become less dependent on established PV companies. The dealer's market spanned both the Germany and the global market, including developing countries (Jacobsson et al. 2002, 27).

[27] Today, Stuttgart University's Centre for Solar Energy and Hydrogen Research (ZSW) is the largest research institute in Germany for CIS cell technology.

5.2.5.6 Actors in the Constellation

After the failure of the responsible federal ministries to implement an effective funding strategy for photovoltaics, steps taken by municipalities and municipal utilities to grant cost-covering compensation for electricity produced by PV systems helped prevent a breakdown in the development of photovoltaics (see Sect. 5.2.4.4). By promoting this concept, these actors played a crucial, pioneering role and helped shape the EEG. An important actor in this respect was the Association for the Promotion of Solar Energy in Aachen, which played a vital part in initiating and supporting the model. A number of German states introduced their own programs to support the development.

Private Investors

Private investment also helped promote the growth of photovoltaics.[28] Due to its characteristic modular design and application in small-scale systems, photovoltaics was the only branch of renewable power generation which offered a viable solution for individual households.

The pioneers of solar energy were initially motivated to act by strong ideals that were primarily rooted in ecological and moral principles. However, it was only later that the introduction of new framework conditions limiting economic risks increased and underpinned their ability to do so. Making a profit was not the primary concern of the first users of photovoltaic systems. However, the prospect of institutional structures that protected them from making losses boosted willingness to get involved in solar energy schemes (Mautz and Byzio 2005, 40). This led to the foundation of the first user collectives and associated companies during this phase with the aim of providing mutual support for the construction and operation of photovoltaic systems (see Sect. 5.2.6.8).

Foundation of New Companies in the Solar Energy Sector

In effect, only two of Germany's major module manufacturers were still active in 1996 (ASE and Siemens). They had established a wide range of technical system concepts (crystalline silicon, a-Si, CIS, CdTe). Nevertheless, a number of start-up companies entered the market (see Sect. 5.2.4.5 and Fig. 5.11) and spurred on developments in spite of the lack of funding strategy.

[28] Private investment in renewable energies totaled ca. 300 million German mark a year. These funds were primarily invested in solar water heating systems and private PV systems (BMU & UBA 1999, 2).

5.2.5.7 Interpretation of the Constellation: Driving Forces and Constraints

Inconsistencies and obstacles characterize the development setback during this phase. After termination of the 1,000 Roofs Program at the end of 1993, the lack of a follow-up program was a shock for many companies in this young sector, especially for small start-up companies in the installations business. Expertise in the photovoltaics field in Germany was extremely advanced; German research institutions led the way in photovoltaics research. However, the niche of the photovoltaics market, which was still extremely vulnerable, was under threat. The Federal Government had no coherent strategy to expand the photovoltaics market in Germany. No ministry felt that it held responsibility for this area or systematically took charge of expanding the photovoltaics market. Actors in the market hoped for improvements to framework conditions.

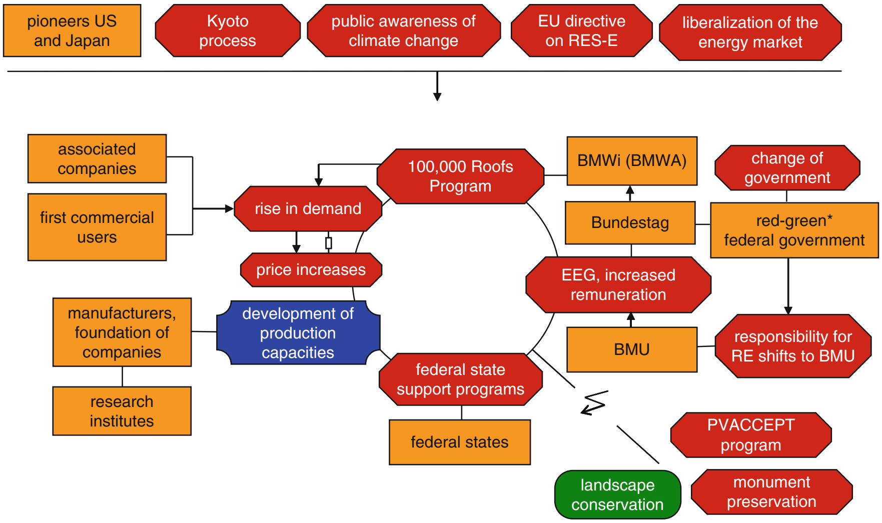
It was first and foremost the introduction of cost-covering compensation and other funding models developed by numerous municipalities that both sustained the photovoltaics market and set a precedent. The Aachen Association for the Promotion of Solar Power played an influential role here. The positive and well-documented experiences gained during the 1,000 Roofs Program and the flourishing international PV market ensured that banks continued to grant loans to investors. Initiatives launched by individuals and groups as well as projects organized by associations and states (in particular North-Rhine Westphalia and Bavaria) helped ease the situation. The appeal of solar power generation and its clear potential – further boosted by rising electricity prices and foreign markets – were also supporting factors, which encouraged manufacturers and operators to start up companies in spite of the relatively unfavorable economic framework conditions in Germany.

5.2.6 Phase 5: Breakthrough, 1999–2003

5.2.6.1 Characteristics of the Constellation

The phase from 1999 to 2003 is described as a "breakthrough" because crucial policy measures at national level brought an end to the critical period and sparked a significant upturn in the development of photovoltaics. Following the change of government, a new regime of actors seized upon these policies. Developments were spurred on by the international and social context as well as the pioneering countries, USA and Japan (see Fig. 5.8).

However, while photovoltaics was experiencing a breakthrough, unintended effects began to emerge. High demand and limited production capacities led to a rise in the price of photovoltaic modules. Representatives of associations for the preservation of historic sites were particularly critical of photovoltaic systems installed on buildings under preservation order. Nature and landscape conservationists expressed concerns about ground-mounted systems, pointing out the possible negative effects on the environment.



BMWi = Federal Ministry of Economics and Technology (under this name 1998–2002, and since 2005)
BMWA = Federal Ministry of Economics and Labour (under this name 2002–2005)
BMU = Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
EEG = Renewable Energy Sources Act
RE = renewable energies
RES-E = electricity from renewable energy sources
* = Coalition of the Social Democrats (SPD) and The Greens (Bündnis90/Die Grünen)

Fig. 5.8 Constellation phase 5: breakthrough, 1999–2003

5.2.6.2 Sector-Specific Context, Influencing Factors and Processes

The international and social context had a significant impact on the development of solar power generation during this phase. The EU Directive on the promotion of electricity produced from renewable energy sources in the internal electricity market (see Sect. 3.3.2.4) had an impact on the development of photovoltaics in Germany, insofar as it stabilized the international legal framework. The directive's most important goal was to increase the share of the EU's gross electricity consumption from renewable energy sources from an average 13.9% in 1997 to around 22% in 2010.

The USA and Japan retained their position as global market leaders and pioneers in the development and dissemination of photovoltaic technology. In 1997 the USA unveiled the One Million Solar Roofs Program. The Residential PV Systems Dissemination Program (also known as the 70,000 Roofs Program) had been running since 1994 in Japan with the aim of facilitating the introduction of photovoltaic systems on the market (Kurokawa & Ikki 2001). This extremely successful long-term program provided inspiration for the 100,000 Roofs Program, just as the 1,000 Roofs Program was modeled on the Swiss Megawatt Program (see Sect. 5.2.3.3) (Perlin 2002, 149).

5.2.6.3 Lobbying for a Market Introduction Program

Various organizations started campaigning for a support program that would create a mass market for solar cells. Two associations that were particularly active in the field of lobbying were EUROSOLAR and the Federal Solar Industry Association (Jacobsson et al. 2002, 24–25). The lobbying campaigns organized by these and other organizations met with opposition from traditional companies in the energy supply sector. Since 1991, these companies had been obliged to pay nearly 17 pfennigs per kilowatt hour for energy fed in from wind sources. In the mid 1990s these interest groups launched a vigorous campaign to convince the Bundestag to abolish the StrEG. However, after the European Court of Justice confirmed the legality of the Electricity Feed-in Act in 2001, the German photovoltaics industry stepped up its lobbying work (see Sect. 3.7.1). Companies had doubts as to whether it was wise to continue production in Germany without any prospect of domestic market growth.

5.2.6.4 Change of Government

1998 saw a change of government when the red-green coalition came to power, an event that sparked hope in the photovoltaics sector. The 100,000 Roofs Program was a "last-minute" addition to the coalition agreement (Rosenkranz 1998, 28). The reorientation of the new government's energy policy had a significant stimulating effect on photovoltaics. During the coalition negotiations, Bundestag members Scheer (SPD) and Fell (Alliance 90/The Greens) initiated a cross-parliamentary-group alliance comprising "solar parliamentarians" from both governing parties. Around 50 members of parliament supported the group (ibid.).

5.2.6.5 Governmental Guidance and Economic Context

100,000 Roofs Program

After an initial attempt to launch the 100,000 Roofs Program failed in 1996, it finally came into force after the change of government on 1 January 1999 under the direction of the Federal Ministry of Economics in cooperation with both of the new government coalition parties.[29] The red-green government thus aimed to usher in the solar era.

The duration of the program was limited to the period between 1999 and 2003 (program runtime: 5 years; 10-year period for loan repayments). It was designed as an investment grants program for private, small contractors (degression of grants).

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[29] The head of the Federal Economics Ministry's department of renewable energies, Paul-Georg Gutermuth, was responsible for the market introduction program. His support for photovoltaics was met with frequent opposition from fellow ministers, but he received a great deal of support in this respect from the Federal Environment Ministry.

The program's core element consisted of low-interest loans for those installing photovoltaic systems, provided by the federally owned KfW bank; the interest rates were around 4.5% points below the market level. The scheme also included a waiver of 10% of the lending volume on the final repayment installment. The grant thus covered a total of some 35% of the investment sum (Stryi-Hipp 2005, 185). These incentives enabled many homeowners to overcome inhibitions about investing. The 100,000 Roofs Program could be combined with other support programs. The lending volume was limited to 500,000 euro. Funding was provided across Germany for the construction and expansion of PV systems on structural surfaces with a newly installed peak capacity of ca. 1 kW or more (nominal capacity according to figures provided by manufacturer). Co-financing was provided for all investment costs, including the purchase of inverters and measuring devices, installation costs and planning costs.

However, the 100,000 Roofs Program only had the potential to generate ca. 4% of the energy produced by a single nuclear power station unit. Solar energy associations and German Shell (Fritz Vahrenholdt) criticized the program for not doing enough to stimulate demand for PV systems, which was necessary in order to reduce the price of solar-powered electricity.[30]

The program gave the market introduction of photovoltaics a significant boost. A total of 55,000 systems with a total capacity of 346 MW received support from loans amounting to ca. 1.7 euro billion. The total investment volume came to 2.3 euro billion (Oppermann 2004, 40 sqq.).[31] Alongside the Residential PV Systems Dissemination Program in Japan, this made it the world's largest photovoltaics support program.

Varying Degrees of Support from German States

At the end of the 1990s the German states supported photovoltaics to varying degrees. Several states (e.g. Baden-Württemberg) granted low-interest loans; others (e.g. the Saarland) provided lump-sum investment grants (Welter 1998, 44–45). At the end of the 1990s various states initiated campaigns to support the use of solar energy. In 1999, for example, Lower Saxony launched its Solar Offensive project; July 2000 saw the start of the Berlin Solar Campaign.

However, following the increase in Federal Government funding in 1999 with the introduction of the 100,000 Roofs Program, several state governments that had previously supported photovoltaics gradually withdrew their support. As a result, the 100,000 Roofs Program did not lead to significant improvements in photovoltaics funding in these states (Kreutzmann 1999, 27 sqq.). Nevertheless, four states[32] did continue to support photovoltaics after 2000, in addition to the Federal Government funding. While it was not the sole factor supporting the development of photovoltaics, funding in these states did play an important role.

[30] See http://www.sfv.de/sob99228.htm (accessed July 7, 2009).

[31] See also (Langniß and Ziesing 2005, 217).

[32] Berlin, Thuringia, Mecklenburg-Western Pomerania, North-Rhine Westphalia.

Adoption of the Renewable Energy Sources Act (EEG)

The situation changed with the introduction of the EEG, which included a huge increase in the feed-in tariff for solar electricity of 8.25 cents/kWh, boosting it to an initial 50.6 cents/kWh (for rooftop installations < 30 kW). The combined effect of the tariff and the 100,000 Roofs Program meant that it was now economically viable to operate solar systems. This tariff would probably never have been possible without the local, cost-covering compensation models.

The combination of the EEG and the 100,000 Roofs Program made solar electricity an appealing option from an economic perspective. The capacity of the photovoltaics market grew from 12 MW in 1998 to 65 MW in 2001. There was a euphoric mood in the solar industry.

The EEG was an improvement on the Electricity Feed-in Act insofar as it:

- Remunerated solar-powered electricity at a rate of 50.6 cents/kWh and not – as had been the case – at the same rate as wind power
- Removed the 5% cap[33]
- Decoupled the compensation rate from the price of electricity

The EEG included an annual degression of 5% of the minimum compensation payment to account for the "learning curve effect". As a result, newly installed systems in 2003 only received a minimum payment of 45.7 cents/kWh. The legislator did not believe this to be sufficient and the EEG amendment of summer 2004 thus increased the minimum compensation payment by almost 12 cents/kWh to 57.4 cents/kWh. Table 5.3 shows the development of minimum compensation payments in nominal and real values based on prices in 2009.

Complications with Funding: Uncertainty Among Applicants to the 100,000 Roofs Program

The high demand for funding from the 100,000 Roofs Program in the period following the adoption of the EEG[34] (see Table 5.3) led to problems allocating the interest-free loans. It was impossible to process the multitude of enquiries and the 90 euro million allotted for the year 2000 was insufficient in view of the vast numbers of applications. The combined effect of the 100,000 Roofs Program and the increased feed-in tariff resulted in a flood of 15,000 applications by the beginning of 2000, which led the Federal Economics Ministry to stop allocating interest-free loans in April of that year. Freezing the 100,000 Roofs Program created uncertainty among investors. Members of Alliance 90/The Greens had promoted

[33] This was of particular significance for the southern German states of Bavaria and Baden-Württemberg, since PV technology was more widespread here than in northern Germany. This was mainly because the area received significantly higher levels of solar irradiation, but also presumably due to effect of regional multipliers and a more favorable economic situation.

[34] After the EEG was passed, the KfW received 10,000 applications amounting to a total capacity of 70 MWp in March 2000 alone (Stryi-Hipp 2005, 185).

Table 5.3 Minimum compensation payment for solar electricity in StrEG and EEG 2000

		1991	1995	1999	2000	2001	2002	2003
Rooftop systems up to 30 kW		StrEG			EEG 2000			
Nominal compensation payment	Cent/kWh	8.5	8.8	8.4	50.6	50.6	48.1	45.7
Compensation payment in 2009 prices		11.9	11.0	10.0	59.3	58.1	54.5	51.2

the 100,000 Roofs Program as a funding scheme that was quick, unbureaucratic and reliable. However, this was no longer the case when applications were halted (Kreutzmann 2000a, 20 sqq.).

The freeze on applications was lifted on 10 May 2000 with the introduction of new framework conditions. According to the new framework conditions of the 100,000 Roofs Program:

- Only installations with a capacity of up to 5 kW received an interest-free loan
- The interest rate rose to 1.9%
- Companies were now only eligible to make use of up to 50% of the funding (loan)
- Eligible investment costs were limited to 6,750 euro
- The waiver of residual debt (the final month) was discontinued (Kreutzmann 2000b, 20 sqq.)

The difference in funding rates for private and commercial applicants sparked a great deal of debate. The solar energy associations feared that the new provisions would result in a sharp decline in the number of projects, which would weaken the solar industry. Politicians claimed that the new provisions were introduced to allow for necessary expenditure cuts and to avoid a situation whereby tax revenue was enabling operators of PV systems to make profits (Kreutzmann 2000b, 20). The debate inflamed the situation once again (Kreutzmann 2001, 8 sqq.). New or unprocessed applications had no prospect of being granted approval that year.

Ultimately, the solar lobby managed to push through improved conditions for the 100,000 Roofs Program. In March 2001 a new program guideline came into effect removing the distinction between private and commercial applicants. In the case of systems with a capacity of less than 5 kW, the same funding conditions[35] applied to both commercial and private operators – both groups received the full loan amount for systems with a capacity of up to 5 kW.[36]

The massive appeal of the 100,000 Roofs Program became particularly apparent in 2003 – in the program's final year. As the future of photovoltaics funding was unclear up until the end of 2003, large numbers were interested in benefiting from the advantages of the program. In the middle of 2003 there was another premature freeze on applications; applications amounting to a capacity of over 200 MW had been received up to this point. As a result of the high demand, the Federal

[35] This was made possible by the EU's new community guidelines on environmental aid.

[36] See Infodienst Regenerative Energie: www.boxer99.de/archiv_2001_03.htm (accessed July 7, 2009).

Environment Ministry, which was now responsible for this area,[37] increased the target for 2003 from 95 to 150 MW – and thus also the funding volume (Stryi-Hipp 2005, 186).

Removal of the 350-MW Cap

In 2002, solar energy associations and members of the Bundestag (in particular Hermann Scheer and Rainer Brinkmann) began a campaign for the rapid elimination of the 350-MW cap, which restricted the allocation of funding provided within the scope of the EEG to solar energy projects below 350 MW. The Federal Association of Renewable Energies also supported this initiative, insofar as it set aside the issues of representatives of other renewable energies and focused solely on campaigning for the abolition of the 350-MW cap. In June 2002 the Bundestag subsequently decided to lift the capacity limitation stipulated in the EEG for PV projects eligible for funding from 350 to 1,000 MW. The EEG itself was not amended; the decision was implemented by means of an omnibus bill. This bill was of great significance for solar energy associations and also created greater investment security. However, they still faced the challenge of convincing banks to approve loans for solar plants (Kreutzmann 2002, 8–9).

Lack of Continuity: No Follow-Up to the 100,000 Roofs Program

The sector reported very positive results at the end of the 100,000 Roofs Program. Carsten Körnig, head of the Solar Industry Trade Association (Unternehmensvereinigung Solarwirtschaft e.V. – UVS),[38] viewed the program as a "powerful 'rocket stage' propelling us toward the dawn of the solar era". The combination of the EGG and the support program was said to have laid the cornerstone for the "founding epoch of solar energy".[39] According to UVS figures, the German photovoltaics market had grown tenfold during the 4-year program (1999–2003). The about 30 German solar manufacturers expanded their production capacities to meet this demand, enabling Germany to become the second most powerful force on the global market.[40]

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[37] The decision to transfer responsibility for renewable energies to the Federal Environment Ministry was taken within the scope of the new coalition agreement between the SPD and Alliance 90/The Greens in fall 2002. This move also meant that the remainder of the 100,000 Roofs Program fell within the remit of the Federal Environment Ministry.

[38] The solar associations UVS (Solar Industry Trade Association) and BSi (German Solar Sector Association) merged at the beginning of 2006 to form the BSW (German Solar Industry Association).

[39] See http://100000daecher.de/forderung-von-solaranlagen/ (accessed July 10, 2009).

[40] Seventy percent of the installations that received funding from the 100,000 Roofs Program were constructed in Bavaria and Baden-Württemberg: southern Germany receives far higher levels of solar irradiation.

The discontinuation of the program created a gap in the funding framework for solar energy. The sector called for the continuation of solar funding either by extending the 100,000 Roofs Program or by introducing alternative follow-up provisions. A study to evaluate the program commissioned by the Federal Environment Ministry and published in February 2002 came to the conclusion that a failure to introduce measures to accompany the phase-out of photovoltaic support measures would create a situation similar to the one that arose at the end of the 1,000 Roofs Program (see Sect. 5.2.4.3): it would create considerable damage to the structures established thus far and above all threaten the existence of small and medium-sized companies (e.g. craft enterprises or retailers and wholesalers) lower down the echelons of the photovoltaics production chain.[41] "The survival of the sector was at stake" (Hinrichs-Rahlwes in ARGE Monitoring PV-Anlagen 2005a, 11). This situation resulted in the adoption of the Interim Act on Photovoltaic Energy (EEG-Vorschaltgesetz) (see Sect. 5.2.6.3).

Energy Industry Act and Connection to the Grid

The revision of the Energy Industry Act in 1998 facilitated the access of photovoltaic systems to the grid. Photovoltaics, which was still 30 times more expensive than conventional electricity, was viewed by the Federal Research Ministry as too costly, too dependent on solar irradiation and not efficient enough to be able to gain a foothold on a liberalized market (Kreutzmann 1998a, 31).

Newly established electricity suppliers were adversely affected by uncertainty concerning the price of network transmission. For this reason, Alliance 90/The Greens called for grid ownership to be taken out of the hands of electric power companies. They also called for the amendment of the Energy Industry Act to ensure non-discriminatory access to the grid and a seal of quality for green electricity (Kreutzmann 1998b, 34 sqq.).

5.2.6.6 Research Funding

The Federal Government's Fourth Energy Research Program (1996–2004) focused on boosting efficiency rates, improving systems and manufacturing technology (cutting costs), integrating photovoltaic systems into different types of building and transmitting electricity from network-independent, decentralized energy supply systems. The Fourth Energy Research Program comprised a sub-program entitled Paving the Way for Photovoltaics 2005 (Wegbereitungsprogramm Photovoltaik 2005), which ran from 1996 to 2005. It aimed to develop solutions for key problems that were preventing more widespread use of photovoltaics. Its support strategy focused on three points:

[41] See http://www.1000daecher.de/index.php?id=3 (accessed July 7, 2009).

- Cutting solar cell costs by reducing manufacturing costs and increasing efficiency
- Cutting costs, optimizing technology and breaking down people's inhibitions concerning the integration of photovoltaic systems into various types of building
- Using photovoltaics to provide decentralized, network-independent energy supply

Another sub-program of the Fourth Energy Research Program was the support scheme Photovoltaics for Devices and Small-scale Systems.

5.2.6.7 Technology and Market Developments

The rising demand spurred on the industrialization of the production processes, resulting in the automation of increasing numbers of production steps. This was the main reason behind the significant reduction in manufacturing costs, which led to a fall in the price of solar modules. There were technological advances and subsequent cost reductions at all levels of the process chain, from silicon and module production to inverters and installation. It was now necessary to adapt many processes that had been developed and refined years previously in laboratories for use on an industrial scale. Thin-film technology was partly able to build upon plasma screen (displays) manufacturing technology developed in the 1990s and experienced particularly dynamic growth. In 2003 the crystalline silicon solar cell celebrated its 50th birthday.

Analysis of the 100,000 Roofs Program revealed that the specific costs (excluding sales tax) for small solar power installations of up to 4 kW had fallen from 7,300 euro/kW in 1999 to around 5,500 euro in 2003 (see Table 5.4). In the case of installations of up to 10 kW, the cost had dropped by about 500 euro/kW (Oppermann 2004, 48). The fall in the cost of photovoltaic installations resulted in a reduction of the specific electricity production costs per kilowatt hour of solar electricity from over 1 euro at the beginning of the 1990s to between 50 and 60 cents (crystalline silicon cells). In the period from the beginning of the 1990s to 2003 – i.e. ca. 10 years – specific investment costs for systems of this magnitude fell by an average of nearly 50%.[42]

Table 5.4 Development of costs for systems of 3–4 kW (in EUR/kW) (as per Oppermann 2004, 48)

Year	Number	kWp	Mean system size (kWp)	Cost of system
1999	70	247	3.53	7,262
2000	150	507	3.38	6,817
2001	396	1,322	3.34	6,865
2002	427	1,448	3.39	6,416
2003	274	947	3.46	5,530

[42] At this point it is important to remember that in the 1990s only a part of the PV module was produced in Germany and the module only accounted for about three quarters of the investment costs. Measured on the basis of installed capacity, the leading countries on the PV market used to be Japan and the US. Thus it would be wrong to consider the cost minimizing potential solely in relation to Germany; it must be viewed in the context of an increase in demand at global level.

The cost of inverters, installation and other components fell disproportionately over the course of the 100,000 Roofs Program when compared with the price of modules. During the 5-year program, costs in the aforementioned areas more than halved, while the price of modules only fell by 20% (see Table 5.5). In the case of inverters, the specific price fell from 0.83 to 0.53 cents per watt. The company SMA was the clear market leader in this segment with an almost 100% share, as had also been the case at the time of the 1,000 Roofs Program.

Table 5.5 Development of costs for systems of up to 10 kW (in EUR/kW)according to component over the course of the 100,000 Roofs Program (as per Oppermann 2004, 48)

Year	Number	kWp	Mean system size (kWp)	Generators	Inverters	Installation	Other components	Total
1999	102	312	3.1	4,758	831	693	602	6,884
2000	147	553	3.8	4,499	641	484	509	6,133
2001	514	2,181	4.2	4,939	630	474	479	6,522
2002	752	3,695	4.9	4,413	564	373	429	5,779
2003	289	1,660	5.7	3,861	527	303	330	5,021

The combined impact of the EEG and the 100,000 Roofs Program resulted in a rapid increase in the number of systems installed in Germany. The period between 1999 and 2003 saw the construction of installations totaling 363 MW (see Table 5.6). According to figures provided by the German Solar Industry Association (BSW), the sector's turnover increased substantially from around 200 euro million (2000) to around 500 euro million (2003) (BSW 2007).

Table 5.6 Photovoltaics: installed capacity in Germany, 1990–2003 (BMU 2009b)

	1990	1991	1992	1993	1994
Installed capacity (MWp)	1	2	3	5	6
New installations (MWp)		1	1	2	1
Growth on previous year		100%	50%	67%	20%
Market stimulated by:		1,000 Roofs Program			

	1995	1996	1997	1998	1999	2000	2001	2002	2003
Installed capacity (MWp)	8	11	18	23	32	76	186	296	439
New installations (MWp)	2	3	7	5	9	44	110	110	143
Growth on previous year	33%	38%	64%	28%	39%	138%	145%	59%	48%
Market stimulated by:	Municipal cost-covering compensation				100,000 Roofs program, Interim act on Photovoltaic energy				

At the beginning of the millennium Germany assumed a leading role in the photovoltaics sector on the global market. After Japan, which has traditionally held a large share of the solar power segment, the German photovoltaics industry managed to secure second place for the first time in 2001, relegating the USA to third position. However, a large proportion of the modules installed in Germany (80%) were not produced in Germany, but were imported from other countries (Oppermann 2004, 49).

The corporate landscape also underwent further changes and saw a range of company takeovers (Iken 2005) (see Figs. 5.5 and 5.9. During this phase, the number of employees in the solar sector rose from 2,500 to 6,500 and production capacity increased from roughly 6 MW to just under 100 MW (BSW 2007).

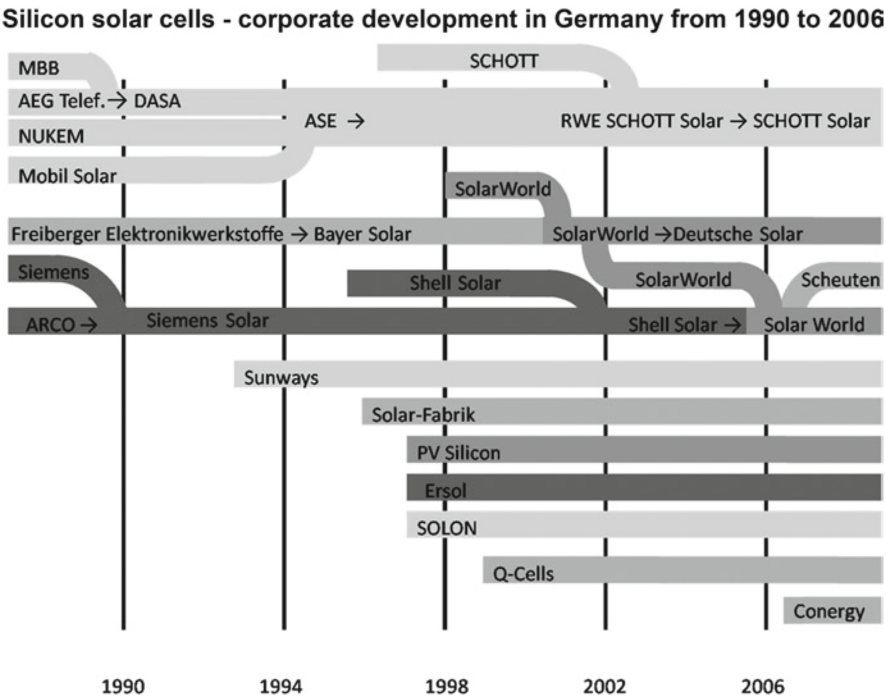

Fig. 5.9 Developments of selected companies in the field of silicon solar cells from 1990 to 2006 (author's own diagram based on information from Prognos et al. 2007b, 408)

5.2.6.8 Actors in the Constellation

The new red-green Federal Government emerged as one of the most important driving forces in this phase. It worked incredibly hard to secure support for renewable energies and – with the cooperation of the Federal Economics Ministry – managed to gain approval for the 100,000 Roofs Program. The Federal Environment Ministry and a number of parliamentary groups in the Bundestag played a major role in the breakthrough of photovoltaics by campaigning for an increased compensation rate for photovoltaic electricity in the EEG (Fell 2008, 1 sqq.). The support programs launched by a number of German states formed another component of this successful constellation.

Foundation of New Associations

The activities of existing, newly established or consolidated associations supported and strengthened the ministries, the Federal Government and the parliament. April 1998 saw the foundation of the Solar Industry Trade Association (UVS). In 2003 the German Solar Energy Association (BSE) and the German Solar Industry

Association (DFS) merged to form the German Solar Sector Association (BSi). Up until 2006 the German Solar Sector Association (BSi) represented the interests of Germany-based manufacturers and wholesale dealers of solar systems and components. In 2006 it merged with the Solar Industry Trade Association (UVS) to form the German Solar Industry Association (BSW). Since then the association has represented over 600 solar energy companies. In addition, over 350 other small solar energy societies work to promote the solar cause (Dilger 1997, 16 sqq.).

New Operator Models Act as Multipliers for Photovoltaic Installations

Political actions in this phase sparked a dramatic increase in demand for solar cells. Associated companies and the first commercial users played a particular role on the consumer side. Since the beginning of the 1990s, initiatives and companies had been searching for ways to develop new investor groups in order to spread the use of photovoltaic systems. User collectives seemed to be one way to pool capital.[43] In 1994 Hans-Josef Fell founded one of the first user collectives to operate a photovoltaic installation in Hammelburg (Fell 2007, pers. comm.; Fell 2008, 1 et sqq.). That year, the energy and solar agency Energieagentur Regio Freiburg developed the concept of a community PV plant and offered shares in the Regio solar power plant at a price of 10,000 German mark per 500-watt share (Stryi-Hipp 2005, 184). In the years that followed the idea of the community photovoltaic power plant spread across Germany. The citizens' solar power plant operator model run by volunteers has become a mainstay in the creation of user groups. Thus the role of volunteer work in the spread of PV power plants should not be underestimated (Mautz & Byzio 2005, 35 sqq.).

Investment in associated companies involved in the construction of photovoltaic installations rose with the introduction of cost-covering feed-in payments in the EEG. It gradually became clear that it was no longer merely "idealists" who were installing PV systems on their roofs, but also operators interested in the commercial potential of PV systems. The various policy measures influenced the economic calculations of actors, who had assumed the role of energy producers. Actors in the field of energy production now ranged from homeowners with their own PV systems and self-organized citizens' groups (e.g. citizens' solar energy initiatives), to farmers who operated their own photovoltaic installations and founders of medium-sized operating companies (Mautz & Byzio 2005, 7).

5.2.6.9 Acceptance of Photovoltaic Systems

In 2001 the EU launched the research program PVACCEPT to investigate acceptance levels for PV systems in sensitive areas such as monument preservation and landscape conservation. One of the reasons behind the program was criticism of PV

[43] Cooperatives to operate wind power plants emerged as early as the end of the 1980s in the form of the "citizens' wind farm" operator model and may have inspired user cooperatives in the area of photovoltaics. In the field of wind energy, the model experienced massive growth from the end of the 1980s (up until around the end of the 1990s) (Byzio et al. 2002, 310 sqq.).

installations on buildings under preservation order. From the perspective of monument preservation bodies, the installation of PV systems on buildings under preservation order is frequently incompatible with the goals of monument preservation. Critics view PV systems as "foreign bodies" that do not fit in with the character of rural areas or damage the shape of the urban landscape.[44]

Landscape conservationists objected above all to "greenfield" PV plants. The EU research program aimed to establish whether acceptance levels could be boosted by adapting the design of these plants.[45]

The project's final report, released at the beginning of 2005, presented innovatively designed modules and demonstration objects and contained detailed surveys on the topic of acceptance as well as results of the life cycle assessment conducted as part of the project. The findings from numerous surveys of residents, tourists, architects, planners and monument preservation bodies revealed that the impact of design on acceptance levels had been previously undervalued. One in ten of those surveyed in Germany said they found the PV modules currently on the market "aesthetically displeasing". However, three quarters of those surveyed did not, per se, object to the installation of PV systems on the facades or rooftops of historic buildings if the design of the technical components suited the structure.[46]

5.2.6.10 Interpretation of the Constellation: Driving Forces and Constraints

The constellation in this phase was set against the backdrop of many favorable factors influencing the development of photovoltaics in Germany. These include international climate protection measures, pioneers in other countries, a change of perception within society and initiatives at EU level to liberalize the market and promote renewable energies (see Sects 3.2 and 3.3). One of the key driving forces was the much called-for 100,000 Roofs Program, which was modeled on the Japanese Residential Program[47] and implemented by the red-green Federal Government. Another impulse came from the EGG, adopted by the Bundestag after intensive campaigning by the Federal Environment Ministry. It created long-term, government-stipulated framework conditions and promoted the growth of the market and the PV industry. The change of government and the transfer of responsibility to the Federal Environment Ministry opened a window of opportunity to stimulate developments. The development of mass production techniques during this phase initiated industrialization processes in the sector, supported by investment from large corporations, young companies and also private investors. In addition to environmental and climate change policy goals, industrial policy objectives were becoming an increasingly important motivating factor in the provision of

[44] To avoid conflict concerning aesthetics, the solar energy sector has started offering special solar tiles or slates in the same color as the rest of the roof cladding to make the solar installation less noticeable. See http://www.pvaccept.de/eng/index.htm (accessed July 13, 2009).

[45] See Krampitz (2001, 36); see also Bernreuter (2001, 28 sqq.).

[46] See www.pvaccept.de/akzeptanz.htm (accessed July 13, 2009).

[47] The full program title was: Residential PV Systems Dissemination Program.

funding. At the same time, however, a subconstellation – albeit not particularly strong – was forming, made up of naysayers who raised the concerns of landscape conservation and monument preservation bodies.

5.2.7 *Phase 6: Development Boom from 2004*

5.2.7.1 Characteristics of the Constellation

The EEG was a central element of the constellation in the phase starting in 2004. After the 100,000 Roofs Program came to an end, the act sparked a development boom in the field of photovoltaics. As in the previous phase, background events in the constellation facilitated the development. The EU's climate change goals and a dynamic international photovoltaics market in conjunction with national climate change goals provided new impetus for developments in Germany. In the area of technological developments, particular advances were made with regard to the optimization of manufacturing techniques (Fig. 5.10).
However, the continued diffusion of this technology made it necessary to create provisions to deal with unintended outcomes. A shortage of raw materials and the

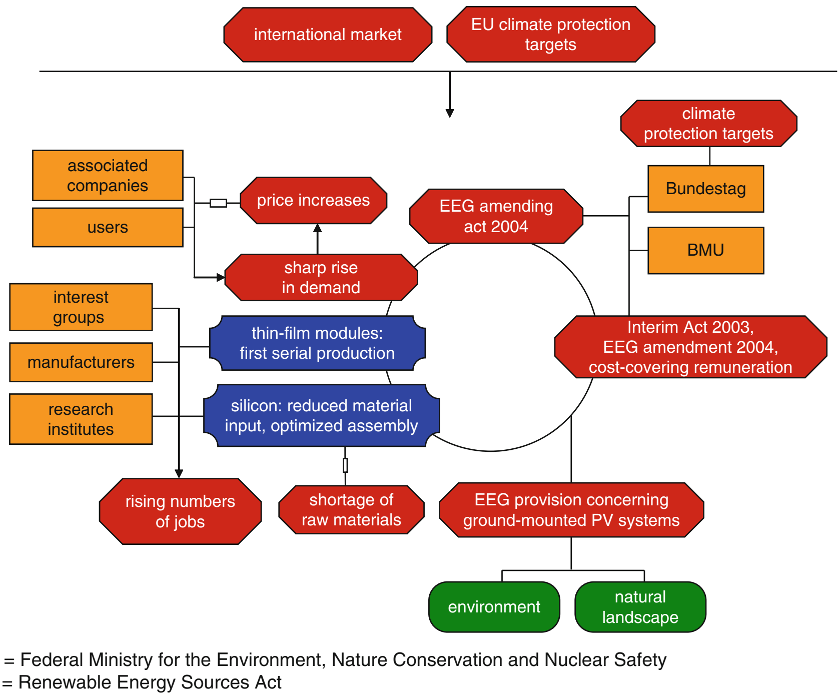

Fig. 5.10 Constellation phase 6: development boom, from 2004

high demand generated by the EEG had an ambivalent impact. On the one hand, it led to an increase in the number of jobs in the sector and a decrease in production costs. On the other hand, the high demand and the shortage of the raw material silicon pushed up the price of modules. These factors sparked a lively debate concerning the compensation rates stipulated in the EEG for electricity generated by photovoltaics. There were also fears that ground-mounted systems would have adverse effects on the environment and the countryside. The EEG included provisions concerning ground-mounted systems to limit these effects.

5.2.7.2 Sector-Specific Context, Influencing Factors and Processes

Within the context of the constellation, a significant factor in this phase was the EU Directive on the promotion of electricity produced from renewable energy sources in the internal electricity market, which had been adopted in 2001. The directive aimed to significantly increase the share of electricity consumption from renewable energy sources and to establish the necessary support schemes at national level. Germany's key instrument here was the EEG, which also provided considerable support to photovoltaics. In 2005 the EU Commission published a report on the success of various funding models (COM 2005) in it referred to the EEG as a particularly effective market introduction instrument.

Following the amendment of the EEG, the market in Germany continued to expand. However, as a result of insufficient production capacities Germany increasingly became an importing country for manufactures across the world (Räuber 2005, 164). This fact motivated the sector to rapidly expand national production capacities in this phase.

5.2.7.3 Governmental Guidance and Economic Context

The Interim Act on Photovoltaic Energy and the EEG amendment

After the 100,000 Roofs Program came to an end in 2003 (see Sect. 5.2.5.5), the photovoltaics sector faced a gap in funding until the adoption of the EGG amendment, which was scheduled for 2004. Half a year without any support would have been a massive setback for the photovoltaics sector. The Interim Act on Photovoltaic Energy filled this gap in funding. The act focused on compensation conditions for photovoltaics in the EEG and compensated for the discontinuation of the interest-rate reduction provided by the 100,000 Roofs Program. The Interim Act on Photovoltaic Energy was adopted on 22 December 2003 and came into effect on 1 January 2004, over a half a year before the EEG amendment. The act was developed on the basis of a compromise paper, drafted with the participation of a range of different lobby groups.

The Interim Act on Photovoltaic Energy introduced new compensation rates for PV installations that went into operation from 1 January 2004. Solar power received a compensation of 45.7 cents/kWh (basic compensation). This compensation was calculated to enable the operator of a solar installation in southern Germany to make an annual return on investment of 6.5% on the basis of medium levels of irradiation and average PV system prices (Stryi-Hipp 2005, 186).

One of the main factors that led to the Interim Act on Photovoltaic Energy was the debate surrounding the provision of support for ground-mounted PV systems. Article 8 of the version of the EEG valid up to 31 December 2003 specified that all electricity fed into the grid should receive a general minimum compensation, irrespective of the site or type of system used to generate electricity from solar radiation energy. The compromise paper comprised several changes concerning this matter, which went some way to ensuring that ground-mounted PV systems were implemented in an environmentally friendly and ecologically sound manner, thus increasing acceptance of the legal specifications.

Ground-mounted systems were incorporated into the EEG, in spite of the fact that many in the Federal Environment Ministry did not believe they were necessary, as there was sufficient roof surface area available. The reason for this decision was the economy-of-scale effect that resulted from the volume of demand generated by a ground-mounted system. Nevertheless, the Interim Act on Photovoltaic Energy set a lower basic compensation rate for large, ground-mounted systems that fell within the scope of a development plan. It was assumed that ground-mounted systems were generally megawatt plants and were thus significantly more cost-effective. The compensation payments for electricity from ground-mounted systems were limited until 2015. Furthermore, the obligation to provide remuneration only applied to areas with sealed surfaces, to conversion sites or to Greenfield sites that had previously been used as arable farmland. This provision aimed to balance the interests of industry with the interests of environmental protection and nature conservation.

The compensation for solar systems on buildings increased by 11.7 cents/kWh up to an installed capacity of 30 kW, by 8.9 cents/kWh for systems with an installed capacity of between 30 and 100 kW, and by 8.3 cents/kWh for installations with a capacity exceeding 100 kW. The act also introduced a bonus of 5 cents/kWh for systems that were integrated into building facades. All in all, in anticipation of the amendment of the EEG under discussion at that time, the Interim Act on Photovoltaic Energy established improved conditions for the remuneration of solar power. The amendment of the EEG, which went into effect on 1 August 2004 incorporated these changes.

Table 5.7 Compensation for PV rooftop systems up to 30 kW as stipulated in the StrEG and the EEG

		1991	1995	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Rooftop systems up to 30 kW		StrEG			EEG 2000				EEG 2004					EEG 2009	
Nominal compensation payment	Cent/kWh	8.5	8.8	8.4	50.6	50.6	48.1	45.7	57.4	54.5	51.8	49.2	46.8	43.0	39.6
Compensation payment in 2009 prices		11.9	11.0	10.0	59.3	58.1	54.5	51.2	63.3	59.2	55.4	51.4	47.7	43.0	38.9

After the amendment, demand for modules increased significantly. However, sales were now limited by the ability of manufacturers to supply the goods. The number of new systems installed each year rose dramatically compared with the period before the adoption of the EEG amendment (see Sect. 5.2.6.7 and Tables 5.7 and 5.8).

After the change of government in November 2005, the new governing coalition of the CDU/CSU and the SPD continued to support the EEG and its objectives. Decisions to make changes to the act were based on the EEG Progress Report, which monitored its effectiveness. On the basis of this report, the Federal Government passed a draft bill on the amendment of the EEG in December 2007, which specified a significant increase in degression rates. It planned to reduce the compensation for new, small rooftop systems up to a capacity of 30 kW from 44.41 cents/kWh to just 42.48 cents/kWh from 1 January 2009.

Table 5.8 Photovoltaics: installed capacity in Germany, 1990–2008 (BMU 2009b)

		1990	1991	1992	1993	1994	1995	1996	1997	1998
Installed capacity (MWp)		1	2	3	5	6	8	11	18	23
New installations (MWp)			1	1	2	1	2	3	7	5
Growth on previous year			100%	50%	67%	20%	33%	38%	64%	28%
Market stimulated by:			1,000 Roofs Program				Municipal cost-covering compensation			
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Installed capacity (MWp)	32	76	186	296	439	1074	1980	2812	3977	5877
New installations (MWp)	9	44	110	110	143	635	906	832	1165	1900
Growth on previous year	39%	138%	145%	59%	48%	145%	84%	42%	41%	48%
Market stimulated by:	100,000 Roofs program, Interim act on Photovoltaic energy					EEG 2004				

After lengthy negotiations (the CDU/CSU, for example, called for a one-off 30% reduction of the compensation rate) and some controversial publications on the anticipated costs of expansion (Frondel et al. 2008), the coalition government decided on a degression of 8% for rooftop systems (10% for systems over 100 kW) from 2009 and an across-the-board degression of 9% from 2010. The degression for ground-mounted systems amounted to an initial 10% in 2009 and then also 9% from 2010. A targeted market volume was also agreed upon: if the volume exceeded or fell below the target, the degression rate in the following year would increase or decrease respectively by 1% point. The bonus of 5 cents/kWh for integrating systems into building facades was discontinued (BMU 2008).

Research Funding

The Fifth Energy Research Program launched in 2005 was jointly financed, for the first time, by the Federal Research Ministry and the Federal Environment Ministry. The program focused on boosting efficiency, reducing material input (using new materials and combining materials) and automating and optimizing manufacturing technologies for both silicon wafer technology and thin-film solar cell technology.

A desire to secure Germany's leading position in the field of technology development and in particular in the area of thin-film photovoltaics in the long term led to the formation of groupings, or "clusters", comprising actors from research and industry, with the aim of transferring knowledge and ensuring the rapid application of research findings to the industrial domain. An example of such a cluster is Solar Valley, an alliance of medium-sized companies in Thuringia, Saxony and Saxony-Anhalt, which is home to an extraordinarily high density of companies. The cluster comprises the entire production chain from the manufacture of the base material silicon, and wafer-cutting, to the production of solar modules. Regional photovoltaics clusters, which are predominantly located in eastern Germany, not only consist of semiconductor and photovoltaic producers, their suppliers, distributors and respective service providers, but also research institutes. In 2007 around 80% of solar-cell production by German companies and ca. 18% by international companies took place in eastern Germany. In 2008 the photovoltaics industry in eastern Germany employed around 14,000 people, including supply companies (Nölting 2009).

The conditions that made the site of the Central German Technology Park (TechnologiePark Mitteldeutschland) an appealing location for the formation of a cluster included the availability of local, qualified personnel who had previously worked in the GDR's chemicals and semiconductor industry and possessed expertise with regard to exposure processes, surface coatings and the use of special materials. Furthermore, the companies had access to an infrastructure that consisted of low electricity prices, investment from federal funding programs and Structural Funds and other aids to help companies establish their operations, such as a technology and start-up center, which benefited from the support of local politicians and uncomplicated decision-making processes when it came to granting licenses. In addition to economic ties, the technology and knowledge transfer that resulted from linking industrial production and the scientific expertise of seven research institutes and four higher education institutes also played a central role (e.g. the Faculty of Photovoltaics at the University of Halle, the Fraunhofer Research Center for Silicon Photovoltaics CSP and the dual degree and training courses in solar technology at Anhalt University of Applied Sciences in Köthen). The initiative is one of five leading clusters in Germany supported by the Federal Research Ministry since 2008 (Rech 2008, pers. comm.).

However, due to the close ties between research and industry, some fear that a sharp decline in industry (caused, for example, by falling prices and a drop in demand as a result of the economic situation caused by the financial crisis or because of increased competition from emerging markets) would also affect research institutes and thus jeopardize the leading position of the research and development field.

5.2.7.4 Acceptance of Photovoltaic Systems

PV rooftops systems have enjoyed high levels of public approval to date. Although photovoltaics has attracted criticism for being the most expensive of all renewable power generating technologies insofar as it receives the highest compensation rate in the EEG, it is more widely endorsed than any other form of renewable energy. Its accessibility to "ordinary people" stems from the fact that a large proportion of the systems are financed using private capital and installed on private rooftops.

The visual impact of both PV rooftop systems and the increasing numbers of solar thermal heating systems is becoming increasingly evident. In some parts of southern Germany, photovoltaic modules in various colors and sizes give the impression of a "patchwork rooftop". To date, however, screwing solar modules onto roofs has been more cost-effective than the more aesthetically pleasing option of integrating systems into rooftops or facades. The "facade bonus" of 5 cents/kWh was discontinued in January 2009. However, the bonus was not enough to cover the costs of integrating systems into buildings (Heup 2009b, 51–52). Building-integrated systems could help avoid potential acceptance problems caused by the rising numbers of systems installed on rooftops.

5.2.7.5 Conflicting Goals in the Area of Ground-Mounted Systems

Economic Objectives

Endorsement of the inclusion of ground-mounted systems in the EEG 2004 compensation regulations primarily stemmed from industrial policy considerations. Advocates of the new regulations argued that ground-mounted systems were necessary at that time to boost and professionalize the photovoltaics market and create planning security. They held the view that ground-mounted systems had an important role to play in the solar industry as it moved to mass production because they created economy-of-scale effects and thus enhanced the competitiveness of photovoltaics. They also maintained that one of the key functions of constructing such plants in Germany was to sustain the international perception of German competence in the area of ground-mounted systems. It was considered important for Germany to sustain its systems expertise in the area of ground-mounted systems, particularly in view of its export market. It was argued that the value added had to remain in Germany in order to ensure acceptance of ground-mounted PV systems: it would be counteractive to the political objective of strengthening this industry's segment in Germany if it became necessary to import the technology from abroad.[48]

Plants Predominantly Located in Solar Parks

The inclusion of ground-mounted systems in the EEG compensation scheme boosted interest in constructing these systems. Around 90% of PV systems are installed on building rooftops or facades or integrated into the building envelope. Ground-mounted systems account for the remaining 10% of newly installed solar power capacity and these are often constructed on industrial wastelands or conversion sites.

[48] ARGE Monitoring PV-Anlagen (2005a, 34–36).

At the time of this study's editorial deadline, the largest plant was Solarpark Lieberose in Brandenburg, which was constructed on a former military training area. The park, which comprises 700,000 thin-film solar modules with a total capacity of 53 MW, went into operation in 2009.

Siting and Acceptance of Ground-Mounted Photovoltaic Systems

As in the case of wind energy, measures to support photovoltaics led to the emergence of conflicting goals in the areas of climate protection and biodiversity conservation. The inclusion of ground-mounted systems in the EEG sparked fears that there would be similar problems in the field of photovoltaics relating to phenomenal growth in undeveloped, non-urban areas (*Außenbereich*)[49], especially as the sector had expressed a great deal of interest in developing solar parks (ARGE Monitoring PV-Anlagen 2005a and b as well as ARGE Monitoring PV-Anlagen 2006a and b).

As a result of the distinctions made in the Interim Act on Photovoltaic Energy regarding remuneration, a clear preference remained for PV systems installed onto or integrated into buildings as opposed to ground-mounted installations (ARGE Monitoring PV-Anlagen 2005a, 20).

As there were no binding planning instruments to control the application of photovoltaics in undeveloped, outlying areas,[50] nature conservation societies developed criteria to ensure the environmentally friendly implementation of PV technology and prevent undesired, unbridled growth. Protecting nature and landscape conservation interests was said to be a prerequisite for the acceptance of solar parks.[51] Avoiding conflicts was also considered wise in order to ensure the smooth running of approval processes. Ground-mounted PV systems were only acceptable as an "intermediate step". As before, the emphasis was on the installation of systems on buildings and building-integrated systems. It was also considered necessary to exclude sites that were particularly significant and worthy of protection from a nature conservation perspective from the EEG's provisions on ground-mounted systems (ARGE Monitoring PV-Anlagen 2005a, 20).

Monitoring systems are one way to recognize and, where possible, avert the undesired outcomes and impacts of ground-mounted PV systems.[52] They provide

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[49] The term *Außenbereich* comes from German zoning law and describes a category of areas which are not within the area designated by a binding land-use plan and which are not part of the built-up area (*Innenbereich*).

[50] The use of regional or land-use planning in decisions concerning site location (Article 7, Section 4 of the Regional Planning Act – ROG) was not considered to be worthwhile, since developments up to that point had not yet resulted in crucial, site-related problems that could only be solved at regional planning level (ARGE Monitoring PV-Anlagen 2005a, 42).

[51] See http://www.nabu.de/themen/energie/erneuerbareenergien/solarenergie/04300.html (accessed July 14, 2009)

[52] At the end of 2004 the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety assigned the PV Systems Monitoring Working Group with the task of monitoring the impact of the revised EEG on the development of ground-mounted PV arrays (ARGE Monitoring PV-Anlagen 2007).

information on the impact of PV support measures and on the expansion of the solar energy sector. They revealed, for example, that as a result of the high degression of compensation rates for ground-mounted systems, project developers were increasingly opting for greenfield sites, as they can be more easily adapted for the installation of photovoltaic modules. Conversion sites, on the other hand, are a less cost-effective option, as they entail high land clearance and adaptation costs. Monitoring also involved a process of dialog with the relevant actors in municipalities, with environment and nature conservation associations and with representatives of the solar industry. Submission of an approved development plan was a prerequisite in order to receive feed-in compensation. This strategy aimed to guarantee public participation in the approval process and thus ensure the local population was well informed and involved in the project at an early stage.[53]

5.2.7.6 Site-Specific Obstacles to Obtaining Licenses

The process of finding roofs that are suitable for the installation of PV systems varies greatly depending on the site and often involves significant obstacles. In Berlin, for example, in spite of the Solar Roof Initiative[54] created by the senator for environmental affairs, very few buildings have been fitted with PV systems to date. In a nationwide ranking of 40 municipalities, Berlin only occupies position 29 (Pirch-Masloch 2008, pers. comm.). This is due to the complex constellation in the city: responsibility for granting approval falls with the district and not the senate level. The approval process for a photovoltaic installation on a public rooftop involves the environmental, building and legal departments of the district in question. In the case of school rooftops, the school administration is also involved. There is no central point of contact for investors who wish to apply for a license. Furthermore, procedures vary from district to district. In the case of new roofs, which are often suitable for PV systems in terms of statics, a roofing company in Berlin has a 5-year warranty obligation. This means that roofs that are, in principle, suitable for PV installations may not be used during this period (Pirch-Masloch 2008, pers. comm.). After successfully locating a suitable roof and securing a license, the investor must then negotiate the leasing agreement and the rental cost for the rooftop. The Berlin Senate lacks the capacities to systematically collect data concerning both potentially suitable roofs and systems already fitted. This example demonstrates how, in spite of a supportive legal and economic framework at international and national level, considerable implementation problems at local level can present huge obstacles to the diffusion of decentralized rooftop systems.

5.2.7.7 Technology and Market Developments

The 2003 Interim Act on Photovoltaic Energy and the 2004 EEG amendment resulted in the introduction of cost-covering compensation for solar energy, which

[53] See Stein in ARGE Monitoring PV-Anlagen (2005b, 2).

[54] The scheme makes roofs of public buildings available for private investors to install PV systems.

led to a sharp rise in demand. For example, 2004 alone saw the installation of 600 MW, which was more than the total installed capacity up to that point. PV systems in Germany had never experienced such massive growth before. The annual expansion rate subsequently continued to rise until 2008. The additional capacity in 2008 was estimated at around 1,600 MW and the total installed capacity at 5,400 MW. Large, ground-mounted systems with a total capacity of up to 40 MW accounted for ca. 7% of the annual installed capacity.

However, the installation of smaller-scale house rooftop systems dropped significantly. On the one hand, this was due to price developments (see below). On the other, the complex bureaucratic hurdles to obtain a license and install a house rooftop system deterred many who were potentially interested in the idea (see Sect. 5.2.6.6). Commercial investors, such as farmers or companies, played a significant part in this boom phase. They installed comparatively large rooftop systems of up to several 100 KW. The sector is currently expanding at a dynamic rate and substantial progress was – and still is – made in all areas of solar technology (Rentzing 2009, 62 sqq.). The global market is growing and subsequently also the export ratio of German companies (ca. 50 %).

Developments in the Price of PV Systems

Between 2004 and 2006 the price of PV modules in Germany rose by almost 30%, contrary to the anticipated development (see Fig. 5.11). This was not due to an increase in production costs, but rather as a result of the classic market effect of supply and demand. The high compensation rates in the revised EEG of 2004

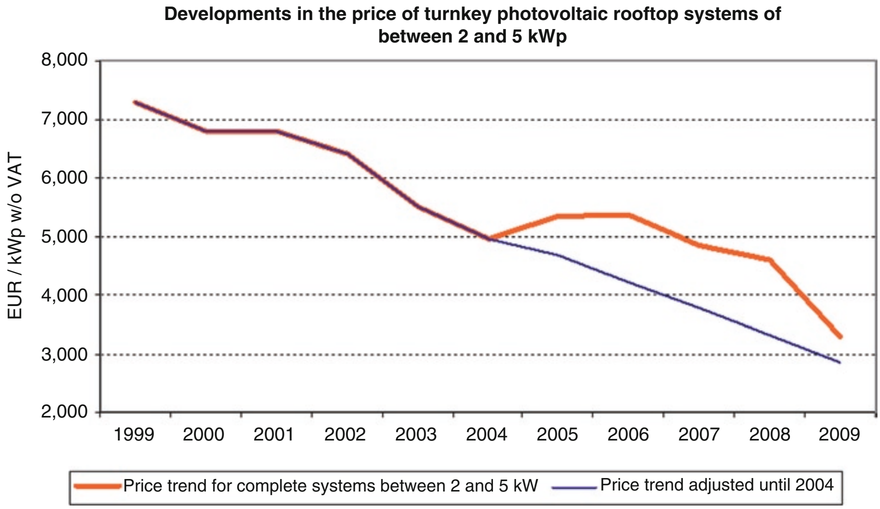

Fig. 5.11 Developments in the price of turnkey photovoltaic rooftop systems of between 2 and 5 kW (Oppermann 2004, 48; *Photon* (several issues); IfnE calculations)

created a demand-driven market. The annual degression rate of 5% stipulated in the EEG 2004 was designed to put pricing pressure on those who provided the systems (manufacturers and dealers) and thus also lower costs on the market. In practice, however, it did not have the desired effect in this period. Demand for PV modules in Germany and elsewhere, exceeded production capacities. Module manufacturers found themselves in the comfortable position of simply having to distribute their modules, and were able to do so at prices that only allowed investors to make a relatively low return on their investment. This led to the market price for photovoltaic modules decoupling from production costs, which continued to drop. As a result, it was primarily highly integrated companies[55] whose operations comprised the entire value creation chain that made high returns on investment. This was evident from the high profits of successful companies such as Q-Cells or SolarWorld.

In spite of protests from the solar energy sector, the realization of the actual reduction in costs of over 5% a year resulted in the introduction of a compensation rate degression of between 8% and 10% in the 2009 EEG amendment, depending on the performance class and site of the system. This limited the profits of operators of solar energy systems.

For the first time in many years, 2009 saw an above-average fall in the price of complete systems, exceeding the EEG degression rate. In addition to the financial and global economic crisis beginning in 2008, one of the major reasons behind this fall was the fact that the Spanish market largely disappeared as a result of changes in the law. Furthermore, increases in capacity led to a considerable surplus on the market. On the other hand, the fall in the price of systems brought the price trend back to the course it had taken for many years up until 2004 (see Fig. 5.11). Conversely, the price trend reveals a significant surplus of aid from the year 2004, if one assumes that the majority of those investing in systems expected at least a small return on investment.

In 2008 alone, global cell production once again nearly doubled compared with the figures from the previous year (see Fig. 5.12. In the company rankings, the German company Q-Cells was able to retain its leading position in terms of production output, although China remained the top global cell producer. Germany came next, in second position with a global market share of around 19%, and Japan followed in third place (Hirshman et al. 2009, 57).

German manufacturers made up significant ground in terms of cell production during this "boom" phase, yet production still lagged somewhat behind demand in Germany, which was around 1,600 MW in 2008 (see Fig. 5.12). The result was a market that required imports flew. But the intention of the national strategy was to promote technology as part of the goal to create domestic value added in the field of renewable energies. The EEG should not support systems that need to be purchased from abroad. Nevertheless, worldwide, seven out of ten of the largest cell

[55] Highly integrated companies are companies that integrate many different stages of production (vertical integration) in order to avoid buying in services.

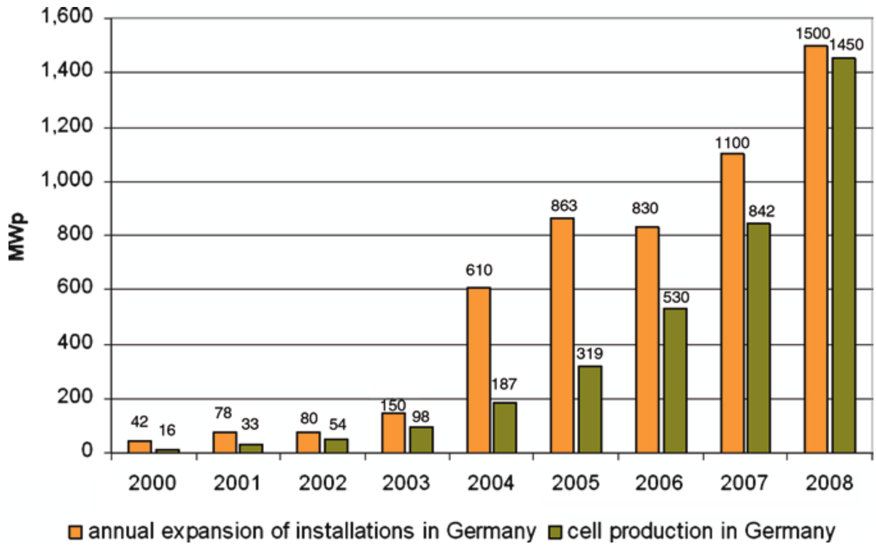

Fig. 5.12 Annual expansion of installed capacity compared with cell production in Germany (BSW 2009; BMU 2007; author's own diagram)

producers come from Asia. In the case of modules, this rises to eight out of ten producers. Around 65% of solar cells come from Asia and are primarily sold on European markets such as Germany and Spain. In contrast, there is barely any market in Asia to date (Waldermann 2008).

Developments in Production Technology

Up to this point, manufacturers of photovoltaic systems had benefited from the booming chip industry, which had supplied manufacturers with "impure" silicon produced during the process of recycling ultrapure silicon. However, the dramatic rise in the production of photovoltaic systems resulted in increased demand for impure silicon. Using ultrapure silicon would significantly increase the price of photovoltaic systems. Over the course of the development of photovoltaics, silicon shortages have occurred on a number of occasions when demand for modules increased rapidly and the production planning of silicon manufacturers was not sufficiently in synch. These imbalances were caused by changes to the (political and legal) framework conditions, which actors on the market could not anticipate. However, in retrospect, the periodic occurrence of capacity bottlenecks for solar silicon did not fundamentally impede the creation of cell production capacities: global cell production (of which around 90% was silicon-based) increased sixfold between 2003 and 2008 to ca. 7,900 MW. Rapid expansion of production capacities is currently a global phenomenon and not confined to Germany.

Silicon production is also receiving a great deal of investment worldwide,[56] which should greatly increase the amount of silicon available for photovoltaic modules over the next few years.

With regard to production technology, developments in this boom phase were clearly geared toward introducing fully automated manufacturing processes. To achieve this goal, new manufacturing steps were developed, such as the plasma and PVD processes (coating the substrate material with a layer of silicon of less than 0.05 mm) in the area of thin film production, or specific steps of the process were left out.

The "competition" between thin-film technology and silicon technology remained unresolved, even though the American company First Solar claimed to have become the first company to achieve specific production costs of under 1,000 euro/kW in 2008 with its telluride thin-film technology.[57] Nevertheless, there has been no evidence to date to conclusively establish which material, which technical design or which system is most effective or creates the lowest energy costs for the large range of applications (Luther 2008, pers. comm.).

Technological Innovations

In this phase, photovoltaic technology and its applications made the move from the development stage to commercial production. The earlier uncertainty surrounding solar products had largely disappeared. The number of possible applications for the technology grew with the development of numerous new products, such as solar roofs, solar tiles, roof-integrated technology, and customized systems to fit a variety of roof shapes, solar facades and solar sound-insulating walls.

As heat and power generation technologies "compete" for space when harnessing solar energy, work has been in progress for over 10 years to develop marketable hybrid collectors. In practice, however, this concept is not without complications. The efficiency of integrated electricity and heat production systems, for example, is lower than when generated separately. Furthermore, it is essential not to disrupt operation of the solar cell water cooling system, as this will result in the collector reaching temperatures of up to 150 °C, which will destroy the cells, as they should only reach temperatures of 80 °C. In view of these technological challenges, it remains to be seen whether these modules will prove to be durable and competitive in terms of price (Berner 2008, 20 sqq.).

Concentrated solar power systems use Fresnel lenses (also used in lighthouses) to focus sunlight on solar cells, resulting in efficiency rates of over 40%. This is

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[56] A tenfold increase in worldwide silicon production to around 400,000 t is expected between 2005 and 2015, for example. According to estimates, at least 120,000 t will have already been produced by 2010. After deducting the amount required for the semiconductor industry, this would enable the production of PV modules with a total capacity of around 13 GW in 2010 (Siemer 2007, 75).

[57] Press report from 24 February 2009: "First Solar Passes $1 Per Watt Industry Milestone". http://www.finanznachrichten.de/nachrichten-2009-02/13200068-first-solar-passes-dollar-1-per-watt-industry-milestone-004.htm (accessed August 9, 2009).

more than twice the efficiency rate of normal solar cells. Many believe this technology holds great potential, especially in the case of PV power plants.

The production of crystalline silicon also underwent fundamental changes, as researchers established a method of producing solar cells that substituted the expensive, ultrapure silicon with a significantly less expensive, metallurgically refined silicon, or UMG silicon (upgraded metallurgical silicon). It can be manufactured far more cost-effectively, as the investment costs in UMG silicon production plants only amount to one tenth of those for ultrapure silicon (Photon 2008, 35). Preventing the impurities in the material from producing inferior efficiency rates demands a more complex cell production process, which must be precisely adapted to the respective UMG silicon.[58] Large cost reductions are also anticipated in the area of ultrapure silicon production.

The efficiency rate of market-leading inverters had, in this phase, reached up to 98%. The mean time between failures rose from 100,000 h in 1990 to 500,000 h in 2009.[59] Based on this fact, whereas systems installed during the 100,000 Roofs Program required on average two inverters over the course of a 20-year service life, systems installed in 2009 would not require a change of inverter during the 20-year EEG compensation period (equivalent to 175,200 h) and would even remain operational for over 50 years. This is also a significant cost-reducing factor.

Corporate Developments

This phase saw numerous restructurings and strategic changes within companies (see Fig. 5.9) (Prognos et al. 2007b, 99–100). It emerged that the most economically successful solar companies were those that had opted for an integrated production process, i.e. had operations at many or even all levels of the value creation chain (silicon production, wafer, cell and module manufacture). Companies that only had operations at the end of the manufacturing chain (module production) were forced to accept the prices of their preliminary suppliers when raw materials were in short supply. In order to reduce this risk, a number of companies tried to expand their vertical integration (known as "backwards vertical integration"). Essentially, this is a question of corporate strategy: highly specialized manufacturers have an advantage in markets where there is a surplus of supply, as is demonstrated by the low level of vertical integration in established industries.

In order to secure their position, companies also diversified their technologies by investing in thin-film technologies to reduce their dependency on crystalline silicon. However, the success of this strategy is dependent on the realization of anticipated, significant price reductions in the area of thin-film technology. Furthermore,

[58] Q-Cells plans to base a large proportion of its cell production on UMG silicon and has entered into a long-term supply agreement up to 2018 with the Chinese company LDK Solar for 20,000 t of UMG silicon. See http://in.reuters.com/finance/stocks/keyDevelopments?symbol=LDK.N&pn=4 (accessed, June 18, 2010).

[59] SMA company presentation from May 6, 2008.

it is not yet clear which of the various thin-film technologies will come to dominate the market. In 2007 thin-film modules still held a market share of under 10% (see Table 5.9).

Table 5.9 Thin cell production in Germany 2007/2008

Company	Location	Technology[60]	Production capacity (megawatt)
Antec	Arnstadt	CdTe	20
Sontor	Thalheim	a-Si/μ-Si	Pilot line, another 60 MW planned
Calyxo	Thalheim	CdTe	Pilot line 8 MW =25 MW, another 60 under construction
Ersol thin film	Erfurt	a-Si, a-Si/μ-Si	40
First solar	Frankfurt/Oder	CdTe	120
Johanna solar	Brandenburg/Havel	CIGSSe	30
Odersun	Frankfurt/Oder	CIS	N/S
SCHOTT solar	Putzbrunn	a-Si	N/S
	Jena	a-Si	33
Solarion	Leipzig	CIGS	N/S
Sulfurcell	Berlin	CIS	10
Würth solar	Schwäbisch Hall	CIS	14.8

Established companies also took a growing interest in this successful and innovative sector, as was demonstrated, for example, when well-known companies operating in other fields made strategic acquisitions of solar technology companies, such as Bosch's acquisition of Ersol in 2008. Another example is the robot manufacturer Kuka, which had mainly been active in the automobile industry, began equipping PV module assembly lines with robots in 2005.

Emergence of Regional Hubs

Eastern Germany was the focal point for the development of German production capacities, especially with regard to new thin-film production sites. A major reason for this was the funding available to eastern German states from the EU Structural Funds (Aulich 2008, pers. comm.). Solar industry hubs include Erfurt and the surrounding area (Thuringia), Bitterfeld (Saxony-Anhalt) (see Sect. 5.2.6.7), Frankfurt/Oder (Brandenburg) and Berlin.

The Competence Center Thin-Film- and Nanotechnology for Photovoltaics (PVcomB) is in the process of opening in Berlin. It aims to strengthen eastern Germany as a center for innovation and technology, improve conditions for training and cut the costs of solar power production. The center's partners include the Helmholtz Association (Helmholtz Center Berlin for Materials and Energy, HZB), the Berlin Institute of Technology (TU Berlin) and leading companies from the field of thin-film solar module production. The PvcomB qualified for funding

[60] Cadmium telluride (CdTe), amorphous silicon (a-Si), microcrystalline silicon (m-Si), copper indium diselenide (CIS), copper indium gallium diselenide (CIGS), copper-indium-gallium-sulfur (CIGSSe).

within the scope of the Ministry of Research's program Cutting-edge Research and Innovation in the New States (Spitzenforschung und Innovation in den Neuen Ländern), which aims to promote high-tech research in eastern Germany. The program is part of the Federal Government's High-Tech Strategy and promotes cooperation between science and industry.

The competence center will be equipped with facilities to develop at least two lines of thin-film technology (Si and CIGSe solar modules). The aim is to enhance efficiency rates to 12% and 15% respectively by making improvements at every level of the value creation chain, from basic research to application in industry. In its work in the area of technology transfer, the center places value on taking a hands-on approach to education, exploiting marketable concepts and enhancing industrial processes. There are plans to incorporate partner institutes and research groups from Saxony, Saxony-Anhalt, Thuringia and Brandenburg in the competence center's projects.

Links Between the Photovoltaics Sector and Solar Thermal Power Plant Development

In Germany, photovoltaics is the only significant form of solar power generation technology. At international level, however, solar thermal power plants have been experiencing dynamic growth since about 2006. When compared to support provided globally, Germany has allocated a great deal of research funding to this area of technology, which has enabled German research institutes and companies to become one of the world's leading forces in the area of construction technology for parabolic trough power plants. German research funding has played a fundamental role in bringing collector, absorber and storage components up to their current technical standards.

The company Solar Millennium AG holds a large market share as a project developer for solar power plants (see Pecka 2008, 22). The company has already constructed two solar thermal power plants in Spain (Andasol I, which has a capacity of 50 MW and has been connected to the grid since 2008 and Andasol II, which was connected in 2009). Construction work has also begun on a third power plant (Andasol III). Three further power plants are under construction in Spain, each with a capacity of 50 MW, which were set to go into operation in 2009. One power plant is under development in Egypt, one in Algeria and one in Morocco, each with a capacity of 20 MW. These power plants are set to be commissioned in 2010 (BMU 2009a, 58).[61] Further mega projects are in the pipeline in North Africa. However, they are still under debate due to potential implementation problems (Scheer 2009; see Sect. 5.2.6.10).

[61] The electricity production costs of the Spanish power plants are in the region of 20–25 cents/kWh. The aim is to cut these costs to between 15 and 18 cents/kWh. Feed-in compensation in Spain is 27 cents/kWh. The next generation of systems in California and Egypt are expected to reduce electricity production costs to as little as 8–9 cents/kWh (Pecka 2008, 22).

Germany also has its own solar power plant: the solar tower power plant in Jülich, which was a research project, was connected to the grid at the end of 2008. Mirrors covering a total area of 20,000 m² concentrate sunlight onto a receiver on the 49-meter tower. Temperatures of up to 700 °C are generated in the receiver, which is made of porous, ceramic elements. A water-steam cycle then drives a turbine, producing an output of 1.5 MW (BINE 2008, 3).

Sector Turnover and Employment Statistics

According to figures provided by the sector, it employed around 48,000 people in 2008 (BSW 2009). A study for the Federal Environment Ministry claimed the number was as high as 57,000 (O'Sullivan et al. 2009, 6). According to figures provided by associations, the turnover amounted to around 7 euro billion. According to the aforementioned study, the turnover of companies based in Germany alone was 5.2 euro billion (ibid. 5). Thus since 2004 the number of those employed in the sector has increased almost threefold and turnover is roughly five times as high.

5.2.7.8 Actors in the Constellation

One of the most important actors in this phase was the Federal Environment Ministry. In cooperation with members of the Bundestag, it played a crucial role in shaping the Interim Act on Photovoltaic Energy and the 2004 amendment to the EEG (see Sect. 5.2.6.3). By initiating the Interim Act on Photovoltaic Energy, the Federal Environment Ministry succeeded in preventing the feared "cracks" from emerging in the development of photovoltaics. In addition, the sector's interest groups, research institutes and manufacturing companies were a driving force behind the progress and diffusion of photovoltaic technology and thus played a part in the development boom (see Sect. 5.2.6.7).

Professionalization of the photovoltaics sector began as early as the end of the 1990s with the development of commercial operator models for large-scale installations. In this phase, a major share of the growth in photovoltaic systems can be attributed to the sharp increase in investment from commercial investors, such as farmers. A number of states introduced measures specifically aimed at encouraging the involvement of farmers in photovoltaics. From 2004, for example, the state of Lower Saxony offered grants to farmers for photovoltaic systems as part of the Program to Promote Investment in Agriculture (Agrarinvestitionsförderprogramms – AFP).[62] The support was designed to lessen the burden of the high initial investment for systems on the large rooftop surfaces of agricultural buildings.

A variety of actors have begun to work in parallel in the solar energy sector, including a range of individual, private operators (above all homeowners), a growing number of civil society actors (such as operators of citizens' solar plants or solar initiatives run on a voluntary basis) and an increasing number of professional

[62] The Chamber of Agriculture was responsible for processing these grants.

operators of large-scale solar power plants. The model of the citizens' solar plant is being widely emulated, thus expanding the user and investor base. Voluntary work not only plays a significant role in the operation of plants, but is also important for gathering and passing on knowledge concerning financing, licensing requirements and PV plant construction. It is a characteristic feature of the photovoltaics field that diffusion channels rooted in civil society in the early development phases remain intact and continue to play an important role in later stages (Mautz & Byzio 2005, 61–62).

5.2.7.9 Interpretation of the Constellation: Driving Forces and Constraints

The amended version of the EEG has been a central driving force behind the development boom since 2004. In effect, it enabled the photovoltaics market in Germany to continue uninterrupted along its path of expansion. For the first time in 2004 Germany's installed annual capacity was greater than Japan's. However, as a result of the boom, German photovoltaics manufacturers were faced with the challenge of keeping pace with demand both in terms of material production and module manufacture. A shortage of the base material silicon slowed down development and although capacities were continually expanded, they still lagged behind demand. Ties between research and industry grew ever closer. The market underwent dynamic change, which had the unintended impact of pushing up the price of modules. The decision was made to increase the rate of degression in the EEG to between 8% and 10%, which came into effect in 2009. Opponents of this political measure argued that it would jeopardize a large number of jobs that had been created. Companies in the installations business were particularly concerned that the increased degression rate would result in a slump on the domestic solar market, jeopardizing the ca. 20,000 jobs in this segment if companies were no longer able to achieve a return on investment.[63] With regard to the increased use of undeveloped areas as sites for large-scale PV plants, the introduction of regulations based on nature conservation considerations should prevent a loss of acceptance for this technology, which has in principle gained the support of large sections of the public.

5.2.7.10 Outlook

A study conducted for the Federal Environment Ministry by Nitsch (2008) estimates that in Germany alone there will be an increase in solar system capacity of around 11 MW by 2020. The Federal Association for Renewable Energies considers this to be a conservative estimate. It expects an increase of as much as 35 MW by 2020 (BEE 2009). Thus nothing would seem to prevent the development boom depicted in this study since 2004 – but is this really the case?

Will we see the same phenomena in the photovoltaics innovation biography which so often emerge in the diffusion of new technologies: increasing problems

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[63] According to information provided by the Central Association of the German Electrical Trade (ZVEH), services provided by craft enterprises account for between 25% and 30% of the costs of a solar power system (press release from 3 May 2008).

integrating into the established system, declining growth rates after the initial boom, a market shakeout and increasing acceptance problems in the public domain as a result of undesired side-effects connected to the technology?

The current dynamic growth in installed capacity – which is expected to continue in the future – has put the issue of integration into the existing electricity networks on the political agenda. Calls are growing in particular to connect large, ground-mounted systems to the grid. These are few and far between in Germany, but there are many elsewhere, above all in Spain.

Requirements with regard to the electricity grid are also changing for the increasing numbers of decentralized systems. Photovoltaic systems will have to increasingly develop power plant characteristics and offer additional services to support the grid. As was the case with wind energy following its first boom phase, the sector is currently faced with the new task of developing the necessary inverters in order to provide grid services in the future (Heup 2009a, 58 sqq.).

It remains to be seen whether the German PV sector – like the wind sector – will be hit by a critical phase with a far-reaching impact and a sharp drop in demand after the initial boom phase. The price of solar electricity fed into the grid will become cheaper in the medium term due to the current fall in the price of modules and above all as a result of the compensation rate degression as stipulated in the EEG. Based on current calculations, solar electricity in Germany will achieve grid parity as early as the middle of the next decade, i.e. it will cost the same as household electricity and thus become competitive on a sub-market. This may happen even sooner in countries with high levels of solar irradiation.

However, it is not only a success story. The fall in price was also a result of the financial crisis, which led to intermittent slumps in demand worldwide. Many major customers are not able to purchase the number of modules they had planned to, due to difficulties in financing projects. Manufacturers must thus battle with a combination of capacity surpluses, high levels of stock and falling revenues due to a drop in price. Lulls in demand, falling prices and harsh competition have already proved the undoing of a number of companies that have had to file for bankruptcy. While the current developments are likely to benefit the consumer, manufacturers in Germany – who have become accustomed to making solid profits – are faced with the threat of losing shares in the market due to cuts in subsidies, a fall in demand and the huge expansion of production facilities worldwide. The market is undergoing its first shakeout. Companies with unfavorable cost structures will not survive this phase and are thus prime acquisition candidates. These changes could obstruct the development process in the future, particularly in view of the close ties between the manufacturing industry and research institutes.

Additionally, there are signs of another bottleneck on the horizon that would affect Germany's expansion goals. According to project planners there are no lack of current and future investors, however, they do report an increasing shortage of suitable roofs and sites (see for example Bettzieche and Heup 2009, 61). While many roofs are suitable for photovoltaic systems in terms of alignment, incline and size, they lack the required statics or building fabric. Furthermore, leases for attractive sites and suitable roofs (the larger the more attractive) are growing increasingly expensive.

As its use expands, the technology becomes increasingly visible. Photovoltaics has enjoyed high levels of public approval to date. In order to enable the photovoltaics sector to achieve its expansion goals by primarily installing decentralized systems and to prevent objections from residents and visitors about aesthetically displeasing designs, it will be necessary in future to develop varied solutions to integrate PV systems into roofs and facades in a visually harmonious manner (Heup 2009b, 46 sqq.). Failure to do so could create acceptance problems for photovoltaics as a mass product. The goal in the future will be to develop integrated concepts rather than subordinating the building to the needs of the technology.

At present, plans to harness the sun's energy in solar thermal power plants are making headline news. The focus of interest is the megaproject DESERTEC, a project concept that intends to use a section in the Sahara that would be enough to generate Europe and the MENA regions electricity requirements. The project comprises plans to construct solar thermal power plants in this region using low-loss high voltage direct current transmission systems (HVDC) to deliver the electricity to European and African centers of consumption. A comparatively high level of research funding in this field in Germany enabled its researchers to take a leading role in developing the technology. In future the solar thermal power plant segment will gain in significance. In addition to the current installed capacity worldwide of 604 MW, plants with a capacity of around 760 MW are already under construction and plans are in the pipeline for a further 5,800 MW (Pecka 2009, 1). It remains to be seen whether megaprojects in southern Europe or the projects in Africa's deserts – which are the subject of debate due to high costs and potential implementation problems – will dominate the future of electricity generation from solar energy sources (Scheer 2009). This uncertainty is less due to technical problems than the major hurdles of a primarily political and administrative nature that exist in the North African countries concerned.

It will be at least 10 years before the electricity from these regions will be able to flow into Germany's grid. Photovoltaic unit costs will continue to decrease during this period and the costs will near the costs of solar thermal electricity. It is conceivable that two competing technologies of solar power generation will emerge – photovoltaics and thermal power plants. Compared with photovoltaics, solar thermal power plants have advantages on the production side thanks to their heat storage systems, which allow them to capture heat and transform it into electricity in the evening and at night.

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Chapter 6
Conditions for Innovation in Geothermal Power Generation

Abstract The innovation process of generating electricity from deep geothermal heat is still in its early stages – the current phase is one of preliminary research. The state of this technology today is comparable to that of photovoltaics in the 1970s. The number of actors engaged in this field is small, comprising primarily of non-university research institutes, drilling technology companies, as well as municipalities, municipal utilities, power companies and district heating companies. It is mainly research actors, dedicated individuals and research funding that act as a motor for advancing the relevant pilot and demonstration plants.

So far there has been little practical experience in the harnessing of deep geothermal heat for electricity generation. The physical potential of geothermal power is extremely promising, yet tapping this source of energy is accompanied by high exploration risks and costly investments. There are no commercially operated plants to date, so future experience with the plants currently being commissioned will be key to the further development.

Characteristic of geothermal power is the low public awareness of this source of energy. So far there has hardly been any competition with other renewable energies. However, conflicts may arise due to the electricity sector's recent interest in deeper aquifers and safeguarding mining rights, which it may need to store captured CO_2. Acceptance problems may occur in the context of deep geothermal projects when geothermal drilling produces seismic responses.

Keywords Geothermal energy • Renewable energy sources • Investment risk • Energy potential • Deep drilling

6.1 Preliminary Remarks

The Greek expression geothermal means heat from the earth. The earth's heat is generated primarily by the permanent natural decay of radioactive isotopes in the earth. Furthermore, the earth's core still contains a great deal of residual heat from

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the time of its formation. Heat from deep in the earth is transported by means of thermal conduction and convection to layers where it can be accessed and utilized.

The significance of geothermal power production lies in the fact that this practically inexhaustible domestic energy source[1] has the capacity to provide a continual energy supply (base load capacity). Unlike hydroelectric, wind and solar power, this energy source deep below the earth's surface is not subject to daily or seasonal fluctuations. The constant level of electricity produced means that it can be integrated into the existing electrical grid with relative ease from a control engineering perspective (BMU 2007c). However, due to the cogeneration of heat and power, geothermal power generation is subject to seasonal fluctuations, since greater levels of geothermal heat are required for heating purposes in winter, resulting in the reduction or even cessation of power generation. Nevertheless, geothermal power generation has the potential to make a major contribution to climate protection, reduction of environmental pollution and conservation of resources.[2] Yet while the performance of wind, hydroelectric, biomass and solar plants can be calculated in advance, the process of planning a geothermal plant always entails the risk that exploratory hydrothermal drilling will fail to yield results.

Sophisticated geological exploration techniques can reduce this risk, but it can never be ruled out entirely (Janzing 2004b, 74). The technological challenges of geothermal power generation.

Hot water reservoirs close to the earth's surface are rarely found anywhere in Germany. For this reason, heat from the earth was primarily used to supply warm water in the past.[3] Only a few sites appeared to offer the possibility to use the earth's heat to generate electricity.

However, technologies have been developed by now to harness deep geothermal energy, which appears to hold the potential to generate levels of electricity large enough to impact the energy industry. Great hopes have been vested in geothermal projects for over 15 years now, but they have yet to fulfill expectations and profitably harness deep geothermal energy. Technology to generate electricity using deep geothermal heat is still in the research stages.

Generation of electric power from geothermal sources requires hot water with a minimum temperature of 120°C. Water with lower temperatures can certainly be used, but doing so does not make economic sense. In Germany, the required

[1] The Financial Times estimates the electricity generating potential of geothermal energy worldwide at one billion MWh, which amounts to ten times the world's total energy consumption (Janzing 2004a, 62). There is also great potential in Germany: in theory, the heat reserves deep below the Upper Rhine Valley are sufficient to cover all of Germany's energy needs for over 1,000 years (Janzing 2004b, 72–73).

[2] http://www.izt.de/pdfs/SKEP/SKEP_AP5_Technologiereport.pdf (accessed July 24, 2009).

[3] There are currently some two dozen geothermal plants in Germany with heat outputs ranging from 100 kW to 20 MW. Thermal water generally has a high salt content. Consequently, the water transported from deep within the earth cannot be directly fed into the heating circuit. It is conducted via corrosion-resistant pipes through a heat exchanger, where it releases its energy to the heating circuit. The water is subsequently pumped back into the bedrock via a second borehole.

temperature is generally only to be found from depths of 3,000 m, primarily in the Northern German Basin, the southern German Molasse Basin and the Upper Rhine Valley. In principle, the drilling procedures to tap this deep geothermal heat can build upon technologies used in mineral water, crude oil and natural gas extraction. However, the process of making this heat useable brings with it particular technological demands. Endeavors to tap geothermal heat in Germany are currently focused on hot water reservoirs that have high temperature levels and sufficient flow rates. Furthermore, work has been in progress for almost three decades to tap "dry" rock. This entails pumping water into the rock by means of a two-borehole system in order to create artificial fractures. If this process succeeds, water can be injected into the rock and will subsequently capture its heat, forming a binary cycle. In the relevant literature, this process is known as an enhanced geothermal system (EGS), a hot dry rock system (HDR) or a hot fractured rock system (HFR). In 2009 the Renewable Energy Sources Act introduced a new term: "petrothermal processes".[4]

Deep geothermal power generation systems installed across the world (from depths of 400 m) produce an estimated total output of 8,500–9,000 MW_{el}.[5] The USA leads the way with 2,544 MW_{el}, followed by the Philippines (1,931 MW_{el}) and Mexico (953 MW_{el}). Indonesia (797 MW_{el}) and Italy (791 MW_{el}) also generate a significant share of electricity from geothermal sources (Prognos AG et al. 2007a, 113). In most of these cases, the plants have access to high-temperature water relatively close to the earth's surface. However, geological conditions of this kind cannot be found in Germany. Power generated from geothermal plants in Germany totaled about 400 MWh in 2007.

The development process of geothermal power generation in Germany since 1985 can be divided into two phases (see Fig. 6.1), which will be delineated in Section 6.2.

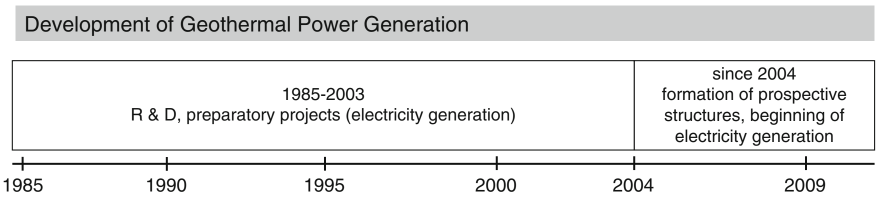


Fig. 6.1 Development phases of geothermal power generation in Germany

[4] The so-called "Deep Geothermal Group" coined this umbrella term. Work is still in process to produce a conclusive definition (see PK query Tiefe Geothermie 2007).

[5] Figures published in the relevant literature vary greatly.

6.2 Phase-specific Analysis of the Innovation Process

The development of geothermal energy dates back far beyond the current period of investigation beginning in the mid-1980s. It has its origins in thermal springs, which people in countries across the globe have used for bathing, washing and cooking for thousands of years.[6] It was not until the turn of the millennium – since the widespread introduction of metal pipes and radiators – that geothermal energy was used for space heating.

The earliest reported case of supplying heat generated by geothermally heated water to residential buildings was in Boise, Idaho (USA) (Kellermann 2005, 36). A geothermal district heating network was constructed there as early as 1892. Individual geothermal wells have supplied heat to houses in Klamath Falls, Oregon, since 1930.[7] France, Romania, Georgia, Russia, China and the USA were home to the first municipal heating systems to use geothermal water.[8]

Geothermal electricity was generated for the first time at the beginning of the last century: the first experiments to produce electricity from geothermal sources were conducted around 1904 in Larderello, Italy. It was here that the world's first geothermal plant went into operation in 1913, generating an output of 220 kW. The turbines were powered using steam (Kellermann 2005, 36). Today, the electricity produced in Larderello and fed into the Italian electricity grid totals 400 MW.

Further plants followed in the 1950s and 1960s in countries such as New Zealand, Mexico, the USA and Japan. The first international conferences to discuss geothermal power generation plants were the UN Conference on New Sources of Energy in Rome in 1961 and the UN Symposium on the Development and Utilization of Geothermal Resources at Pisa in 1970 (Lund 2000).

6.2.1 Use of Geothermal Heat in the Former GDR

In Germany, the former GDR conducted particularly intensive research into the scope for large-scale use of deep geothermal energy (from depths of 400 m). In the 1960s and 1970s largely fruitless exploration for crude oil and natural gas led to the discovery of thermal waters in the GDR (Etscheid 2002). However, these findings did not spark particular interest until the end of the 1970s when it became apparent that lignite coal reserves were limited and a decision was taken to reduce the increasing level of dependency on oil and other imported energy sources following the oil

[6] Hot springs played an integral role in the societies of the ancient Romans, Greeks, Mexicans, Japanese, Turks and the Maoris in New Zealand. In addition to their warmth, they were also ascribed healing powers.

[7] http://www1.eere.energy.gov/geothermal/history.html (accessed July 24, 2009).

[8] www.geothermie.de/egec_geothernet/menu/frameset.htm (accessed July 24, 2009).

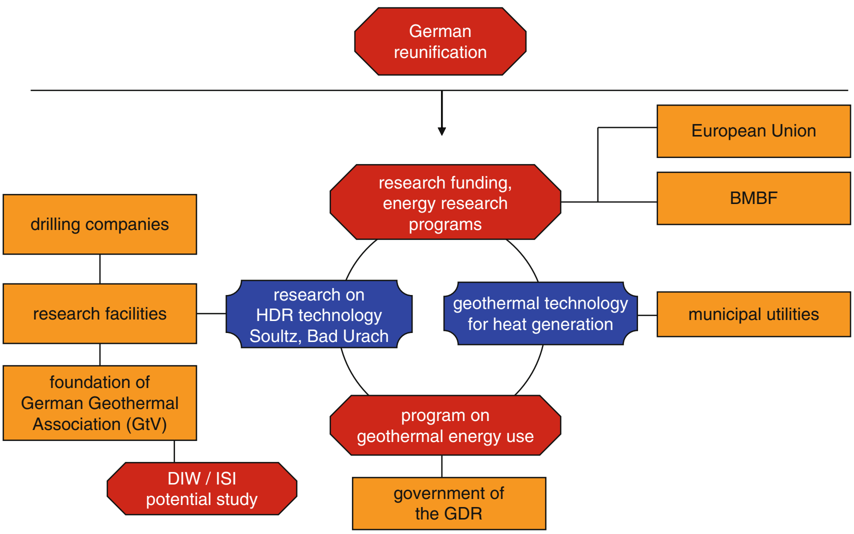
price crisis in 1973 (Kniesz 2006, 5). Avoiding the use of lignite coal also aimed to conserve nature and avoid transportation costs in particular biosphere reserves.

Efforts were focused on performing a comprehensive exploration of the potential of using thermal water for (district) heating. The GDR's geological and energy-saving potential, which was mapped out on a geothermal atlas, appeared to be extremely promising and resulted in the launch of a program to exploit these resources (Kniesz 2006, 6).

6.2.2 *Phase 1: 1985–2003, Research and Development, Preliminary Projects to Generate Electricity*

6.2.2.1 Characteristics of the Constellation

In the phase from 1985 to 2003, geothermal heat was primarily used for heating purposes in Germany. Prior to Germany's reunification, the GDR government had already launched a program to boost the use of geothermal energy, which West German energy supply companies chose not to pursue after the fall of the Wall. Interest in geothermal power generation was also lacking in political circles in reunified Germany. The Federal Research Ministry's support programs provided limited backing to studies conducted by research institutes in cooperation with



BMBF = Federal Ministry of Education and Research
GDR = (former) German Democratic Republic
DIW = German Institute for Economic Research
ISI = Fraunhofer Institute for Systems and Innovation Research

Fig. 6.2 Constellation phase 1: Research and development phase, 1985–2003 (drilling) companies. Activities after 1989 focused on researching, developing and testing the technology for the cogeneration of heat and power on the basis of several pilot plants. The aim was to probe the technology's potential, which was initially viewed with skepticism – at least on the part of government actors in the Federal Republic of Germany. However, many experts – particularly from the field of research – were convinced that technology to generate geothermal power and heat held great potential and demonstrated this commitment by founding the German Geothermal Association. Research focused on petrothermal processes, which entail hydraulic stimulation of fractures in the bedrock. Water is subsequently injected into the substrate, where it captures the heat and is then transported to the earth's surface.

6.2.2.2 Sector-specific Context

During this phase, the development of geothermal energy was spurred on above all by inflated fears concerning resource shortages and in the context of a drive to become less dependent on energy imports. German reunification was significant for the development of geothermal energy, since the GDR, due to its limited energy resources, had conducted comprehensive geological research into the scope for using the earth's heat (Kniesz 2006, 5–6). These studies produced optimistic estimates concerning the potential to use geothermal energy, which resulted in a program aiming to exploit this resource. Activities in this field in reunified Germany built upon these developments at research level yet did very little at the application level.

6.2.2.3 Technology and Market Developments

The relatively low ground temperatures in Germany preclude the use of the conventional steam-powered process to generate power from geothermal sources. This would require temperatures of above 250°C, which unfortunately cannot be found in Germany. Generating power using the low-level temperatures common in Germany necessitates new energy conversion processes, such as the Organic Rankine Cycle process (ORC) or the Kalina process, which employs a similar technology (Schellschmidt et al. 2007; BMU 2007c, 19). Both the ORC process and the Kalina process produce steam at temperatures as low as ca. 90°C, which can then be used to power turbines. These processes also involve depressurization of steam in the turbine, which subsequently drives a generator.

Geothermal projects comprise three basic categories: underground technology, surface technology and project development (Frick and Kaltschmidt 2009, 7 et sqq.). In the area of underground technology, many of the international companies come from the field of crude oil/natural gas extraction. Suppliers operating at the national level tend to come from the field of well sinking. The surface technology utilizes classic power plant components, supplied by established plant construction companies. These companies increasingly endeavor to offer "turnkey" solutions by packaging their products with components from other subcontractors. Some project developers also offer package solutions.

6.2.2.4 Government Policies: Research and Development Promotion

The Federal Republic of Germany made only limited use of thermal waters to supply heat in this phase (e.g. in Aachen, Staffelstein, Baden-Baden, Bad Urach, Bad Füssing, Bruchsal Erding). Thermal waters were often discovered incidentally while drilling for groundwater and probing for oil and gas deposits (Bußmann 1991, 16–17). In the mid-1980s there were very few geothermal projects in operation, and the few that did exist were used to generate heat (primarily in the form of thermal baths) and not electricity. Thus there was still a great lack of knowledge in all technical areas. In comparison to the funds allocated to wind energy and photovoltaics, geothermal energy received very little research funding during this phase. However, the level of research funding was still higher till 1985 compared to the period from 1986 onward, (see Fig. 6.3[9]): in addition to the aforementioned projects, Germany was involved in two research projects in England and in the US state of Tennessee. The change of government in 1982 brought with it radical cutbacks in

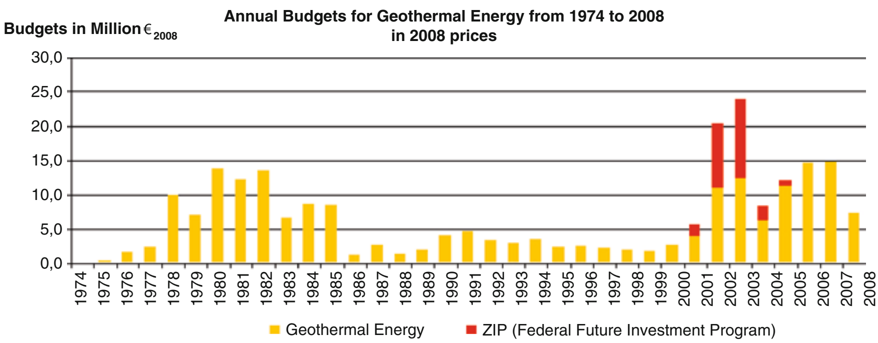


Fig. 6.3 Federal project funding for renewable energy since 1974 (BMU 2009b, 42)

[9] Clarification of Fig. 6.3: tapping geothermal energy only made sense in conjunction with a heating network. However, in the mid-1980s, Helmut Kohl's new government also ceased to provide support for cogeneration of heat and power and district heating networks. Funding for the geothermal project in Bruchsal (which was relaunched in 2008) was discontinued primarily for economic reasons – an American settlement had opted for a gas-powered heat supply system (see Section 6.2.2.4). An insufficient flow of knowledge then also led to Germany's withdrawal from the two projects abroad. This explains the sharp decline in funding in the mid-1980s. After his appointment as head of the division responsible for renewable energy within the Federal Research Ministry in 1985, Eisenbeiß endeavored to at least resume research into HDR technology in Germany. The German–French project in Soultz-sous-Forêts enabled implementation of this goal from 1987. However, in the 1990s geothermal energy was seen to hold little promise in view of the geological conditions in Germany (Eisenbeiß 2009, pers. comm.; see Section 6.2.1.5). This situation did not change until a new government came to power in 1998.

research funding for geothermal projects, with the exception of projects which had a clear chance of yielding returns. However, geothermal energy was viewed as uneconomical in the 1990s (Eisenbeiß 2009, pers. comm.).

Research Projects in West Germany and in the Alsace Region

The research projects launched in the 1970s and 1980s in West Germany investigating the use of petrothermal processes to exploit geothermal heat were continued in the 1990s. Research projects that received attention at the international level include the German–French project in Soultz-sous-Forêts (France), which commenced in 1987, and the German project launched in 1977 in nearby Bad Urach,[10] both of which were designed to test and develop petrothermal technology. The aim was to use the findings from the project in Soultz and to apply this knowledge to the geological conditions in Bad Urach, as the town already had a well and favorable temperatures (Prognos AG et al. 2007b, 55). However, the project in Bad Urach came to a halt in 2004 due to a failure to convince those responsible for allocating funding that continuing the costly endeavor would result in a successful outcome (Dürrschmidt 2007, pers. comm.). Completion of the project would have required a further four million euros. In addition, support was given to other, smaller research projects, such as a project in Falkenberg (Bavaria), which involved construction of an HDR system at a depth of just 250 m.[11] The project's primary aim was to test fissure-opening processes.

Among other issues, research focused on – and continues to focus on – the diverse technical challenges, such as corrosion and incrustation problems caused by the high salt content of the water extracted, re-injecting the used water and avoiding gas release. Research and development is particularly needed with regard to exploration methods, simulation methods and drilling technology.

These activities were primarily financed with research funding from the Fourth Energy Research Program (which ran from 1996 to 2005) and from the proceeds of the sale of UMTS licenses (Federal Future Investment Program)[12] (Prognos AG et al. 2007b, 23). The Federal Government allocated approximately 184 million euros to geothermal research in the period between 1974 and 2004. The projects in Bad Urach and Soultz received a large proportion of this funding (31 million €) (see Fig. 6.3).

[10] The Federal Research Ministry and later the Federal Ministry for the Environment supported the project in Bad Urach.

[11] Under the direction of the Federal Institute for Geosciences and Natural Resources, the HDR project in Falkenberg (1978–1986) conducted basic studies on hydraulic stimulation in crystalline rock.

[12] Cf. *Geothermische Energie* (2002, 7). The Federal Future Investment Program was a federal economic stimulus package to improve economic stability and employment. It was financed by the sale of UMTS licenses.

6.2.2.5 Lack of Political Support in the 1990s

During the 1990s in particular, geothermal energy received little political support. Representatives of research funding saw minimal potential in the technology (Dürrschmidt 2007, pers. comm.; Sanner 2008, pers. comm.). The relevant decision-makers in the Federal Ministry of Economics did not endorse promotion of this technology. Furthermore, the key department heads in the Federal Ministry of Economics were in favor of using fossil and nuclear energy and saw no reason to increase funding for geothermal energy. At the end of the 1990s the Federal Government wanted to discontinue funding for geothermal energy. However, when the red–green coalition came to power in 1998, this situation changed. Federal spending on research into geothermal energy rose significantly after the change of government (see Fig. 6.3). The figure shows a rapid decline in research funding in 1986 and again in 2004. The decline in 1986 can be attributed to the Federal Research Ministry's loss of interest in geothermal energy after the change of government. The 2004 decline can be explained by the transition of responsibility for allocating research funding from the Federal Ministry of Economics to the Federal Ministry for the Environment: the Federal Ministry of Economics no longer wanted to grant research funding and the Federal Ministry for the Environment was not yet in a position to do so.

The Electricity Feed-in Act Fails to Include Compensation Regulations for Electricity Generated from Geothermal Sources

The main impetus behind the Electricity Feed-in Act, which was adopted in 1990, came from representatives of hydroelectric power as well as pioneers of wind power. Biomass energy was also able to benefit from this initiative. The geothermal energy lobby, on the other hand, was only just emerging at this time. The law thus contained no compensation regulations for electricity generated from geothermal sources. The 1994 amended version of the Electricity Feed-in Act also failed to include feed-in compensation for geothermally generated power, stating that, as there were no plants powered by geothermal electricity, there was no need for electricity feed-in payments (Bußmann 2007, pers. comm.).

Developments in East Germany

Authorities in the GDR planned to use thermal water in district heating systems. The first geothermal heating station was commissioned in 1984 in Waren an der Müritz. 1984 saw the foundation of the Volkseigene Betrieb (VEB) Geothermie Neubrandenburg, a people-owned enterprise that aimed to promote geothermal energy and ultimately employed 800 people. The success of the station led the GDR government to implement its "strategy enabling the utilization of geothermal resources to the benefit of the national economy". By the end of the 1980s, a total of three projects (Waren, Neubrandenburg and Prenzlau) had been realized, generating a combined output of 22 MW_{th}, which was used to heat apartments. Expansion schemes up to the year 2000 planned to construct heating stations in the Northern German Basin with a total output of 262 MW_{th} and feed geothermal electricity amounting to approximately 150 MW_{el} into the grid. The VEB Geothermie in Neubrandenburg had a whole series of projects in the pipeline[13] (see Kniesz 2006, 6; Bußmann 1991, 4). Shortly before the end of the GDR, these plans appeared to indicate that it was within the realms of possibility for geothermal energy to supply heat to North-East Germany in the medium term.

However, these visions were largely abandoned after reunification in 1990. Possibilities for follow-up projects were disregarded. Proposals for some 30 geothermal sites were shelved and the wells were sealed. As a result of the powerful influence of West German energy providers, municipalities in East German states were connected to the natural gas network within just a few years. The newly installed gas pipeline network initially killed any incentive to investigate alternative heat supply concepts.

There were initial problems accessing the findings of geothermal studies conducted across Germany after reunification, which further aggravated the situation concerning use of geothermal resources. The GDR's Central Geological Institute (ZGI) in Berlin and the Central Institute for Physics of the Earth (ZIPE) in Potsdam had been transformed into private enterprises. The privatization of large sections of material documenting the studies initially created obstacles to conducting research in this area. The findings are, however, freely available today.[14]

Within the space of just a few years, the energy supply system in the East German states had undergone extensive modernization, which was primarily geared toward the use of fossil and nuclear resources (natural gas, oil, coal, nuclear energy). Energy providers had no interest in utilizing heat or electricity generated from geothermal sources. Only a very small minority of independent public utilities, such as Stadtwerke Neubrandenburg, continued to use geothermal energy (Bußmann 2007, pers. comm.).

Harnessing Geothermal Energy in Neustadt-Glewe

The geothermal project in Neustadt-Glewe, which continued after the demise of the GDR, was an exception to this trend. In 1984 plans were initiated here for a geothermal heating station, which was later to be used to generate geothermal power (see Menzel 2003). The initial aim was to supply heat to a leather factory (a leather "combine", or state holding company) and a residential area. Drilling was undertaken in 1988 and 1989, resulting in the creation of the first wells. After reunification,

[13] The most significant projects were: Neustadt-Glewe, Neuruppin, Pritzwalk, Stralsund, Schwerin, Velten, Rostock, Pasewalk, Ludwigslust, Neustrelitz, Nauen, Hohennauen.

[14] The Geothermie Neubrandenburg GmbH can provide access to all documentation.

the project initially came to a halt, since the closure of the leather factory, which had operated using outdated production methods, meant that the energy's main consumer disappeared. However, a part of the factory was transformed into a company[15] after the GDR came to an end. 1992 saw the foundation of the company Erdwärme Neustadt-Glewe GmbH, whose purpose was to continue the geothermal energy project.[16] The Federal Research Ministry, the state of Mecklenburg-Western Pomerania and Hamburg electric utilities (Hamburger Elektrizitätswerke) funded the project. The heating station went into operation in 1994 and supplied heat to the leather factory in the former state combine. The project in Neustadt-Glewe also managed to achieve the goal of generating power: since the end of 2003 the plant has also converted geothermal heat into electricity. It was the first plant of its kind in Germany, albeit a very small one. The 200 kW plant only generates electricity in summer, as the heat is required for heating purposes in winter (Jung 2007, 5; Leuschner n.d.).

Before the end of the GDR, Neuruppin in Brandenburg had planned to construct a geothermal heating plant. In the 1990s the Minister for Economic Affairs, Walter Hirche, endorsed geothermal energy in Brandenburg.[17] But while work proceeded on the geothermal energy project in Neustadt-Glewe, plans were shelved in Neuruppin for many years. The project was not resumed until 2007.

6.2.2.6 Experiences in France, Austria and Italy

In addition to the European research project in the Alsatian town of Soultz-sous-Forêts, construction of geothermal plants took place in Austria and Italy. These projects also impacted research and development in the area of geothermal power generation in Germany. Both research and implementation projects frequently involve an international network of actors, as the following example aims to illustrate.

The municipality of Altheim in Austria had constructed a district heating network, which it planned to expand at the end of the 1990s in response to requests from residents who did not have access to the network. The authorities were of the opinion that this required a second well. In its search for a solution the municipality of Altheim contacted the German Geothermal Association and a planning office in Bavaria. This led to the proposal to combine heat and power generation, as the necessary turbines (ORC turbines) had been developed in Italy and were available for use. Interest in developing ORC technology enabled the project to gain support from EU funding.

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[15] Today's NordLeder GmbH is part of the Möllergroup.

[16] The company's shareholders are the town of Neustadt-Glewe (47%), WEMAG AG Schwerin (45%) and GTN Geothermie Neubrandenburg GmbH (8%). In GDR times VEB Geothermie Neubrandenburg operated the plant.

[17] Karl Walter Hirche was Minister for Economics, SMEs and Technology from 1990 to 1994 in the state of Brandenburg.

6.2.2.7 Actors in the Constellation

Market Actors

Companies operating in the geothermal sector were, and still are, predominantly small businesses with fewer than 50 employees. The configuration of actors in this phase was fairly heterogeneous and there was no competition yet in the traditional sense of the term, since the sector's level of development is still in the "pioneering stage" (Prognos AG et al. 2007b, 74; Hagedorn & Menzel 2003).

Investors were generally major energy suppliers or their subsidiaries. Subsidiaries of the energy company Vattenfall, for example, provided a substantial share of the funding for the Neustadt-Glewe plant; EnBW (Energie Baden-Württemberg) invested in the project in Bruchsal.

In spite of the base load capacity of power generated from geothermal sources, energy suppliers appeared to have relatively little interest in this technology. While suppliers have made moves to demonstrate a willingness to invest by participating in several geothermal projects, at the same time they frequently pointed out how little realizable potential the technology holds. Major energy suppliers are accustomed to plant outputs of at least 100 MW_{el}, whereas geothermal plants under construction in Germany have an output of between 3 and 5 MW_{el}.

Emergence of the First Networks of Geothermal Experts

In 1988 geothermal energy representatives from the GDR (VEB Geothermie Neubrandenburg) were present at the Hanover Messe[18] for the first time. 1989 and 1990 were the first years in which representatives from the fields of deep geothermics, shallow geothermics and hot dry rock systems (HDR) and specialists from East and West Germany established contact. The Protestant Academy Bad Boll hosted in November 1989 an international symposium on geothermal energy, which was a key step in the exchange of knowledge between specialists in this field (Bußmann 2007, pers. comm.).

The German Geothermal Association (Geothermische Vereinigung e.V. – GtV) was founded in Bonn in 1991 as a scientific and technical organization for the promotion of geothermal energy[19]. The association is primarily a scientific and technical organization that aims to promote the exploration, extraction and utilization of heat from the earth, to bring together experts active in this field and to provide the public with information.

The German Research Centre for Geosciences in Potsdam was founded in January 1992. Its predecessor was the GDR's Central Institute for Physics of the Earth.[20] Federal Minister for Research, Paul Krüger, supported research into

[18] An annual trade fair and showcase for industrial technology that takes place in Hanover.

[19] The association was initially called the Geothermische Vereinigung e.V. (GtV) but was later renamed the Geothermal Association – Federal Association of Geothermal Energy (Geothermische Vereinigung – Bundesverband Geothermie e. V. – GtV-BV) (see Section 6.2.2.6).

[20] See http://www.gfz-potsdam.de/portal/ (accessed July 24, 2009).

geothermal energy during his time in office (1993–1994). He came from the area of Neubrandenburg and could also relate to geothermal energy on a practical level: his apartment was geothermally heated (see Bußmann 2007, pers. comm.).

The Institute for Geoscientific Community Tasks (Institut für Geowissenschaftliche Gemeinschaftsaufgaben – GGA), part of the Federal Institute for Geosciences and Natural Resources in Hanover, was founded in 2000. It conducts scientific research to assist in the selection of suitable geothermal sites.

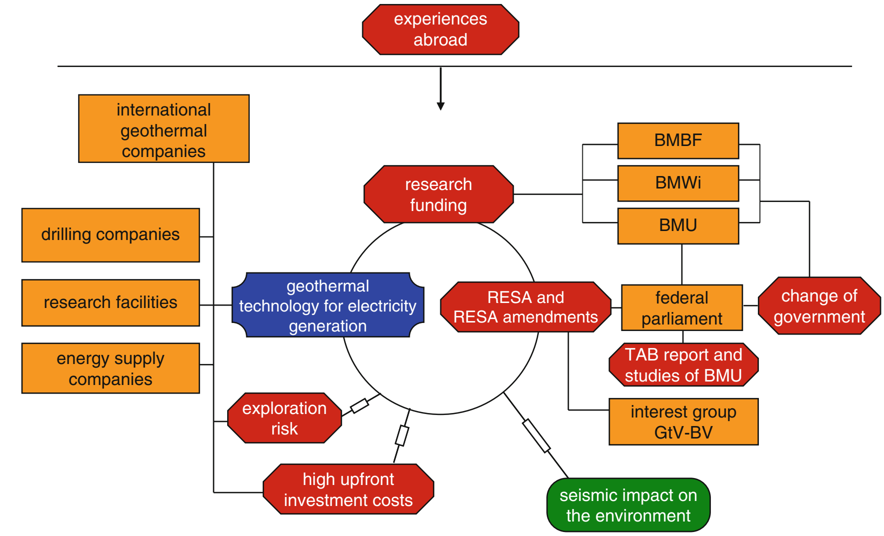
6.2.2.8 Interpretation of the Constellation: Driving Forces and Constraints

Research funding from the Ministry of Research was fundamental to the development of the geothermal sector in this phase. However, the level of funding allocated was relatively low and the Electricity Feed-in Act did not account for geothermal energy. Consequently, it would be incorrect to talk of a powerful "driving force" emanating from governance. The fact that government actors in the FRG saw little potential in geothermal energy also obstructed development. The GDR government's geothermal energy use program played an important role in the sector's development, but was discontinued after the demise of the GDR due to West German energy suppliers' insufficient level of interest. However, in a similar way to the first studies conducted to gauge the technology's potential, the program identified the enormous capacity of the earth's heat to supply energy and thus had a stimulating effect, particularly on the field of research.

6.2.3 Phase 2: Formation of Prospective Structures from 2004

6.2.3.1 Characteristics of the Constellation

From 2004 the geothermal energy sector experienced a phase of development that was marked by a significant increase in political interest in the technology, which many now viewed as holding great potential to supply energy. The constellation was assuming a progressive structure (see Fig. 6.4). The phase began with an increase in the statutory compensation rate for electricity generated from geothermal sources in the EEG in 2004, which came about primarily as a result of the new governing coalition (after 1998), but also thanks to the engagement of the Ministry for the Environment. The German Geothermal Association (GtV-BV) also worked extremely hard to achieve a fixed compensation rate. Furthermore, this phase saw a significant increase in federal research funding for geothermal energy. From 2004 onward, research institutions, companies working in the geothermal sector, and energy suppliers began to implement the first geothermal electricity generation projects. However, as a result of the great number of exploration risks and the high investment costs incurred by deep geothermal drilling,



BMBF = Federal Ministry of Education and Research
BMU = Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BMWi = Federal Ministry of Economics and Technology
GtV-BV = German Geothermal Association – Federal Association
RESA = Renewable Energy Sources Act (EEG)
TAB = Office of Technology Assessment at the German Parliament

Fig. 6.4 Constellation phase 2: Formation of prospective structures from 2004

it was not yet possible to develop a market for the technology in Germany. Geothermal power generation was still in the research stages. A report by the Office of Technology Assessment at the German Bundestag (TAB) (Paschen et al. 2003) clearly demonstrated the great potential for generating energy from geothermal sources.

6.2.3.2 Sector-specific Context

The decision to incorporate electricity generated from geothermal sources into the EEG was taken in the international and social context described in Chapter 3, which enabled renewable energies to assume a new and key role. Electricity generated from geothermal sources has a particular role to play in the context of expanding renewable energies as it is capable of supplying base load: it does not fluctuate according to weather conditions or depending on the time of day. Experience gathered during geothermal projects abroad, stimulated developments in Germany.

6.2.3.3 Governmental Guidance and Economic Context

A look at the early phase of renewable energy promotion in West Germany reveals a rather neglectful attitude toward geothermal energy. At the end of the 1990s the

Federal Government wanted to cease promotion of geothermal energy (Bußmann 2007, pers. comm.). However, this changed when the red–green coalition came to power in 1998. Since then, great hopes have been vested in technologies designed to harness geothermal energy, which is viewed as holding considerable potential for Germany's energy supply. According to a study conducted in 2003 by the TAB, temperatures at a depth of 7 km are sufficient to meet more than 600 times Germany's annual electricity requirements (Paschen et al. 2003).

Research and Development Promotion

Since 2005 the German Federal Government's Fifth Energy Research Program has provided the framework for the promotion of research into renewable energies at the federal level. Promotional schemes comprise project-related (run by the Federal Ministry of Economics, or the Federal Ministry for the Environment) and institutional promotion (run by the Federal Ministry of Research). The Federal Ministry for the Environment is responsible for the area of deep geothermal energy, while the Federal Ministry of Economics is in charge of shallow geothermal energy (BMU 2007a, 31). In 2006 the Federal Ministry for the Environment allocated 14 million euros to geothermal energy research projects, which amounts to ca. 18% of total funding for research in the area of renewable energies. The funding volume for newly approved projects in 2006 amounted to 23.7 million euros (BMU 2007a, 33).[21]

In the area of deep geothermal energy, the Federal Ministry for the Environment supported the following power plant projects: Bad Urach (14 million €, decommissioned), Unterhaching (6 million €),[22] Landau (2.1 million €), Groß Schönebeck (14 million €) and Soultz-sous-Forêts (6.4 million € for the current project phase) (BMU 2007a, 35–36). In addition to these large-scale projects, the Federal Ministry for the Environment also promotes the development of technology[23] and the creation of a geothermal information system at the Institute for Geoscientific Community Tasks (GGA Institut Hannover)[24], which aims to improve the success rate of deep drilling probes for geothermal heat (2.3 million €).

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[21] However, according to information provided by the Federal Ministry for the Environment, it will not be possible in future to sustain this huge increase in allocated funding (see BMU 2007a, 33).

[22] 4.8 million euros came from the Federal Environment Ministry's Environmental Demonstration Program. Furthermore, research funding amounting to 1.2 million euros will enable Geothermie Neubrandenburg GmbH and GGA Hannover to provide geoscientific support.

[23] The Federal Ministry for the Environment provided funding amounting to 1.6 million euros to support the development of the new deep drilling rig Herrenknecht Vertical Terra Invader 350 (Binder & Ruder 2008, 9). The Ministry has also allocated 4.7 million euros to the development of a feed pump by the company Flowserve, which is designed to meet the special requirements of geothermal energy. The Ministry has granted 163,000 € to a research project conducted by the TU Hamburg to optimize plant technology (see BMU 2007a, 34–35).

[24] The GGA was renamed the Leibniz Institute for Applied Geophysics (LIAG) in 2008.

The Federal Ministry for the Environment's program to promote demonstration projects was also significant for geothermal power generation plants. These projects are obliged to implement new technologies or reconfigure existing technologies from a process engineering perspective. The program supports the project in Unterhaching. The Federal Ministry of Research provides institutional support from the Federal Government. It supports research institutions such as the Helmholtz Association of German Research Centres (HGF), which also comprises the German Research Centre for Geosciences in Potsdam (BMWA 2005, 62).

Inclusion of Geothermal Energy in the EEG

The engagement of individual delegates (Hermann Scheer and Hans-Josef Fell, among others) and employees at the Federal Ministry for the Environment played a particular role in securing the inclusion of a provision concerning compensation for geothermally generated electricity in the EEG – albeit at feed-in rates that were lower than those for electricity generated from biomass. However, it was only after the introduction of the amended version of the EEG in 2004,[25] which significantly expanded the scope of remuneration regulations and increased compensation rates for electricity generated from geothermal sources ("Tiefengeothermie," Article 9 EEG 2004), that the current developments were set in motion (Sanner 2008, pers. comm.). The EEG 2004 introduced a new compensation category for installed electrical capacity up to and including 5 MW_{el} (see Table 6.1).

The EEG 2009 once again significantly increased the compensation rates, reduced the output categories to two (up to and including or over 10 MW_{el}) and introduced two additional bonuses for technology and heat use (see Table 6.1). The

Table 6.1 EEG 2004/2009 compensation rates for geothermal energy

Electrical output	Compensation EEG 2004 (cent/kWh)	Compensation EEG 2009 (cent/kWh)[a]
Up to and including 5 MW	15	–
Up to and including 10 MW	14	20 (16)
Up to and including 20 MW	8.95	–
Over 20 MW	7.16	–
Over 10 MW		14.5 (10.5)
Heat use bonus	–	3
Technology bonus for petrothermal technology	–	4
Degression	1% a year from 2010	1% a year from 2010

[a]Prices in brackets are from 1 January 2016

[25] The sources for the legal information used in this chapter are given in the Index of Legal Sources.

heat use bonus amounting to 3 cent/kWh$_{el}$ is designed to encourage plants to also feed geothermal heat into local heating networks. It aims to enable production of geothermal electricity at sites that do not yet have a heating network. The technology bonus will benefit petrothermal plants insofar as electricity generated from geothermal energy in petrothermal plants commissioned prior to 2015 will receive a compensation of between 24 and 27 cent/kWh. This is almost double the compensation in the EEG 2004. An annual 1% degression of compensation rates from 1 January 2010 will apply to all plants commissioned after this date.

Since 2008, in addition to the EEG, the Federal Ministry for the Environment's market incentive program has also supported the construction of geothermal plants to generate electricity. This support comes in the form of a guarantee fund (from the KfW[26] in cooperation with the insurance industry) for exploration risks, which can cover up to 80% of the costs for unsuccessful drilling projects. Furthermore, up to 1.5 million euros have been allocated to unplanned cost overruns during drilling and up to 1.5 million euros toward the construction of heating networks. Geothermal electricity generating plants can also receive support in the form of low-interest loans with repayment grants.[27]

6.2.3.4 Technology and Market Developments

Commercial Viability and Economic Framework Conditions

It is currently virtually impossible to provide concrete figures concerning the economic viability of geothermal power generation projects under realization or development, as project operators have not published the relevant data. In principle, the basic compensation of between 16 and 27 cent/kWh, as stipulated in the new EEG in 2009, aims to enable the economically viable operation of geothermal plants from temperatures of 120°C. However, this makes geothermal energy the second most expensive source of regenerative energy after electricity generated from solar power. Nonetheless, the technology is in the early stages of development and application, and thus still possesses potential for further development. Exploiting this potential should reduce its costs.[28]

The ability to achieve a high number of full load hours and a high water flow rate, the geological conditions at the site and the resulting ability to feed in a large amount of electricity are deciding factors that have an impact on the economic viability of geothermal power generation. In order to ensure economic viability, a plant must also have efficient and reliable technologies that require as little electricity as possible to

[26] The Kreditanstalt für Wiederaufbau (KfW) is a government-owned development bank.

[27] When exploration proves unsuccessful, the investor is released from the obligation to repay the remainder of the loan from that point in time. The exploration risk of the respective deep geothermal project – and thus its eligibility for financing – is established prior to granting the loan. In addition to the standard loan interest, the promotional loans include a "risk premium" to cover the exploration risk. In return, the investor receives an expert review and supervision of their deep geothermal project prior to and during the drilling phase.

[28] http://www.izt.de/pdfs/SKEP/SKEP_AP5_Technologiereport.pdf (accessed July 24, 2009).

pump and re-cool the water before re-injecting it into the bedrock. Plants that also use low-temperature heat for heating purposes are particularly efficient.[29]

The initially high cost burden incurred by drilling at depths of several thousand meters is the greatest obstacle to tapping geothermal energy. Furthermore, the availability and price of drilling equipment is closely connected to international demand in the oil and gas sector, where high prices quickly have an impact on drilling costs. In addition to the already high drilling costs, the significant rise in steel prices has resulted in further cost increases. Furthermore, in the worst case scenario, drilling may not hit upon suitable conditions and thus be to no avail.[30] The area of geothermal energy lacks a capital base to absorb the drilling risk (unlike the oil sector, for example) (Janzing 2004a, 60). Drilling costs and risks represent a significant obstacle to future site development. Awareness of these issues resulted in the market incentive program's safeguards against exploration risks and the significant increase of the compensation rates in the EEG 2009. Insurance is also available to cover exploration risks, but only if the likelihood of success is above 80%. Due to the lack of experience with this type of coverage, the premiums for it also vary greatly and can amount to up to 25% of the insurance costs (Janzing 2009, 41).

Drilling accounts for a significant share of the overall costs. Geothermal energy plants require two boreholes (doublet) to create a water cycle. Depending on the depth, this currently costs between four and eight million euros, which amounts to between 1,000 and 2,000 € per meter of borehole. If it transpires that the necessary geothermal heat potential is available, large amounts of special steel are still required for a second borehole and the overground piping. The investment costs for constructing a geothermal plant without a heating network total between 25 and 50 million euros; drilling, drilling services and steel account for 50–60% of this cost (Staiß et al. 2007, 169–170). If no heating network is available and the project requires construction of such a network, investment costs rise significantly, irrespective of the length of the planned pipeline.

Using a borehole that already exists as a result of exploration for natural gas, oil or coal offers a small amount of scope to reduce costs. To date, only the project in Groß Schönebeck has put this method into practice (Staiß 2007, 153; Huenges 2004).

The cost of drilling and piping, which account for approximately half of the total cost of geothermal plants, rose by approximately 30% within a very short period of time as a result of high demand for drilling equipment for the exploration of crude oil and natural gas fields and the coupling of drill prices to crude oil and natural gas prices, as well as high global market prices for steel (BMU 2007d).

[29] Geothermal plants cool and re-inject the brine pumped up to the surface during the power generation process. There is, therefore, no need to create a separate disposal infrastructure. Brine is re-injected in order to prevent depletion of the water supply. It is possible to pump all substances back into the bedrock without causing any environmental damage or related costs (Fromme 2005, 186).

[30] Supported by funding from the Federal Ministry for the Environment, the GGA-Institut Hannover is currently constructing a digital, Internet-based 'geothermal information system' which aims to reduce exploration risks (Jung 2007, 5).

Further cost increases are anticipated, resulting in a situation where cost and a lack of drilling personnel represent a major obstacle to developing geothermal energy.

Water temperatures of between 120°C and 150°C produce a gross plant efficiency of 10–11%. Deducting the plant's own power consumption from this results in a net efficiency of 5–7%. For this reason, cogeneration of heat and power has a significant impact on economic viability: all plants realized to date have thus generated both heat and power.

Securing funding is one of the greatest obstacles before a geothermal energy project can even begin. The unique structure of projects makes it difficult for banks or venture capitalists to assess the situation, as the classic instrument of risk calculation – high risk combined with high rates of return – cannot be used to evaluate the exploration risk. If exploration fails to yield results, the entire investment must be written off. As a result, funding for projects realized to date or currently under construction has primarily come from the municipality concerned and been co-financed using research funds; investors have largely been municipal utilities, municipalities and private investors.

The area of geothermal energy also lacks a capital base to absorb the drilling risk (unlike the oil sector, for example). Consequently, potential investors in geothermal power have not only been deterred by the issue of economic viability, but above all by the risk that exploratory drilling for underground hot water may fail to yield results. Sophisticated geological exploration techniques can reduce this risk, but it can never be entirely ruled out (Janzing 2004b, 74).

Geothermal Power Generation Projects

With regard to electricity generation, the national geothermal energy market is still in its pioneering phase. The first German project to generate electricity from low-temperature geothermal heat went into operation in Neustadt-Glewe in 2004, generating an output of 230 kW_{el}. However, due to its low output, it should be viewed more as a pilot application of the technology. A pilot project in Bad Urach was terminated in 2004 because the operators could no longer guarantee its continued success[31] (see Section 6.2.1.4). Aside from the project in Neustadt-Glewe, the first commercial geothermal power plant did not go into operation until 2007 in Landau. Thus it has proved impossible so far to construct stable actor and market structures. The projects to date have all been individual projects with heterogeneous structures. The majority of operators have been energy supply companies.

Germany's First Geothermal Power Plant in Neustadt-Glewe

The project in Neustadt-Glewe aimed to expand the plant's function as a heating station and utilize surplus heat during the summer months to generate electricity.

[31] The unfinished borehole was sealed and the drilling tower dismantled (Janzing 2004b, 73). Research is underway to establish whether exploration in Bad Urach can be resumed with the participation of EnBW (Energie Baden-Württemberg AG) and the municipality of Bad Urach.

To this end, the company Erdwärme Kraft GbR[32] was founded at the end of 2002. A short time later in 2003 the first German geothermal electricity generating plant (210 kW) went into operation in Neustadt-Glewe (Kellermann 2005, 36–37). Thus, since the end of 2003, geothermal energy has supplied a limited amount of electricity in Germany. It generated 0.2 GWh in 2005,[33] about 0.4 GWh in 2007 and as much as 18 GWh in 2008 (BMU 2009a).

Commissioning of the geothermal energy plant in Neustadt-Glewe was only possible as a result of considerable funding from the Federal Government's Energy Research Program (the Federal Ministry for the Environment provided almost 50% of the funding for the plant), particularly as the water temperature at the site is only 98°C. Further government investment in research is required to boost the plant's efficiency. The German Research Centre for Geosciences in Potsdam is conducting accompanying research to support the project.

Landau Geothermal Plant

In comparison to Neustadt-Glewe, the second German geothermal power plant in Landau (Upper Rhine Plain, Rhineland-Palatinate) has an extremely high output. This 3 MW_{el}-plant, which was commissioned (with the participation of the company Siemens) in November 2007, is the first fully commercial geothermal power generation plant. The plant is reported to supply in the region of 22 GWh of electricity annually. An ORC turbine generates electricity using brine at temperatures of 155°C. The residual heat extracted in the process is reported to amount to approximately nine million kWh_{th}. Research funding for the project from the Federal Ministry for the Environment totaled some 2.6 million euros (BMU 2007b, 3). In addition, the state of Rhineland-Palatinate advanced a repayable exploration grant totaling 450,000 euros, which ultimately did not need to be activated, and a state guarantee to assume a share of the geological exploration and investment risk to the amount of 7.6 million euros. Geox GmbH, a subsidiary of the energy supply companies Pfalzwerke AG and EnergieSüdwest AG, which each hold a 50% stake, operates the plant.[34]

Unterhaching Geothermal Power Plant

The geothermal project in Unterhaching near Munich, which commenced in 2004, involved the drilling of a thermal borehole at a depth of approximately 3,500 m in the southern German Molasse Basin. Thermal water at temperatures of 130°C is delivered

[32] Erdwärme Kraft GbR's shareholders are Vattenfall Europe Berlin AG und Co. KG (94.26%) and WEMAG AG Schwerin (5.74%). See http://www.erdwaerme-kraft.de (accessed July 24, 2009).

[33] The amount of heat generated (primarily using heat pumps) totals 1,586 GWh.

[34] http://www.geox-gmbh.de/de/Aktuelle_Meldungen.asp?Id=259 (accessed July 24, 2009). The municipality of Insheim is situated next to Landau and it will probably become the site of the third plant in the Upper Rhine region. Drilling of two boreholes is already complete. Another project is in the pipeline in the municipality of Rülzheim, also located in the Palatinate.

to the surface where it is firstly fed into the district heating network. The power plant, which went into trial operation in 2008, has an electrical output of 3.4 MW_{el} and, following a long testing and optimization phase, has been in continuous service since February 2009, generating an initial output of 2 MW_{el}. Installation of more powerful pumps over the course of 2009 aimed to allow the plant to work at full capacity. The plant is the first in Germany to use a Kalina system constructed by Siemens. The project operates on a heat-demand basis, which means that the geothermal heat is primarily used in the existing district heating network, with electricity generation adjusting to the heat requirements at minute intervals. Heat output currently amounts to 28 MW_{th} and is to be increased to 40 MW_{th}. The Federal Ministry for the Environment allocated research funding to the project amounting to 7 million euros.[35] Including investment in a comprehensive heating network, the project is reported to have cost a total of ca. 73 million euros. Geothermie Unterhaching GmbH & Co KG – owned entirely by the municipality of Unterhaching – operates the plant.

Bruchsal Geothermal Power Plant

Another plant is set to be commissioned in 2009 in Bruchsal. The projected electrical output is 0.5 MW with an additional heat output of 4 MW_{th}. The Bruchsal project was launched in 1983 with total investment amounting to around 17 million euros within the scope of a joint project involving the EU, the Federal Government, the state of Baden-Württemberg and Energie- und Wasserversorgung Bruchsal (municipal utility company). The two boreholes (doublet system) were drilled in 1983 and 1984/85 and tap a hydrothermal spring (an aquifer) with an approximate temperature of 130°C at depths of 1,900 and 2,500 m. The project was shelved in 1987 for economic reasons. Funding from the EEG enabled resumption of the project in 2001 and reactivation of the two boreholes. A test run at the end of 2005 established a flow rate of 24 l/s. The Federal Environment Ministry subsidizes the project to the amount of 1.3 million euros. Similar to the Unterhaching project, the Bruchsal plant uses a Kalina system to generate electricity.[36] Energie- und Wasserversorgung Bruchsal GmbH constructed and now operate the facility.

Further Plans for Geothermal Power Generation Projects

A total of some 150 geothermal projects are currently in the preliminary stages in Germany (BMU 2007b, 3). There are plans to construct geothermal power generation plants in several places in southern Germany (such as Bad Urach, Karlsruhe, Speyer – see Table 6.2). A number of sites are also under development in the Northern German Basin: plans are underway to open a plant on the basis of an existing research project in Groß Schönebeck to the north-west of Berlin. Vattenfall is planning to operate the plant in Groß Schönebeck. Plans are also under development to open

[35] http://www.geothermieprojekte.de/projektbeispiel-unterhaching-1 (accessed July 24, 2009).

[36] http://www.ie-leipzig.de/Geothermie/Portal/Projekte/Bruchsal.pdf (accessed September 17, 2009).

Table 6.2 Geothermal power generation in Germany (or projects with German participation)

	Technical details	Specifics
Bad Urach, Baden-Württemberg, Southern German Molasse Basin	Commissioned: 1977 Terminated in 2004 as a result of technical and administrative difficulties	Research and development of petrothermal technology
Soultz-sous-Forêts, France, Upper Rhine Plain, German–French research project	Commissioned: 2008 (drilling commenced in 1987) Depth of well: 5,000 m Temperature: ca. 200°C Output: 2.1 MW_{el}	EGS pilot plant
Neustadt-Glewe, Western Pomerania, Northern German Basin	Commissioned: 2003 Depth of well: 2,300 m Temperature: world's lowest temperature of 98°C Output: 230 kW_{el} and 5.5 MW_{th}	ORC plant of pilot nature;[a] only generates electricity in summer, as geothermal heat is required for heating purposes in winter
Landau, Rhineland-Palatinate, Upper Rhine Plain	Commissioned: 2007 Depth of well: 3,000 m Temperature: 155°C Output: 3 MW_{el} and 5 MW_{th}	First fully commercial geothermal power generation plant; ORC system; state guarantee to assume a share of the investment risk
Unterhaching, Bavaria, southern German Molasse Basin	Commissioned: 2004 (thermal) Depth of well: ca. 3,400 m Temperature: 122°C Output: 3.4 MW_{el} and 38 MW_{th}	First Kalina system; in trial operation since 2008
Bruchsal, Baden-Württemberg, Upper Rhine Plain	Commissioned: scheduled for 2009 Depth of well: 1,900 and 2,500 m Temperature: ca. 130°C Projected output: 0.5 MW_{el} and 4 MW_{th}	Kalina system; drilling commenced in 1983; discontinued in 1987; resumed in 2002

[a]The plant in Neustadt-Glewe proved for the first time that it was possible to generate electricity from geothermal sources in Germany, which played a very significant role in the political debate surrounding compensation payments during the process of amending the EEG in 2004

a power plant with an output of max. 25 MW_{el} consisting of several units in Eberswalde to the north-east of Berlin. The plant plans to extract geothermal heat from depths of 5,000 m.

Influence of the International Market

The world market plays a major role in developments in the area of geothermal energy. In addition to companies from Australia and America, Icelandic enterprises have been particularly active on key global geothermal energy markets in the past few years. Networks with ample capital consisting of Icelandic drilling companies, planners, energy suppliers, government organizations and banks were also active in Germany. It remains to be seen whether this will continue in view of the financial crisis.

6.2.3.5 Environmental Impact, Risks and Acceptance

The environmental impact of geothermal power generation resulting from construction and operation of plants, possible incidents or follow-up maintenance currently appears to be minimal (Krewitt et al. 2005, 37). In terms of possible environmental effects and primary energy consumption, geothermal energy comes off just as favorably as other regenerative power generation methods. With regard to CO_2 emissions it performs considerably better than power generated from natural gas (factor 5) or bituminous coal (factor 10). Utilizing the heat produced as a by-product of electricity generation enables an even more efficient structuring of the already outstanding environmental attributes of geothermal power generation.[37]

Drilling through the aquifer is only believed to entail very slight risks. Cooling the bedrock also has only a minimal effect on the chemical composition of the aquifer. Impact on flora and fauna is limited to the immediate vicinity of the plant and is also low, not least as a result of the low space requirements (Krewitt et al. 2005, 37). On the other hand, there has been an overall increase in the number of wells (shallow and deep geothermal) and individual problems have emerged. Although problems have primarily arisen in the case of shallow geothermal projects,[38] the water management sector fears a weakening of groundwater protection. Thus water authorities have to deny drilling permission if there is a possibility it may be detrimental to the common good. However, in practice there is a great deal of scope for administrative discretion. As of yet, there are no regulations specifically dealing with geothermal energy (Janzing 2009, 42).

The micro-seismic effects caused by deep geothermal drilling are only considered to present a minor risk. However, a seismic event in Basel that was triggered by geothermal drilling clearly demonstrated that these kinds of incidents spark public concerns and can consequently obstruct further development of the innovation.[39] A deep drilling project within the city of Basel triggered a quake of the type

[37] http://www.tab.fzk.de/de/projekt/zusammenfassung/ab84.pdf (accessed July 24, 2009).

[38] An extreme example of this occurred in Staufen in Baden-Württemberg: in 2007 an operation to drill boreholes 140 m beneath the city hall to harness geothermal heat appears to have perforated a gypsum-keuper layer. Water then seeped into this layer, causing the anhydrite to turn into gypsum and expand by up to 60%. Since this incident, parts of the town's historic center have already risen by 10 cm, which has so far led to damages worth tens of millions. The building contractor was the town of Staufen (Janzing 2009, 43).

[39] The authorities recorded over 2,000 reports of damage in connection with this incident (Janzing 2009, 42). However, no personal injuries occurred.

that is common in mining. There is a particular risk of this type of micro-earthquake occurring during the construction of plants using enhanced geothermal systems (involving the creation of artificial waterways).

Seismic reactions such as those in Basel during geothermal drilling projects may be common and possibly beneficial, in that they release existing tension and, in all likelihood, eliminate the possibility of seismic activities for a long subsequent period (Bußmann 2007, pers. comm.). However, the project in Basel failed to prepare residents for the possibility of noticeable seismic reactions in good time and did not explain the causes. Weak earth movements of this kind also happened in Soultz (HDR). It is evident that the geothermal sector must prepare for acceptance problems when seismic reactions occur, even if they are only isolated incidents.

6.2.3.6 Actors in the Constellation

At both European and national levels, geothermal energy lacks the support of a political and institutional coalition of actors of the kind that exists in other renewable energy sectors.

Political Actors

After its promotion in 1998 to the position of central actor in the field of renewable energy policy under the red–green coalition government, the Federal Environment Ministry did not initially accord a great deal of significance to geothermal energy. Economic risks that were virtually impossible to calculate and the fact that many facets of the technology had yet to be explored meant that other branches of renewable energy took priority over geothermal energy in the Federal Environment Ministry's funding policy. This situation did not change until the EEG 2004 came into effect, following the publication of a TAB[40] study demonstrating geothermal energy's great potential.

The Geothermal Lobby

In February 2006 the Geothermal Association (GtV)[41] underwent structural changes and changed its name to the Geothermal Association – Federal Association of Geothermal Energy (Geothermische Vereinigung – Bundesverband Geothermie e. V. – GtV-BV).[42] However, at the level of political decision-making, the association

[40] Report by Paschen et al. (2003) at the Office of Technology Assessment at the German Bundestag.

[41] The Geothermal Association (Geothermische Vereinigung – GtV) was founded in Bonn in 1991 and was initially conceived as a scientific and technical organization (www.geothermie.de). Rapid changes in the field led to a sharp expansion of its membership base.

[42] The Geothermal Association is a member of the German Renewable Energy Foundation (BEE). The specialist journal *Geothermische Energie*, published by them, has been in circulation since 1998.

initially only managed to have a relatively small impact with regard to the legislative process concerning funding. The association covers the entire spectrum of geothermal technologies: from shallow geothermal energy systems and deep, hydrothermal or petrothermal geothermal energy, to heat and cold generation and geothermal power production. The association aims to publicize the various possibilities to harness geothermal energy and inform the public about ways to implement geothermal technologies and systems. As a lobby group, the association endeavors to encourage national and international policy-makers to give greater support to the utilization of geothermal heat and to improve the legal and administrative framework conditions.

The association comprises members from all geothermal energy-related domains: scientists, representatives from specialist agencies, planners, architects, journalists, research institutes, drilling companies , drilling services, well sinking and heating system construction, manufacturers of heat pumps and pipes, the supply industry, accessory dealerships, municipalities, municipal utilities, energy and district heat suppliers and individuals interested in harnessing geothermal energy have joined forces and formed an alliance – a fact which complicates the process of promoting specific interests.

There are a number of other associations that work to further the cause of geothermal energy, such as fesa e. V., a Freiburg-based association, which has organized events and published literature promoting the use of geothermal energy since 2003. The association publishes the GeoNewsletter and has produced a geothermal handbook.

Research Institutes

For a long time the area of geothermal energy was not accorded a great deal of prestige by the field of research and thus not considered a top priority. In the 1990s there was also a significant lack of engagement on the part of bodies allocating research funding[43] as well as actors in the field of science. As a result, important research institutes were founded at a late stage in the development of geothermal energy.

Although commercial geothermal plants already exist, geothermal energy is still in the research and development phase. While the geothermal market is growing and undergoing rapid changes, research and development continues to play a central role and this has led to the founding of further research institutes.

2003 saw the foundation of the GeothermalCenter Bochum, which was inaugurated on 12 March 2004.[44] Funded by the state of North-Rhine Westphalia, this center is in the process of developing a large-scale research institute that will focus on investigating and developing processes to harness geothermal resources. The new GeoTechnikum[45] was conceived as the core scientific facility of the GeothermalCenter Bochum, as a research institute that combines science and business with the aim of

[43] Federal Ministry of Research and Federal Ministry of Economics.

[44] http://www.geothermie-zentrum.de/portrait.html (accessed September 17, 2009).

[45] See http://www.tiefegeothermie.de (accessed October 2, 2009).

conducting implementation-oriented research and development in an environment that simulates real production conditions. Its laboratories, large testing hall and testing field will be used for drilling experiments[46] to develop and optimize drilling technology. The aim is to reduce drilling costs by developing new technologies and to provide infrastructural support for founders and companies in the fields of geothermal and heat mining applications.

Suppliers of Underground and Surface Technology

The pioneering deep geothermal market requires actors with a range of expertise. The field of underground technology primarily comprises international drilling companies from the oil and gas industries, such as Schlumberger Ltd. (Houston, USA), Baker Atlas (Houston, USA), but also several German companies such as Herrenknecht AG, Angers & Söhne, Drilltec GUT GmbH (Deggendorf) and ITAG Tiefbohr GmbH & Co KG (Celle). Due to a lack of constant demand, a domestic deep drilling market has not yet emerged in Germany (see Prognos AG et al. 2007b, 77).

There are a number of suppliers in the area of surface technology (low temperature turbines, generators, heat exchangers and cooling systems). There are only a few suppliers for the type of turbines used in ORC and Kalina systems. The GMK Gesellschaft für Motoren und Kraftanlagen mbH (Bagershagen) is the only German company to offer ORC turbines. Siemens AG and M+W Zander Gruppe (Stuttgart) supply Kalina turbines. Furthermore, several foreign companies also offer both types of turbine. Geothermal steam has an extremely corrosive nature and contains high levels of gas, which places particular demands on cooling system technology. Leading German suppliers on this market include Balcke-Dürr GmbH (Ratingen) and Mumme-Cooling Tower International GmbH (Wesel) (Prognos AG et al. 2007b, 79).

Public–Private Partnerships

Siemens is one of the first major German companies to participate in a geothermal power generation project (Unterhaching). The municipality has also assumed an influential role in the Unterhaching power plant. Together with industry partners in the form of a public–private partnership, the municipality and the mayor represent a strong driving force in the project's implementation.

6.2.3.7 Approval Requirements for Geothermal Projects

In legal terms, the initial situation concerning the exploration and extraction of geothermal heat is a complex one in comparison to other forms of renewable energy.

[46] Key components are a coiled-tubing drilling system, pressurized water technology and facilities to monitor hydraulic stimulation of the bedrock.

According to Article 3 of the Federal Mining Act,[47] geothermal heat falls into the category of natural resources that are "free for mining". According to this statement geothermal heat is common property and not the property of the landowner.

According to Klinski (2005, 88), as a rule, four types of mining permit must be obtained before the process of extracting geothermal heat can even begin: an exploration permit, an exploration operating plan, extraction approval and an extraction operating plan. The effort required is thus comparatively high, particularly as the permits and approvals are only issued for a limited period of time (2 years).

The exploration permit and the extraction approval required after a successful exploration phase are granted within the scope of a simple administrative procedure (without public participation, without an environmental impact assessment and without the so-called "concentration effect", i.e. the procedure is not required to account for other related administrative decisions) (Klinski 2005, 88). The user aims to secure as extensive a licensed area as possible in order to have a sufficiently large exploration zone. The responsible mining authorities, on the other hand, are obliged to restrict the exploration area if there is a possibility that other parties may be interested in the site.[48] Such interests include quarry mining projects and schemes to utilize the bedrock as underground storage space for gas and compressed air, among other things. The application of delimiting criteria thus has a crucial impact on the scope of geothermal exploration.[49]

The operating plans concerning exploration and extraction are authorized in a standard approval procedure. It is a simple administrative procedure that does not require other related administrative decisions.[50] If approval is granted, the applicant must apply for further official permits (usually water use permits for groundwater extraction and building permits for buildings above ground).

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[47] Federal Mining Act (BBergG) from August 13, 1980; cf. Index of Legal Sources.

[48] Projects to explore and utilize geothermal energy are faced with competition from carbon capture and storage (CCS) plans to capture CO_2 emitted by coal-fired power plants and pump it underground. CCS projects aim to dispose of carbon dioxide primarily in subterranean cavities and empty oil fields. The ensuing changes in underground pressure could restrict the scope for geothermal drilling.

[49] The federal-regional committee for mining's ad-hoc working group "Delimitation of geothermal areas" elaborated specific criteria to deal with the individual cases (see www.geothermie.de/wissenswelt/gesetze-verordnungen-recht/bergrecht-und-erdwaerme.html, accessed September 10, 2009). The criteria aim to guarantee a standardized approach to delimiting exploration fields across Germany. No clear precedence is given to the harnessing of geothermal energy over other utilization claims – an issue that sparked criticism from the GtV-BV.

[50] According to Klinski (2005, 89), a plan approval procedure is only necessary if it has been decided that the proposed project requires an EIA (see Articles 52a and 57c, BBergG) in line with the Ordinance on the Environmental Impact Assessment of Mining Projects (UVP-VBergbau; see Index of Legal Sources). In principle, this only applies to a geothermal plant project if there are plans to undertake deep drilling at depths of at least 1,000 m (see Article 1, Number 8 of the UVP-V Bergbau) within a nature reserve or a special protection area pursuant to the EC's Habitats or Birds Directive (Directive 92/43/EEC and Directive 79/409/EEC; see Index of Legal Sources). Therefore, as a rule, one can assume that a plan approval procedure, which accounts for other related administrative decisions will not be necessary (ibid.).

As it is not possible to apply the traditional concept of mining to the case of geothermal heat, specific criteria are required to delimit the area to which the license will apply. Delimitation criteria may include the situation regarding seismic profiles, the location of the planned drill holes or the areas designated for geoscientific study. The licensed exploitation zone will generally be a sub-area of the exploration zone.[51]

Due to the small number of projects and the fact that their scope is often restricted to pilot project dimensions, practical experience with regard to possible administrative obstacles in the plant approval process has so far been limited. Thus there would appear to be no immediate need for administrative regulations. However, the question that does arise is how and whether the already limited number of suitable sites for geothermal power generation can be safeguarded from the utilization claims of other parties in the long term. The GtV-BV believes that "underground spatial planning" would be of use here in order to establish a right of way for geothermal energy exploitation.

6.2.3.8 Interpretation of the Constellation: Driving Forces and Constraints

The enhanced economic framework conditions created by the EEG 2004 and the increase in the research budget have been the greatest driving forces behind the development of geothermal energy to date. Assuming the exploitation costs do not continue to rise, the combined impact of the significant increase in compensation rates in the EEG 2009 and the risk coverage provided by the market incentive program should, in principle, provide sufficient impetus to operate plants at many sites in a cost-effective manner. The international and social context was also conducive to development during this phase, as it generated a great deal of awareness and support for renewable energies in general and geothermal energy in particular as a stable source of renewable energy (Wenzel et al. 2009).

Despite its evident potential, geothermal power generation has not yet been able to benefit from governance to the same degree as other forms of renewable energy. The immense exploration risks have presented a particular obstacle. Furthermore, government measures have had few existing initiatives to latch onto. Unlike wind power and photovoltaic plants, which have attracted interest from a large number of private and commercial investors, there are only a few companies or social groups that currently have a stake in geothermal power plants. Major energy suppliers, companies from the fields of hydrology, geology and measuring technology, drilling companies, municipal utilities and municipalities are all actors that are central to driving the technology, yet they only have a limited interest in geothermally generated electricity and heat (Wenzel et al. 2009). Interest is particularly low when the existing, intact infrastructures are designed to meet the needs of other energy suppliers, and as high initial investments – for transition to a heating network, for example – are required, and as the projects entail a great deal of risk.

[51] One of the basic criteria for delimiting the exploitation area is the projected cooling margin. In addition, the distance between the production and injection well is also a significant factor (Schulz 2003).

In addition to this, large-scale geothermal power projects – unlike wind farms, for example – are not viewed as a suitable investment for private investors. Private stakeholders are much more likely to invest in individual geothermal heat plants. The first commercial projects have shown that important actors are primarily large energy supply companies as investors and municipalities as operators. In spite of the base load capacity of electricity generated from geothermal sources, the relatively low returns deter energy suppliers. At present, participation in geothermal projects is rather a tokenistic gesture. Major energy suppliers view geothermal plants with an output of 5 MW_{el} as "small-scale" technologies and fairly unattractive in terms of profitability. This would even be the case if plants had an output potential of 25 MW_{el}. Large-scale technologies – such as coal and nuclear power plants – continue to be less expensive and carry fewer economic risks from the perspective of energy suppliers.

It is too soon to predict the impact of future acceptance problems resulting from the occurrence of micro-seismic effects (earthquakes). Breaking open the bedrock (hydrofracturing) during plant construction is the primary cause of these micro-quakes. Experience has shown that in order to prevent acceptance problems it is incredibly important to prepare residents for possible quakes in good time prior to the projects and to explain the causes. A good publicity campaign that informs residents in advance is essential to convincing them of the benefits of the project and encouraging their tolerance when faced with possible disruptions.

6.2.4 Outlook

The technology to generate geothermal power and heat from low enthalpy sources is still in the very early stages of development and application and is considered by scientists to possess great development potential which, if exploited, is expected to reduce costs. In Germany there are currently a total of some 150 projects which aim to harness deep geothermal heat in stages ranging from preliminary exploration work to actual construction (BMU 2007b, 3). The small number of existing geothermal power generation projects and plants are located primarily in southern Germany (the southern German Molasse Basin and the Upper Rhine Valley) due to the favorable geothermal conditions there (thermal water already available with sufficient flow rates). Several sites are also under development in the Northern German Basin.

In addition to support measures in the EEG, it will also be necessary in future to provide funding for geothermal energy research and development programs. Aside from the major energy suppliers that function as investors and turbine manufacturers, geothermal energy is primarily backed by small and medium-sized companies which require support with regard to technology development and cooperation with research institutes and universities. Moreover, it will be necessary to conduct research into ways to prevent earthquakes and shocks (induced microseismicity) and the related acceptance problems.

In addition to the aforementioned constraints, competition from other power generation technologies and competing claims to utilize the bedrock are also having an increasingly unfavorable impact on the development of the geothermal sector. Geothermal projects not only have to compete with heat generated by fossil fuels – which is still a more economic option – but also, in part, with other renewable energy sources, such as biogas and biofuel plants which produce low-cost thermal energy. Rural areas, where there is greater biogas potential and cultivation of energy crops is on the rise, can create a competitive environment for deep geothermal energy with regard to heat volume, as the CHP bonus for biomass cogeneration plants will now amount to 3 cents/KWh instead of the previous 2 cents/KWh. If a biogas plant is profitable solely on the basis of the EEG payments for electricity feed in, it can then make additional use of the large quantities of available waste heat.

From 2009 onward, the KfW guarantee fund, exempting investors from liability, should result in significant improvements with regard to fears concerning exploration risks.[52] Nevertheless, it is highly unlikely that geothermal power generation plants will become economically viable purely on the basis of EEG compensation payments and will thus have to rely on an additional heat charge. An important prerequisite in this respect is the plant's proximity to a settlement (a "heat sink"). However, there are very few sites that have both the necessary geothermal conditions and access to heat sinks. Furthermore, concentration of a number of geothermal plants in one region can lead to competition for the available sources of hot water. This situation has not yet arisen in Germany, but it has already occurred in California.

Finally, the process of tapping geothermal energy also competes with plans to capture CO_2 from coal-fired power plants and pump it underground, using the bedrock as storage space for gas and compressed air. The aim is to dispose of carbon dioxide primarily in subterranean cavities and empty oil fields. The ensuing changes in underground pressure could restrict the scope for geothermal drilling. As a precautionary measure, coal-fired power plant operators are currently attempting to secure sites for CO_2 compression. Exploratory drilling for geothermal projects cannot proceed on a potential CCS landfill site. In view of the already limited number of suitable sites for geothermal projects in Germany, such restrictions to availability can rapidly become a central limiting factor to further expansion plans. Thus it would appear necessary to further develop the legal framework to incorporate underground spatial planning.

It remains to be seen whether geothermal power generation will become an established branch of renewable energy in Germany. The EEG and the research and development funding provide a supportive economic framework. There are, however, a significant number of competitors, substantial risks and considerable technical challenges.

[52] The guarantee fund covers up to 80% of the costs of unsuccessful drilling projects and 1.5 million euros for unplanned cost overruns during drilling.

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Chapter 7
Innovation Framework for Generating Electricity from Wind Power

Abstract The innovation biography of wind power in Germany underwent six phases. On the one hand, this development was characterized by the technology's successful expansion and its increasing efficiency. On the other hand, however, wind power gave rise to public debate as acceptance of wind turbines decreased during the expansion phase. These challenges were countered by policies from state actors at the regional and local level. Apart from hydropower, wind power is regarded as the trailblazer for renewable energies – it managed to become established as a new form of decentralized, renewable energy. This was possible in spite the fact that it has been difficult to integrate wind power into the energy supply system due to its intermittent nature, and despite resistance from actors of the fossil-nuclear energy supply system.

The successful establishment of wind power has been possible as a result of continually adjusting the policy approaches at various governance levels. Along with the amount, duration and reliability of the feed-in compensation, which was of crucial importance, the funding policy and the zoning and building law were additional decisive factors. The harnessing of offshore and onshore wind power differs in nature. Due to their large-scale scope and high investment requirements, offshore wind power plants resemble, to some degree, centralized power utility systems.

Keywords Wind energy • Successful innovation process • Zoning and building law • Public acceptance • Feed-in compensation

7.1 Preliminary Remarks

The development of wind power in Germany, particularly over the last 15 years, ranks as a global-level success story. Germany, despite possessing relatively limited wind resources, managed to become the world market leader in terms of total installed wind energy capacity. Wind power has reached an economically significant size and Germany has become a lead market in this area (Bruns et al. 2008).

E. Bruns et al., *Renewable Energies in Germany's Electricity Market: A Biography of the Innovation Process*, DOI 10.1007/978-90-481-9905-1_7,

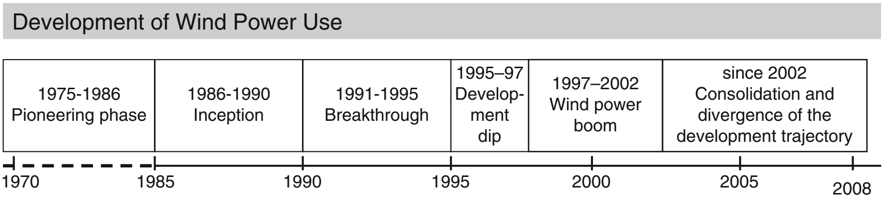


Fig. 7.1 Phases of the development of wind power use in Germany

We divided the development of wind power into the following phases, described in more detail in Section 7.2 (Fig. 7.1).

7.2 Phase-Based Analysis of the Innovation Process

Present-day wind power technology is not new in any fundamental way, but rather a rediscovery and development of a technology with considerable heritage. It was initially ignored as the world went through the process of industrialization (Ohlhorst 2009, 24). In Germany, the first examples of the use of wind power predate the First World War (Hau 1996, 29).

Since the early 1920s, attempts had been made to integrate wind power into a centralized electricity grid based on large power plants. During this period, the fluid dynamics engineer Albert Betz[1] established the basic principles for the understanding and theory of the utilization of wind power, which are still relevant today.

During the National Socialism, wind power was also a topic of interest for the government and industry (Heymann 1995, 162). The ratification of the Energy Industry Act (Energiewirtschaftsgesetz – EnWG) in 1935 resulted in the judicial codifying of a centralized supply system based on large power plants. The consequences of this regulation were significant both for wind power and power supply in general (Stier 1999, 442 sqq.). Smaller installations for power supply remained unreliable, thus no market for them developed (Heymann 1995, 446–447).

It was only with the oil-price, nuclear and environmental crises of the 1970s and 1980s that a change occurred which brought with it a significant increase in interest in wind power. A process of change in structural and societal conditions began (Saretzki 2001, 206; Mautz & Byzio 2005), which allowed wind power to become an increasingly competitive technology (Heymann 1995, 343 and 448).

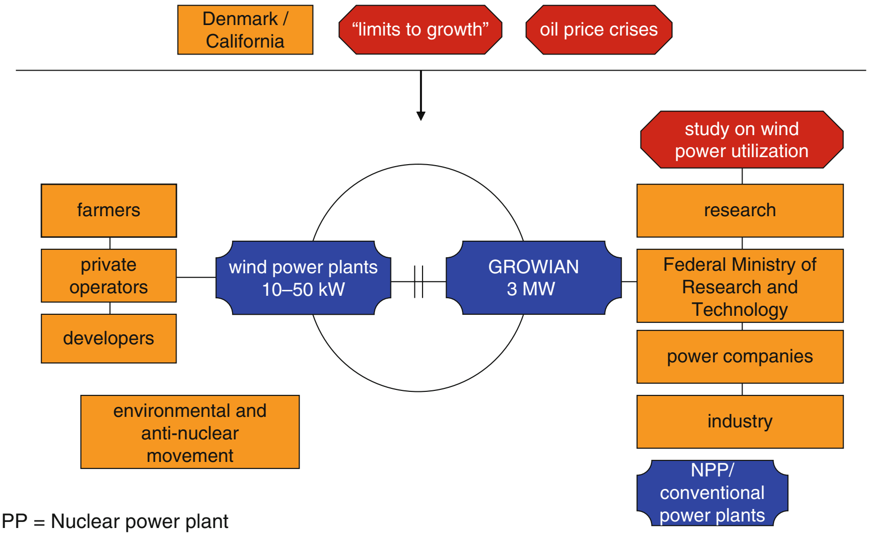
[1] Albert Betz worked at the Aerodynamische Versuchsanstalt Göttingen (Heymann 1995, 117). He developed a fluid mechanics theory for turbines, which even today forms the basis of calculations of wind turbine characteristics (Twele 2005a, 20; Gasch & Twele 2005, 32).

7.2.1 *Phase 1: Pioneering Phase – Mid-1970s Until 1986*

7.2.1.1 Characteristics of the Constellation

In the pioneering phase from the mid-1970s until 1986, wind power hardly made a contribution to the energy supply as it was still in its experimental stage. Various wind turbines with differing ranges of capacity were of great importance in this phase. They formed the core of the constellation and were part of two quite distinct sub-constellations.
Public policies supported research into large-scale installations, the intention being the achievement of a quantum leap in the development of wind power technology (see right-hand side of Fig. 7.2). The motivation was the achievement of technological alternatives to nuclear power and fossil fuels. The GROWIAN project (see Section 7.2.1.4) was a prominent – though failed – example of research into large-scale installations. It was initiated by an alliance of state actors, actors from the established energy sector and researchers.

The niche constellation (left-hand side of the constellation in Fig. 7.2) focused on small-scale installations with limited electrical generation capacity. These were developed with relatively limited investment by pioneers of wind power. These pioneers were a mixture of dedicated engineers and amateurs whose primary motives were the achievement of decentralized power generation and the



NPP = Nuclear power plant
GROWIAN = Experimental large-scale wind power plant
kW = Kilowatt, MW = Megawatt

Fig. 7.2 Constellation phase 1: pioneering phase – mid-1970s until 1986 abandonment of nuclear power. During this phase, farmers began to use wind power to cover their energy requirements. These small installations were characterized by their robust technology and relatively straightforward manageability. This isolated sub-constellation of wind power constituted the technological niche from which later developments originated.

7.2.1.2 Sector-Specific Contextual Events, Influencing Factors and Processes

The pioneering phase occurred in the context not only of the nuclear power crisis, but also the crisis in energy supply (see Sections 3.1.3 and 3.1.4). Following the two oil price crises of the 1970s, interest in wind power increased significantly. For the first time, the use of wind power came to be seen as a possible contributor, even if only a secondary one, to a reduction in the dependence on imported oil and gas.

7.2.1.3 Drivers from Abroad

During this period, German wind power technology was strongly influenced by developments in the USA and particularly by Denmark, where, even as early as the beginning of the 1980s, wind power installations with capacities ranging up to 50 kW were being produced. The equipment had the reputation of being robust and reliable (Bruns et al. 2008; Bechberger et al. 2008; Twele 2005, pers. comm.). They were built not only for local markets, but increasingly for export to the USA. Thanks to a support program with significant tax credits, demand for wind power in the USA even increased (Molly 2005, pers. comm.). The US market served as a "test-bed" for the Danish technology.

Denmark's export success contributed in 1986 to the decision to set up the first development program of the German Federal Research Ministry (Bundesforschungsministerium – BMFT) (Heymann 1995, 428; Molly 2005, pers. comm., see Section 7.2.1.4). Negotiating feed-in conditions for wind-derived electricity, the Danes also became the pioneers within Europe (Heymann 1995, 414 sqq.).

7.2.1.4 Governmental Guidance: Support for Public Research and Development

Government sponsored research was focused on large-scale wind turbines in the multi-megawatt class with a variety of designs. This strategy had the aim of promoting breakthroughs in large-scale wind power.

In 1976, the Federal Research Ministry commissioned a study program on the use of wind power. This was carried out by the German Test and Research Institute for Aviation and Space Flight (DFVLR, now known as the DLR) and the Research Institute for Wind Energy Technology (FWE) under the leadership of Prof. Hütter (Stuttgart University of Applied Sciences). The study (Armbrust et al. 1976) discussed in great detail the available wind data, the potential of wind power, the development of the various systems available for the use of wind power, as well as the economic viability. It was found, that the technology of wind power had significant potential. The authors recommended that the Federal Research Ministry and the Jülich Institute for Nuclear Research (Kernforschungsanstalt Jülich – KFA), who had been assigned responsibility for the coordination of the renewable energy research area, should seek to develop an installation with a capacity in the range of 1 MW and a rotor diameter of 80 m. Prof. Kleinkauf (project leader) and J. P. Molly emphasized the need to proceed with smaller steps in order to be able to investigate vibration characteristics and control engineering. These warnings were ignored, however, and consequently the construction of the so-called GROWIAN began on a test site in 1980 (Ohlhorst 2009, 94–95).

By 1987, the project was considered a failure. GROWIAN had become one of the greatest failures in the history of wind power. It was later speculated that the project´s mission had actually been to demonstrate the lack of viability of larger and more powerful turbines, since such a result would have been in the interests of the power companies. The GROWIAN project typified the focus of German research efforts in the wind power sector following the oil crises of the 1970s. Up until 1988, the Federal Research Ministry had made a total of 218 million German marks available for research into wind power, of which GROWIAN alone consumed 90 million marks (Tacke 2004, 149).

With regard to Federal Government policy and its support for wind power, this first phase was characterized by research and development in its narrowest sense, including research into large-scale wind power installations. Development was not driven by environmental policy or a need to create some kind of alternative source of energy, but rather by the aim of supporting technological innovation. Support for wind power came from the Federal Research Ministry, wind power was a "technology sandbox" (Vahrenholt 2005, pers. comm.) which, given the anti-nuclear sentiment of the time, was being tested in order to demonstrate that non-nuclear technologies were also part of the portfolio.

7.2.1.5 Technology and Market Developments

During this research period, two completely separate ranges of capacity developed within the technology of wind power. Demand from private users, mostly farmers, led to the development and installation of turbines in the 10–50 kW class. In contrast, research funding went into large-scale installations in the multi-megawatt class. Other examples of large-scale installations besides GROWIAN included the WKA-60,[2] Aeolus II[3] and the Monopteros.[4]

The electrical capacity of GROWIAN was 3 MW. Its rotor had a diameter of 100.4 m and the total height of the plant was 150 m, making GROWIAN for a long time the largest wind power installation in the world. The construction had a number of interesting details such as electro-mechanically adjustable rotor blades. However, many design elements had, until then, never been tested in a machine of such a large size. For most of the time from the first test run on 6 July 1983 to the end of operations in August 1987, the turbine stood motionless. Due to an error in the design of the housing, GROWIAN could not be used to full capacity. Material and construction problems[5] meant that a continuous test run was not possible. Despite all of this, GROWIAN is regarded as being the origin of modern wind power use in Germany, and in 1988 the test site near the estuary of the river Elbe, became the first commercial wind farm in Germany, with a total of 30 small turbines.

7.2.1.6 Missing Permit Requirements

During the pioneering phase, the development of wind power was hindered by the fact that zoning and permit requirements for wind power installations did not exist (Battis & Krieger 1982). Responsible authorities were the municipalities whose decision-makers tended toward skepticism when it came to wind turbines, both in regard to their operation safety as well as to their visual appearance.[6] The occasional planning applications submitted at that time generally concerned small installations for private, self-sufficient use on farms.

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[2] The problems with GROWIAN led to the construction of a smaller machine: GROWIAN II (also referred to as WKA-60). The turbine height was limited to 44 m. The three-bladed rotor was notable for its quiet running; its diameter was a mere 60 m. In contrast to GROWIAN, the WKA-60 had a so-called upwind rotor – the rotor turned on the windward side of the tower. The electrical capacity of the WKA-60 was 1.2 MW. This turbine was constructed in 1990 in order to supply power for the island of Helgoland. In 1995 it had to be taken down due to the damage caused to the rotor blades by multiple lightning strikes. In total, only four turbines of this design were built.

[3] Aeolus II had two rotor blades, a rotor diameter of 80 m and a capacity of 3,000 kW (Hau 2003, 54).

[4] Monopteros had just one rotor blade, a rotor diameter of 48 m and a capacity of 600 kW (Hau 2003, 52).

[5] The 50 m long rotor blades of GROWIAN could not be manufactured using the desired composite construction method. They had to be reinforced with steel, resulting in a 2 ton increase in weight. As a consequence, the hub had to be significantly strengthened. This ultimately resulted in a doubling in weight for the nacelle. The first attempts at running the turbine at maximum load resulted in cracks in the hub.

[6] Lönker (2006, pers. comm.) tells of the erection of a 24 m high ENERCON E-66 near the lignite-fired power station Ibbenbüren in 1982. The turbine was described as an “enormous monster”, even though it was vanishingly small in comparison to the power station.

7.2.1.7 Actors in the Constellation

During this phase, it was wind power pioneers that triggered the development. The niche of technological development was occupied mainly by inventors – individualists in the context of the environmental movement. It was the tinkerers and dedicated engineers who developed the first functioning installations. They were motivated by the idea of environmentally friendly, decentralized power generation, independence from oil imports and the abandonment of nuclear power. Farmers, too, were to be found among the pioneers as they began to use wind power to cover their own electricity needs.

7.2.1.8 Interpretation of the Constellation: Driving Forces and Restraints

At the beginning of the period there were two distinct and separate sub-constellations in play. In the niche constellation, in which it was primarily individuals who were active, a concept of environmentally friendly, decentralized power supply was pursued. Meanwhile, the dominant sub-constellation (which consisted of a combination of stakeholders from the energy sector, industry and technology policy) had focused on an economic policy concept based on supply security and sought to achieve a dramatic scaling up of the available technologies. The opposition of decentralized versus centralized power supply is closely connected to these concepts. The technological concepts being pursued in both sub-constellations were mutually exclusive, since each of these two technologies, which operated on very different scales, were associated with incompatible sets of aims, interests and motivations.

The decisive factor was the combination of individuals, motives and technology, which formed a sub-constellation that, through its consistency, allowed innovation to take place. The pressure of the context of the times (increases in oil price, "Limits to Growth"), together with the first technical successes and inspiration from abroad, strengthened this motivation and encouraged the learning process.

At first, the Federal Government supported the dominant sub-constellation: the Federal Research Ministry invested heavily in large-scale installations, both out of a need to legitimize research policy in the face of the environmental crisis (primarily doubts about nuclear power and oil price shocks) as well as to advance technology policy (given Danish sales achievements) (Molly 2005, pers. comm.). However, this support failed to generate any momentum. The attempt to control the course of events failed because policy makers did not make sufficient use of what was already available. The stakeholders involved – the Federal Research Ministry as well as large technology concerns and energy suppliers – were acting according to differing motives, and as a result no momentum developed and the intervention failed. This had the effect of damaging the image of the technology and lowered the hopes and expectations that had been invested in it.

7.2.2 *Phase 2: Inception – Changing Context of Energy Policy Between 1986 and 1990*

7.2.2.1 Characteristics of the Constellation

This phase, besides being defined by the reactor accident in Chernobyl, was also influenced by a reorientation in subsidy policy: development programs had a reduced emphasis on research and development and focused instead on the step-by-step development of equipment that was more reliable and market-ready (Fig. 7.3). Energy policy also changed in the states of Lower Saxony and Schleswig-Holstein, which both had a formative influence on wind power. In Lower Saxony, the Economics Minister, Hirche, launched the first development program for wind power in 1987. After the change of government in Schleswig-Holstein in 1988, a new energy concept was developed under the social democratic government, which aimed to achieve a nuclear-free coverage of energy demand. Finally, this phase was characterized by the appearance of a new kind of stakeholder: operating companies and cooperatives that constituted a new way of jointly running wind power installations.

7.2.2.2 Sector-Specific Contextual Events, Influencing Factors and Processes

The beginning of the second phase was marked by the Chernobyl reactor disaster (see Section 3.1.3). The occurrence of such a catastrophe dramatically demonstrated

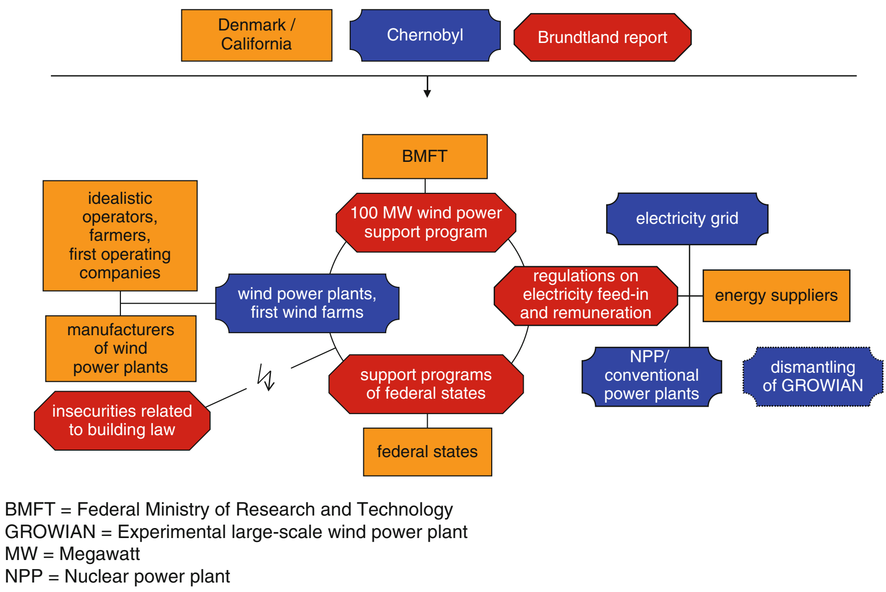

Fig. 7.3 Constellation phase 2: inception – changes in the context of energy policy between 1986 and 1990

the risks of nuclear technology and attracted the attention of the public. As a consequence, the potential of renewable energy started to be discussed more seriously in energy policy.

Climate change also appeared on the political agenda in Germany during this period and functioned as a justification for further public support, thus setting the scene for the wind power "breakthrough" of the early 1990s. With the establishment of the Committee of Inquiry "Provision for the Protection of the Earth's Atmosphere" in 1987 (committee established by the parliament, see Section 3.4.2.2) a change in energy policy manifested itself in Germany. The final report of the Commitee, which was published in 1990, defined the development pathway of renewable energy in Germany.

At the same time, the EU was working toward achieving a functioning single European market by liberalizing energy markets. This prompted the member states to open up their energy markets (see Section 3.3.1).

7.2.2.3 Technology and Market Developments

After the dismantling of GROWIAN following its unsuccessful test run, development was characterized by a decentralized use of wind power using small turbines. No technological concept had yet clearly established itself in Germany and achieved commercial viability (Twele 2005, 41).

Of all the vertical-axis wind turbines, it was especially the design developed by Darrieus[7] that came to be regarded as the most promising design for the modern exploitation of wind power (Hau 2003, 66). In-depth investigations of vertical-axis designs were carried out during the last years of the 1970s and in the 1980s and constructed by individual developers with a variety of capacities. High production costs limited a successful market launch. As a result, vertical-axis designs failed to establish themselves and made no contribution to electricity generation (Hau 2003, 68–69; Twele 2005, 3).

The end of the 1980s also saw attempts to develop another technological alternative in the form of solar updraft towers. However, the proposal to build a demonstration plant with a capacity in the region of 3–5 MW was never realized (Schlaich et al. 1989).

After the GROWIAN experiment, it became clear that further development was to be focused on robust two or three-bladed horizontal-axis turbines. One particular area of focus was the technology that had already achieved success in Denmark: the grid-coupled turbine with a three-bladed rotor; the so-called Danish concept. Germany's position in the field of wind power, in terms of technological development, was significantly behind that of Denmark (Molly 2005, pers. comm.).

[7] The Darrieus rotor was invented by the Frenchman George Darrieus and patented in the USA in 1931.

7.2.2.4 Governmental Guidance: Realignment of Support Policy

Up until 1985, the Federal Government's research policy had produced unsatisfactory results; the operators complained of technical shortcomings and operational issues with wind turbines. All of this resulted in a reorientation in Federal research policy during the mid-1980s:

The BMFT showed a greater openness toward supporting smaller installations and their deployment. At the end of the 1980s it came to be recognized that there was no need for ambitious new concepts and developments but rather for sufficiently robust and reliable installations that had been subjected to sustained testing and practical use and, bit by bit, rendered technically mature (Heymann 1995, 427).

In 1989, the Federal Research Ministry launched the 100 MW wind power support program.[8] High demand, also fueled by the German reunification, increased the support program capacity to 250 MW in the next phase. The 250 MW program supported the operators of wind turbines with subsidies spread over a period of 15 years.

Complementing the federal support, some German states offered their own support programs for wind power.[9] In particular it was Lower Saxony and Schleswig-Holstein who actively fostered wind power. The combination of federal and state support constituted a very effective stimulus package. Critics even said that the combination led to an "oversubsidizing" of the wind sector. However, the high financial incentives induced that many new firms entered the market. The resulting competition had the effect of massively pushing the development of the technology (Molly 2005, pers. comm.).

7.2.2.5 The Need for Approval Processes

During the inception phase, wind power was primarily perceived as being an isolated phenomenon, mostly made up of individual, one-off turbine installations. For the planning authorities, there was not yet any serious need to take action, since beyond idealistic interest in alternative energy, wind power did not yet take place on larger, regionally significant scales.

As a result of the concentration of demand, Schleswig-Holstein and Lower Saxony became pioneers in the development of standardized planning regulations. Policy making took the initiative in promoting wind power. As early as 1984, the authorities in Schleswig-Holstein put together "Guidelines for the layout, set-up and operation of wind turbines" in order to standardize municipal planning practices. These did not yet, however, govern spatial distribution. At the end of this

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[8] The 100 MW program granted claims either in the form of an investment subsidy (up to 60% of the investment costs) or a supplement to the negotiated feed-in tariff (predecessor of the StrEG) amounting to 4 euro cents/kWh.

[9] The states invested more than 1 billion euros in renewable energy between 1991 and 2001. Of this, 14.5% (216 million euros) were invested in wind power (Staiß 2003, I–162).

phase, the primarily private operators were already competing for sites and permissions in the windy coastal zones.

Contrastingly, in the inland states of the German Federation, case-by-case planning decisions continued to dominate. Whether this ended up being positive or rather restrictive was very much dependent on the acceptance of wind power as being an energy supply alternative.

7.2.2.6 Feeding Wind Power into the Grid

Wind-generated electricity was primarily fed into local low-voltage grids (20–50 kW). Operators had to negotiate the supply permission and compensation with local energy providers. The latter often cited the grid's insufficient capacity as a reason to reject the feeding in of wind power into local grids. It was the good will of power companies or energy providers and their enthusiasm for renewable energy that greatly determined if a supply contract was agreed upon and signed. As the supply permission was a decisive precondition for the successful realization of a wind project, operators had to cope with significant uncertainty during the planning phase. In case of failure to achieve permission, the whole project had to be cancelled.

7.2.2.7 Actors in the Constellation

Federal Research Ministry

With the 100 MW wind program of 1989, the Federal Research Ministry created an important incentive for the use of wind power, and within 5 years a capacity of 100 MW had been installed. Due to the large number of applications, the program was modified in 1991 and the capacity was raised to 250 MW (Hemmelskamp 1998, 37). With this market introduction program also acting as a research program, the Federal Research Ministry managed to define a basis for the deployment of wind power. Consequently, much innovation took place during this phase due to the large number of small and medium-sized businesses involved.

Federal States

Of all the German states, Lower Saxony was the pioneer in terms of wind power. Besides benefiting local turbine manufacturers, state policy also benefited an increasing number of farmers, for whom it had become clear that wind power could act as an additional source of income.

New Operator Structures

At the beginning of this phase, wind power operators were primarily private individuals who were looking after their own energy needs. Later, in the second half of the 1980s a new approach came into being in the form of the privately owned wind farm. Just a few months after the reactor disaster in Chernobyl, a local group of opponents to nuclear power in Hamburg/Wedel founded the first organization whose aim was to operate a Danish-made wind turbine in Germany, in order to demonstrate that another way of producing electricity was possible (Byzio et al. 2002, 272–273). The first privately owned wind farms were planned during the second half of the 1980s and were installed by the end of the same decade.

What was new about these cooperatives of operators was their energy policy (rather than their economic) motivations, coupled with collective action. The electricity generated in those wind farms no longer served individual needs, but was fed into the grid instead. Despite the improvement in financial conditions, and the improved prospects of profitability, the pioneers of this period still found that the establishment of wind farms was "especially from the financial point of view, still […] an adventure with an unknown outcome" (Byzio et al. 2002, 271).

Energy Suppliers

During this phase, energy suppliers played a central role, particularly with respect to grid access. The supply of wind power to the grid was often a decision that lay at the discretion of the local energy providers, with whom negotiations had to be made (see Section 7.2.2.6). The construction and operation of any wind power plant therefore constituted a significant financial risk.

7.2.2.8 Interpretation of the Constellation: Driving Forces and Restraints

The process of innovation was to a significant extent driven by the threatening scenario and the pressure for change that was triggered by the Chernobyl disaster. In addition, the visible successes achieved in other places (like Denmark and California) heightened the enthusiasm of actors (Molly 2005, pers. comm.; Molly et al. 1988, 55–56; Heymann 1995, 428). For the first time, a separation occurred in the close alliance between the state and the energy sector actors within the dominant sub-constellation. State actors, who now showed an interest in the incremental advancement of the technology, drove the process by launching development schemes. The Federal Research Ministry strengthened its focus on wind power as a possible future energy technology and became a driver (the BMFT development schemes) to develop turbines in terms of their technical functionality and readiness for the market. Smaller businesses also received subsidies from the Federal Research Ministry. The states acted with a mixture of industrial and energy policy motives and aims (support schemes of the states). In this way, the aims and actors of the niche constellation and the public component of the dominant constellation got closer to each other. In the second half of the

1980s, the foundations for the “breakthrough” phase that followed were laid, both in terms of subsidy policy and in terms of the technological developments that resulted from it.

Materials developers, mechanical engineers, operators, farmers and other actors started to set up the first regional organizations in the form of local and regional citizen groups (privately owned wind farms). The development schemes were intense short-term models focusing on this period and were tailored to these actors and capable of encouraging inspiration. They were more consistent with regard to the aims and motivations of their target groups in the niche, tied in with existing structures and so generated more of an impact on research than the predecessor program concerning large-scale wind installations. The fact that a legal framework (energy-management legislation, building and planning legislation) had not yet been developed still presented something of an obstacle to progress in wind power.

Big technology companies and energy providers no longer played a role in the further deployment of the technology. In contrast to Spanish energy providers, who had been interested in wind power from the very beginning, German energy providers failed to jump on the (then still small) wind power bandwagon. Only once wind power had attained scales the same as those of conventional power plants, would German energy providers become interested.

Small increases in the capacity of the wind power technology which had been regarded as a niche technology validated the respective policies and brought attention to the latent potential of wind power. In comparison to the high-tech attempt of GROWIAN, the technology in this phase was robust. The development process was able to make use of traditional German engineering and knowledge of composite technology and turbine manufacturing. As the same actors often carried out both turbine construction and operation they managed to incrementally increase the capacity of the wind turbines.

7.2.3 Phase 3: Breakthrough 1991–1995

7.2.3.1 Characteristics of the Constellation

A strong dynamic developed in the third phase (Fig. 7.4). The most important event was the enactment of the StrEG, which permitted wind power operators well-regulated access to the market and assured predictable remuneration for the electricity that they supplied. It complemented the still-effective federal and state development schemes.

In terms of technical availability and efficiency, the technology of the turbines improved considerably and was enriched by a number of technical innovations (e.g. gearbox-free wind turbines, pitch regulation, see Section 7.2.3.4). Increasing market competition resulted in a decreasing number of manufacturing companies.

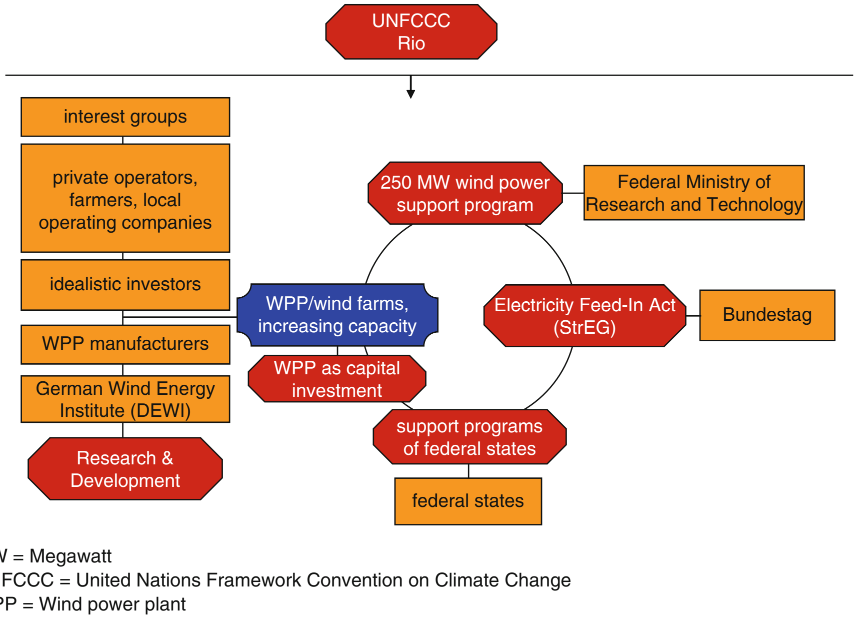

Fig. 7.4 Constellation phase 3: breakthrough 1991 to 1995

The spread of ever-larger installations put the federal, state and local authorities under pressure. At all levels, authorities had to address new rules concerning the siting of wind power. At the same time, conflicts of interest between climate protection and nature conservation became obvious.

7.2.3.2 Sector-Specific Context, Influencing Factors and Processes

Dynamic developments in the niche ran parallel to a national and international debate, which provided important justifications for the expansion of wind power in the context of a sustainable resource management and climate change debate (see Sections 3.1 and 3.2).

Thus, the concept of sustainable development as described in the Brundtland report came into focus as a motivation for wind power in this phase. The Rio Summit in 1992 (UNFCCC), which stressed the need for global climate protection and the need for an energy turnaround also had the effect of highlighting the potential of wind power for climate protection. The new policies introduced by the Federal Government in December 1991 "Energy Policy for the United Germany" stressed the importance of environmental aspects of power supply and the integration of national energy policy with the single European market.

One disadvantage for wind power during this period was the decreasing price of oil, which hovered around just 10 dollars per barrel at the beginning of the 1990s.

Demand in the USA for Danish wind turbines had still been high during the mid-1980s, thereby influencing attitudes in Germany, but the low price of oil now caused the USA's interest in renewable energy to decrease.

7.2.3.3 Governmental Guidance

The Electricity Feed-in Act

The enactment of the Electricity Feed-in Act (Stromeinspeisungsgesetz – StrEG[10]) on 1 January 1991 launched a dynamic development of wind power. According to this law, energy providers were obliged to accept any wind-generated electricity in their supply areas and to pay wind power operators a minimum of 90% of the average revenue generated from power supply to the end-users during the previous year. The regulations of the StrEG opened up the market to wind power operators and induced a strong push: both the average turbine performance and the total installed capacity steadily increased from this point onward. Wind power installations, especially wind farms, came to be seen as capital assets.

On the occasion of the first amendment of 1994, energy providers, the German Association of Chambers of Commerce and Industry and the Federation of German Industries fiercely attacked the legislation. From their viewpoint, the compensation rate for the purchasing of wind power was too high and did not reflect the actual value of the power being generated (Hemmelskamp & Jörg 1999, 86). Energy providers in the windier coastal states were obliged to pay the majority of the compensation for electricity fed into the grid – on the other hand, the profit margins in the energy sector were very high in comparison to many other sectors (Tacke 2004, 173).

National Support Programs and Depreciation Allowances

The 100 MW Wind Power Program caused manifold applications for the construction of wind turbines, resulting in the expansion of the program to 250 MW of wind power in February 1991. Through this program, wind power achieved a breakthrough, because now, for the first time an additional 8 pfennig/kWh was being paid. This was a guaranteed long-term (10 year) supplement to the feed-in tariff of 8.66 pfennig/kWh set by what was called the association agreement. An additional important effect of the program was the ability to assure manufacturers about the sales figures financed by this program from 1989 onward (Hoppe-Kilpper 2003, 86).

[10] The sources for the legal information used in this chapter are given in the Index of Legal Sources.

Furthermore, the Federal Ministry of Economics granted long-term low-interest loans for the financing of wind power plants via the federally owned Deutsche Ausgleichsbank as part of the ERP Environmental and Energy Saving Program[11] as well as through the Deutsche Ausgleichsbank's own environmental program (DtA-Umweltprogramm) (Hoppe-Kilpper et al. 1997, 143). For the years to come, it was through these means that the vast majority of wind turbines within Germany were financed.

The 250 MW Wind Power Program, which was set up in connection with a "scientific measurement and evaluation program" (WMEP, cf. ISET 2006), had the effect of building confidence, for both investors and shareholders in wind power. The independently prepared data, processed by the Institut für Solare Energietechnik at the University of Kassel, served German grid operators as a basis for predictions of expected wind power yield as well as providing a basis for advice, scientific reviews and studies of wind power use. The WMEP thereby contributed to an increase in the respectability of wind power and to greater transparency concerning the performance of the technology.

Following the coming into effect of the StrEG, the financial authorities acknowledged the potential profitability of wind power projects (Hemmelskamp & Jörg 1999, 87). As a consequence, the design of the tax system improved significantly for investment in wind energy projects. The loss in value of the facility could be treated as tax write-offs on depreciated fixed assets or operational goods (§ 7 para. 1 of the Income Tax Law (EstG)). In addition, losses incurred during the start-up period could be set off against future profits, in order to ensure the application of taxation according to performance over the entire operating life span of a facility (Hemmelskamp & Jörg 1999, 88).

Support by the States

A few German states, for example Brandenburg, offered subsidy programs for wind power (Staiß 2003, I–163). The state programs mostly provided investment grants for wind power operators. The regional investment banks of some states awarded low-interest credit for the construction of wind power facilities. In some states, subsidies were also made available to manufacturers for the development of pre-production models. Generally the level of state subsidy was limited by taking federal subsidies into account, so that the maximum possible level of subsidy for operators came to 50%.

The period between 1993 and 1995 was the height of wind power subsidization in the German states. In the course of the second half of the 1990s, a clear reallocation of state subsidies took place, from wind power to biomass and solar thermal power (Staiß 2003, I–166; Hoppe-Kilpper 2003, 79–80).

[11] ERP funds were originally funds from the European Recovery Programme (ERP) which were made available in the 1948 Marshall Plan for the rehabilitation of the German economy.

Planning Legislation

The net effect of feed-in tariffs, federal and state subsidies led to a massive increase in demand for sites and planning permissions. A dominant issue during this phase was the suitability of the permit requirements embodied in the building legislation. The turbines of the 1980s had been predominantly installed as (small) secondary facilities, primarily for exclusive use by the owner, but after the introduction of the StrEG, this changed fundamentally. In order to generate space for the continued development of wind power, planning and building legislation needed to be amended and new forms of planning approaches had to be found.

The planning requirements turned out to be particularly time consuming. In mid-1996, a new regulation came into effect, which predated the actual changes in legislation. Accordingly, turbines in the non-urban areas (Außenbereich)[12] are privileged, but at the same time subject to planning restrictions – which means that through the designation of a site for turbines, the remaining planning area was to be kept turbine-free. This was intended as a legally effective instrument to challenge the anticipated sprawl of wind farms. The state of Schleswig-Holstein yet again turned out to be the pioneer, since it had already stipulated such an approach as early as 1991. On the Federal level, the regulation came into effect on 1 January 1997 (see Phase 4).

The planning legislation affected specific requirements in the eastern German states: apart from a few exceptions, none of these states already had legally binding municipal land-use plans. In contrast to the states of former West Germany, the new states had no experience with land-use permit requirements for wind turbines. For this reason, state policy on wind power siting in these states came to be focused at the regional level. For spatial planning a new zoning category – "appropriate area" (Eignungsgebiet)[13] – was introduced to regulate the siting of wind facilities. Landscapes requiring particular protection were to be kept free by concentrating wind power facilities in these designated zones. In the states of Brandenburg and Mecklenburg-Western Pomerania, which still faced a strong wind-use deployment, the regional planning authorities put a lot of effort into the designation of these zones.

Regulation Via Wind Power Directives at State Level

During this phase, wind power ordinances were issued which specified minimum distance requirements according to the Immission Control Act. These took into

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[12] The term Außenbereich comes from German zoning law and describes a category of areas which are not within the area designated by a binding land-use plan and which are not part of the already built-up area (Innenbereich).

[13] The zoning category of "appropriate areas" was introduced by the BauROG 1998 (cf. Index of Legal Sources). The appropriate wind use areas were identified by overlaying criteria indicating high wind yield with minimal clearance criteria. The latter were meant to avoid conflicts with other land uses (like habitation, recreation) and protection needs (e.g. bird protection, cultural heritage, visual landscape).

account residential areas and protected areas (according to nature conservation law) as well as clearance requirements in accordance with building regulations. The wind power ordinances had an important function during this phase, as they provided guidelines for planners on how to deal with wind power siting.

The implementation of building legislation in combination with wind power ordinances and immission control requirements (particularly noise control) meant that the preparation of planning permission documents had become increasingly complex.

Technology and Market Developments

Even in the previous phase, Germany had already committed itself to a strategy of "evolution" in wind power rather than "revolution" (Tacke 2004, 173), which was put into practice from this point onward. The 1990s saw the greatest improvements in turbine technology (for example: technical availability and efficiency) as well as the most technical innovations, such as gearbox-free turbines and pitch regulation. As a consequence of shorter production cycles for generations of turbines, there was a shift from quality to price competition, which in combination with high investment costs triggered a process of consolidation among manufacturers.

The variety of technical principles employed by manufacturers[14] contributed to technical differentiation amongst the various turbines being constructed. The manufacturer Enercon made an innovative decision to make the transition from geared to gearbox-free technology. The efficiency of turbine technology increased significantly: in 1992 the average rated capacity of newly installed turbines was 180 kW. In Schleswig-Holstein, wind turbines with a rated capacity of 100–300 kW were being installed (Rave 1992, 352). By the mid-1990s, this figure had risen to 500–600 kW.

An important technological developmental aim was to reduce the susceptibility to failure of wind turbines while simultaneously organizing professional maintenance for the turbines, which were constantly increasing in size.

A striking fact is that the most substantial improvements in turbine technology and the reduction of manufacturing costs occurred when state funding of research and development was rather low. Development was primarily triggered by the dynamic of growing energy markets, which had been induced by the implementation of the StrEG, and financed by the businesses that were involved[15] (Hoppe-Kilpper 2003, 95).

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[14] For instance, the manufacturer Tacke Windtechnik originated as a gear manufacturer while Husumer Schiffswerft and Jacobs-Energie took advantage of wind turbine manufacture as a way of expanding their production, which had previously concentrated on shipbuilding (Hemmelskamp & Jörg 1999, 94).

[15] Besides the technical development of turbines, significant research activity was carried out in universities and independent research institutes; e.g. development in material science, aerodynamics, electrical supply engineering, measurement and control technology, meteorology etc. (Hoppe-Kilpper 2003, 95).

Rising Employment Figures

The number of employees in the sector rose from below 2,000 in 1991 to just under 10,000 direct and indirect employees in 1995. Thus, the sector was able to point to its appreciable effect on the job market as a positive outcome.

Turbine Manufacturers

As a consequence of the profit-oriented support of operators and depreciation allowances, demand for wind turbines temporarily exceeded supply. The manufacturers came under considerable pressure to satisfy the demand with turbines of the required quality. Price competition and the high investment costs for the continued technological development of turbines resulted in increasing market concentration. In the mid 1990s, five manufacturers dominated the German market: Enercon, Micon, Vestas, Tacke and AN Windenergie.[16]

Installed Turbines and Total Capacity

The deployment of wind turbines after the enactment of the StrEG exceeded even the most optimistic expectations. Between 1991 and 1995, installed capacity rose from 105.9 MW to over 1,120 MW – a more than tenfold increase (see Table 7.1).

Table 7.1 Development of turbine numbers and installed capacity in Germany 1991–1995 (Molly 2009, 9)

Year	Installed capacity/year in MW	Cumulative installed capacity in MW	Number of turbines/year	Cumulative total of turbines	Installed turbines – average capacity/ year in kW
1991	50.85	105.9	295	700	168.80
1992	68.29	173.74	399	1,084	178.60
1993	152.00	325.74	591	1,675	255.80
1994	292.61	618.35	792	2,467	370.60
1995	503.72	1,120.87	1,062	3,528	472.20

7.2.3.4 Actors in the Constellation

Public Policy Making

State actors (the Bundestag, the Federal Research Ministry, the Federal Environment Ministry and the states) were of central importance during this phase and set the

[16] Manufacturer market shares in 1998: Enercon 32.5%; NEG Micon 14.4%; Vestas Deutschland 13%; Tacke Windenergie 12.9%; AN Windenergie 9.8%; Nordex Balcke-Dürr 7.4%; Husumer Schiffswerft 1.5%; Südwind 1% and other 6% (Wind/Energie/Aktuell 8/98). Available online at http://www.windkraft.de/... (Accessed: 15 September 2009).

course of events. Through subsidy programs and especially through the legally guaranteed compensation rate they promoted wind power to the point where it became attractive to investors.

Actors at the Local and Regional Levels

The sprawl of ever-larger turbines and wind farms meant that the federation, the states and local authorities needed to reorganize the spatial zoning of wind power. At the same time, conflicts between environmental and nature conservation objectives became obvious.

In states in the west of Germany, the local authorities were the bottleneck in terms of granting permission for the siting of turbines, and were put under pressure by both applicants and local opponents to wind power. The local authorities of the states in eastern Germany were overrun by the demand after reunification. As a result of a lack of planning legislation at the local level, regional planning communities were established to deal with planning issues.

Market and Operator Structures

For reasons of efficiency, combined with the interest in concentrating turbines in certain areas, installations consisting of just one turbine became increasingly rare, and wind farms became more common. The necessary investment volumes exceeded the capabilities of users who were just private individuals, and larger investors and operating companies took their place. Thanks to the support conditions provided, shares in wind farms became attractive targets for investment and capital allowances. However, the majority of wind turbines were still to be found in the hands of local or regionally-based operators (primarily farmers). Many operators decided on the corporate structure GmbH & Co KG (limited partnership with a limited liability company as a general partner), which offered tax advantages. This advantageous structure for the operators contributed to the breakthrough in wind power. The commitment of local authorities also increased: many municipal utility companies started operating turbines or wind farms.

Institutionalization of Interests and Knowledge

During this phase, the development was stabilized by the establishment of a wind power centered association structure. The first journals[17] for renewable energy and wind power were also established at this time.

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[17] The journals Neue Energie and Wind/Energie Aktuell (the latter now known as: Erneuerbare Energien) were first published during this phase, for instance.

As early as 1974, the Deutsche Gesellschaft für Windenergie (DGW) was founded, followed by the Interessenverband Windkraft Binnenland (IWB). The two organizations merged in 1996 to become the still active German Wind Energy Association (Bundesverband Windenergie – BWE).

In 1993, within the German Engineering Federation (VDMA), the VDMA Association for Wind Energy was founded. This organization concerned itself mainly with lobby work and publicity for wind power (Schiel 2005, pers. comm.). In 1990, the state of Lower Saxony founded the German Wind Energy Institute (DEWI), which has since become one of the leading international institutions in the area of wind power, carrying out measurements, studies and forecasting as well as offering opportunities for education and technical, economic and political advice.

Another influence on the further technical development of wind power was the work carried out by the Institute for Solar Power Supply Technology (ISET), where the data from the 250 MW Wind Scientific Measurement and Evaluation Programme (WMEP) were collected. Detailed fault statistics yielded important information regarding technological optimization and development potential and contributed to the very limited downtime of the turbines (Schlegel 2005, 41).

Escalation of the Conflicts Between Climate Protection and Nature Conservation

The objectives embodied by climate protection and immission control on the one hand and nature conservation and the protection of landscape scenery on the other diverged noticeably during this phase: climate protection and CO2 reduction had a high priority, but on the other, the EU was implementing guidelines for endangered species and the protection of biodiversity which required member states to specify corresponding protected areas. The strict species protection regulations, especially the list of bird species in the annex of the Habitats Directive, impeded the siting of wind turbines.

By becoming incorporated into the wind power ordinances (as no-go zones or as restricted areas) nature conservation areas had a restrictive effect on the preselection of sites. Conservation thus risked being accused of standing in the way of important climate protection requirements and became a hindrance to what was otherwise viewed as a sustainable deployment in environmental policy terms.

Because of this, Germany's conservation organizations[18] sought some kind of compromise on the expansion of wind power: wind power was generally welcomed, but was only to be expanded by taking into consideration conservation issues and landscape protection requirements. The states' authorities for nature protection and landscape management issued recommendations for the consideration of conservation matters and landscape protection when developing wind power.[19] Thus, the

[18] Represented in position paper of BUND – Landesverband Niedersachsen e.V. (1996).

[19] Cf. ARGE Eingriffsregelung (1996).

conflicts between nature conservation and climate protection through the use of renewables were to be handled on a case-by-case basis.

Conservationists raised the issue of the growing number of turbines and their ever-greater dimensions, which were seen as a technological transformation of the landscape.[20] Fears expressed with respect to consequences for biodiversity focused predominantly on possible impacts on birds (Reichenbach 2004, 32). As part of the planning process, applicants were required to consult experts concerning foreseeable effects on the visual landscape and bird life. In some cases this led to considerable delays in the planning and approval process.

Actors who were otherwise not particularly active in conservation also used these arguments in order to support their own negative attitudes to the construction of turbines. To an extent, it sometimes seemed as if conservation-based arguments were being exploited for campaigns by local opponents to wind power.

However, this critical debate also generated a series of planning guidances and criteria[21] that contributed to the ability to solve conflicts when siting wind farms.

7.2.3.5 Interpretation of the Constellation: Driving Forces and Restraints

In the third phase, the wind power niche developed dynamically. Increasing numbers of actors and groups of actors with various interests and backgrounds influenced and changed the structure of the constellation.

Through the StrEG and subsidy programs, actors from the political and administrative system promoted the growing economic significance of the technology. The StrEG and its amendments were the decisive regulatory incentives for the breakthrough that was achieved in wind power. The law had become an instrument for the market introduction based on the ideals of consistency, longevity and investment security (Molly et al. 1988, 8, 84; Tacke 2004, 175; Berchem 2006). In combination with subsidy programs (the 250 MW program and the state subsidy programs), a profound effect was achieved during the 1990s. The StrEG was part of a nascent process of institutionalization that accompanied and stabilized the process of innovation. The founding of associations and lobby groups was also part of this process of institutionalization.

Thanks to the market-based stimulus established by policies, wind power technology developed in scale, functional capability and efficiency. It also experienced an increase in value thanks to the broad-based long-term measurement and evaluation program (ISET).

A stronger formalization of wind power use in legal and planning terms was required because of the increasing significance of wind power for landscape scenery and land-use, as well as the increasingly capital-intensive size of turbines and wind farms. For the further deployment of wind power, zoning regulations were

[20] Cf. e.g. Hasse & Schwahn (1992); Nohl (1993); Dattke & Sperber (1994); Klöppel & Krause (1996).

[21] Cf. inter alia Kleinschmidt et al. (1994); Breuer (1996); BUND (1996, 2001).

overdue to guarantee investment security to this growing sector and to provide appropriate sites.

The dynamic in the niche constellation was now no longer solely promoted by financial incentives but also by energy and planning approaches. International and EU strategies and tools also had a decisive influence on the constellation.

Besides the actors who were more motivated by idealism, professional and commercial actors also came onto the scene. This was accompanied by a transition from more informal and familiar relationships to more market-oriented ones: projects were planned and implemented in a goal-oriented way, the financial security of investments became increasingly important, and interests and knowledge were combined in new organizations. Nevertheless, actors from civil society also played a primary role in the further deployment of wind power during this phase. The coming together of like-minded people at this time, who sought to establish a cooperatively operated renewable energy project, can be regarded as a socio-ecological innovation (Byzio et al. 2002, 296 et seq. and 398 et seq.).

In contrast, the traditional energy industry played no significant role during this phase. The absence of a strong opposition cleared the way for wind power. It was only in the next phase that the representatives of the predominating energy industry began to tackle the now flourishing sector.

7.2.4 Phase 4: Development Dip in the Mid-1990s

7.2.4.1 Characteristics of the Constellation

During this phase, various disadvantageous developments came together, causing the hitherto energetic deployment of wind power to falter (Fig. 7.5). This resulted in a slump in the market and bankruptcy in the sector. The dip can be seen in the graph showing capacity installed per year and annual turbine construction totals (see Fig. 7.8 and Table 7.2). Employment figures within the sector also fell.

Due to the preceding growth, price erosion and short product cycles, this young sector was already struggling with technical and economic problems. In addition to this, subsidy programs were coming to an end, and the Federal Ministry of Economics was considering a reduction in the feed-in tariff for the upcoming amendment to the StrEG. That was being used by the subconstellation which dominated the energy sector as a means for the mobilization of a formidable opposition to wind power.

Legal adjustments that could have solved the uncertainty concerning planning requirements and the upcoming amendment were overdue. The abolition of the planning legislation that privileged the siting of wind power, as well as the backlog in permissions intensified uncertainty to the extent that ultimately banks also became hesitant when it came to financing new turbines. The investment and permit backlog (the authorities were unprepared for the multitude of applications) ultimately resulted in a slump in the market. Local resistance to the ever-larger turbines

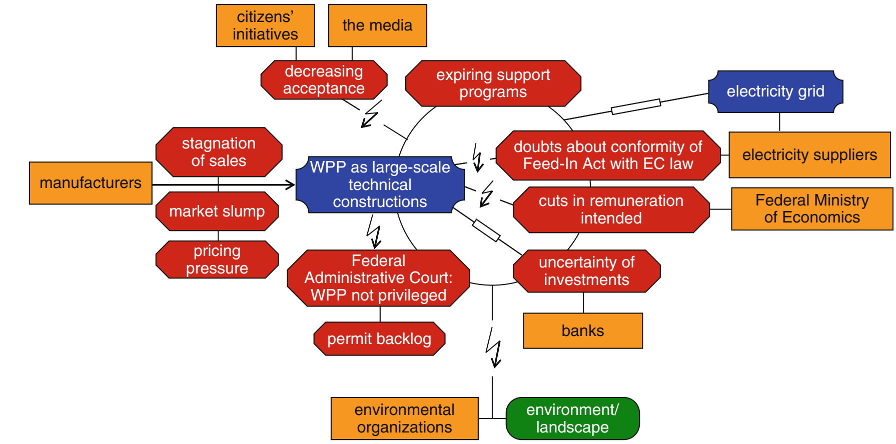


Fig. 7.5 Constellation phase 4: development dip in the mid-1990s

also increased: affected populations increasingly expressed resentment and organised themselves into citizens' groups. Voices which were critical of wind power[22] made themselves heard via the media.

7.2.4.2 Sector-Specific Context, Influencing Factors and Processes

During this phase, actors within the constellation were strongly focused on themselves and their own reorganization. The higher level and international context only played a role to the extent that the liberalization of the energy markets caused a slight decrease in energy prices.

7.2.4.3 Legal and Socio-Economic Context

Sluggish Permission Procedures and Declining Acceptance

Due to a Federal Administrative Court judgment from 1994, which had concluded that wind turbines were not privileged projects according to the Federal Building Code (Baugesetzbuch – BauGB) (§ 35 BauGB, see Section 0), applications were increasingly being turned down. In some cases, planning decisions were deferred for an unspecified period of time. The approval of many wind farms was questioned.

[22] For example "Naturstrom- und Windkrafteuphorie in Deutschland und ihre Folgen"; http://wilfriedheck.de/, the "unofficial" Bundesverband Landschaftsschutz website (Accessed: 6 August 2009).

The debate about the submitted proposals for amendment regarding new rules for privileges (Privilegierung)[23] took on increased urgency and vehemence. After the Federal Environment Ministry had introduced an initiative to the Bundestag, a recommendation for a decision on the amendment to the § 35 BauGB was finally passed in June 1996.

The emotional debate concerning the feared “uncontrolled sprawl” of wind turbines, which occurred during the course of amending the building legislation, led to an increasingly critical attitude among residents affected. Noise and infrasound emissions as well as shading (“shadow flicker”) raised residents’ fears about health dangers. Impacts on the overall appearance of the locality and landscape (looking “out of proportion”), high land usage, bird strikes and the disturbance or displacement of bird species and bats became widely discussed. Besides this criticism, complaints were made about possible losses in value of real estates neighboring wind turbines.

Resistance to the StrEG

The energy industry fought fiercely against the StrEG (see Section 3.7.1). Organizations accused wind turbine operators of enriching themselves at the expense of the consumer. On the recommendation of the VDEW (The German Electricity Association – now the BDEW), some individual power companies cut the legally required compensation of one of their customers who was feeding power into the grid. This course of action met with massive public criticism. Members of the Bundestag from all parties expressed their disapproval of the misdemeanors of the power companies and demanded that the StrEG be respected in the form in which the Bundestag had decided upon.[24]

Amendments to the StrEG

Wind power operators requested an amendment to the StrEG containing new compensation rates, since only 90% of the electricity they were feeding into the grid was being paid for, and prices were falling due to liberalization and competition. Though they were not primarily responsible, specialists from the Federal Environment Ministry demonstrated great enthusiasm for a reform of the StrEG; the Bundestag eventually enacted the reform. This reform left the compensation level as it was, but the existing hardship clause was modified through the introduction of what was referred to as the 5% cap. If the wind power-derived proportion of a power company’s output exceeded 5% of the total amount of kilowatt hours sold, the upstream system operator was obliged to reimburse the additional costs. By way of example, in the case of the north-German energy provider Schleswag, the 5% mark was

[23] Projects with a licensing privilege in non-urbanized areas have to be given approval, unless they are not compatible with public interests (see Section 35 of the Federal Building Act).

[24] Cf. Der Spiegel, 8 May 1995.

exceeded, meaning that the upstream grid operator PreussenElektra had to reimburse the additional costs. However, when the grid operator's own proportion of renewable energy also exceeded 5%, the purchase obligation ceased.[25]

New Legal Conflicts Following the StrEG Amendments

In May 1998, shortly after the amendments to the StrEG had been made, the constitutionality of the law was yet again checked by the Federal Constitutional Court. On this occasion, Schleswag, the subsidiary of PreussenElektra, initiated the process. The case was made before the district court in Kiel that the regional burden caused by the StrEG violated various articles of the Basic Law (GG): article 3 – the Principle of Equality, article 12 – occupational freedom and article 14 – protection of property.[26] In March 2001, however, it turned out that the case, which was now being heard at the European Court of Justice, could be settled. The court judged that the German StrEG was in accordance with EU law, and that it did not constitute unlawful state assistance as far as the Treaty establishing the European Community was concerned (see Section 3.7.1). As a result, a long lasting period of legal uncertainty for the wind power sector ended (Nagel 2001).

7.2.4.4 Technology and Market Development

Uncertainty in the Wind Power Market

Although the downturn in turbine construction and capacity installed per year seemed to be just a short phase in the slump (see Table 7.2), in 1998 the power companies considerably unsettled the still young sector by challenging the legally specified payments which were to be made for electricity from renewable sources.

Table 7.2 Development of numbers in wind turbines and installed capacity in Germany 1994–1998 (Molly 2009, 9)

Year	Capacity installed/year in MW	Cumulative installed capacity in MW	Total turbines/ year	Cumulative total turbines	Average capacity of installed turbines/ year in kW
1994	292.61	618.35	792	2,467	370.60
1995	503.72	1,120.87	1,062	3,528	472.20
1996	427.64	1,546.38	806	4,326	53s0.50
1997	533.62	2,079.97	853	5,178	628.90
1998	793.46	2,871.48	1,010	6,185	785.60

[25] Cf. Johnsen (1997, 8) cited in Hemmelskamp & Jörg (1999, 86).

[26] The case was transferred to the European Court of Justice. On 20 July 1999, and with concerns regarding state aid, the EU Commission resolved to set into motion a procedure against the German Federal Government.

The Economics Ministry also contributed to this uncertainty by contemplating the possibility of a reduction in compensation for electricity fed into the grid.

In addition, the rapidly increasing turbine size presented manufacturers with a substantial challenge. No manufacturer could afford to fail to keep up with the market in terms of developing new generations of turbines. At the same time, development expenditure was significant and increased disproportionately with the overall size of the turbine. Such expenditures required minimum production units of the turbine type under development for refinancing. Manufacturers with too small a market share were not able to afford such minimum production runs. Smaller manufacturers found themselves at an extreme competitive disadvantage and so a significant market shakeout took place (Twele 2005, 24).

In 1996, following the boom of the previous years, the market stagnated and was unable to register any growth. In actual fact, the average installed capacity per wind turbine continued to increase, since 600 kW converters were being installed as standard. However, the capacity of total installed turbines hardly developed. As a consequence, manufacturing firms underwent reduced working hours, redundancies and collapse. The number of direct employees in manufacturing firms fell from around 1,400 in 1995 to 1,200 in 1996. The revenue of the German wind enterprises fell by up to 25% in 1996 (Tacke 2004, 215; Allnoch 1996, 1998).

The power companies had also unsettled the banks and thus, indirectly, the investors. As a result of the supposedly higher risks, financial institutions increased interest rates and demanded greater proportions of own funds (Tacke 2004, 208). In the case of the manufacturer Südwind, the actions of the banks resulted in bankruptcy. In July 1997, the second largest German manufacturer Tacke Windtechnik GmbH & Co KG also had to file for bankruptcy.

Technical Problems

The development of the market had a close interdependence with the progress of the technology. Particularly in the second half of the 1990s, the boom in demand resulted in a scarcity of coastal sites. In terms of technological formation, this scarcity generated an increasing pressure to develop ever-larger wind turbines, since these would use the limited remaining space more efficiently than smaller turbines.

Excessively short product life cycles of 5 years at most and insufficient product maintenance also led to increased interferences. A central technical challenge was to also improve the turbines in this respect, as generations of turbines coming onto the market in rapid succession. As a result of the observed fact that they spent more time standing still than running, some turbine types were regarded negatively and fed doubts concerning the reliability of the technology.

Load Limits of the Grid

In the mid-1990s, the load limits of the grid were already noticeable. It was particularly those sites that promised a high yield of wind, but could only accept a limited load, due to low local population densities and respective limited transmission capacities. In the funding guidelines of the coastal states, however, the relevant grid tolerance criteria emphasized that intelligent management could alleviate the capacity problem. In terms of the technological development, this had the consequence that, with increasing capacity problems, it was particularly those installations with indirect connections to the grid via a power inverter system that gained an advantage through pitch regulation. The loading capacity of the grid was (and is) a central conflict in which one side of the argument focuses on what is technically feasible and the other takes the position that grid integration is a matter of control engineering and managerial competence (Molly 2005, pers. comm.).

7.2.4.5 Actors in the Constellation

The central actors in this precarious phase in were the actors of the dominant system. The energy sector fought keenly against the StrEG. Financial actors gained significance; whilst at the same time governmental actors behaved in an inconsistent way, and therefore had an impeding effect.

It became evident that two coalitions were beginning to form: those who profited financially from wind power were positive with regard to the image of wind power. Those who had no share in the profits, and who were solely exposed to the negative effects of this techno-industrial form of power generation, used arguments from a variety of contexts in order to express their discomfort. Criticisms concerning energy policy were thereby mixed with criticisms regarding the economic reasonability and with counter-arguments from a nature conservation perspective.

Opponents to wind power and citizens' groups had until now worked for their own interests and there had been little coordination. This changed with the founding of the Federal Association for Landscape Preservation (BLS) in May 1995, which functioned as a forum for opponents of wind power. Local resistance was additionally strengthened by critical publications and media coverage which questioned the viability of wind power as an energy policy alternative (Ohlhorst 2009, 204–205).

7.2.4.6 Interpretation of the Constellation: Driving Forces and Constraints

In this phase, the opponents of the StrEG organized themselves by forming lobby groups and succeeded in establishing an atmosphere of uncertainty. This uncertainty took hold of manufacturers and investors as well as regulatory authorities, banks and politicians, which emphasized the powerful position of the German energy sector. Besides the uncertainty of the market, the sluggish planning process also had a negative impact on development. The failure to adjust building legislation to the new generation of turbines also had an obstructive effect on the construction of new turbines. Many local authorities were besieged by floods of applications and were overstrained by the process of implementation.

This still young sector was subject to massive pressures. Furthermore, it had to deal with the consequences of dynamic growth during the breakthrough phase, which appeared in the form of economic problems (price erosion) and resulted in a financial slump as well as a drop in employment figures. Ecology groups expressed criticism of the increasingly industrial character of wind power. This phase in the innovation biography of wind power was defined by an economic and legal struggle in the niche and the economic and legal resistance of the traditional energy sector.

Technical and economic restrictions also played a role in the story. The limited capacities of the grid had an adverse effect when the process of bringing new turbines onto the grid was delayed. The image of wind turbines was affected when technically immature models came onto the market as a result of frantic cycles of innovation, and deficits in operation occurred (Twele 2005, 32).

State actions slowed things down during this phase. The motivations and aims of state actors were vague and inconsistent, such as the consideration of a reduction in feed-in tariffs by the Federal Economics Ministry. Unlimited privilege to site wind turbines, as desired by the wind and farm lobbies, turned out to be unachievable, which had the effect of bringing the granting of planning permission for new turbines to a virtual standstill. However, this escalation also drove forward the process of changing the regulatory fundamentals of planning permission (building law) as well as the development of respective policies at the state level (planning authority ordinances[27]).

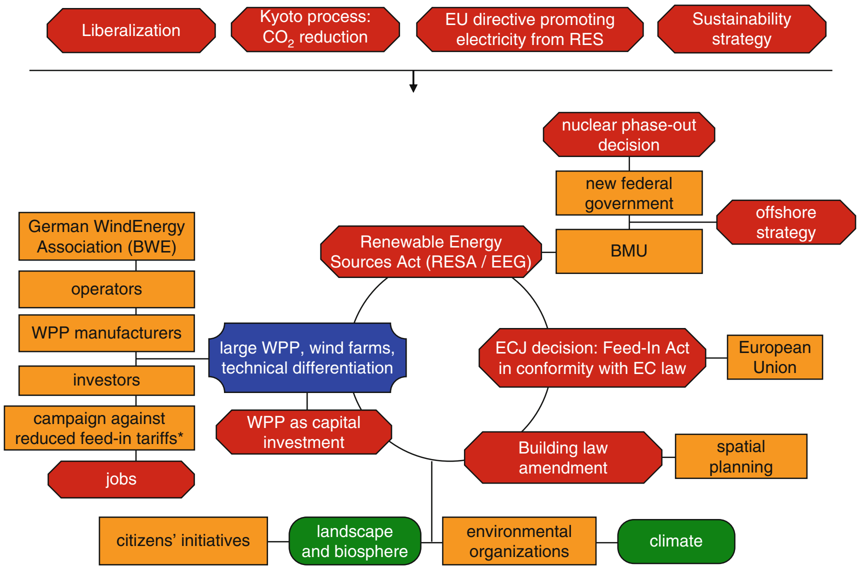
7.2.5 Phase 5: Wind Power Boom and Reorganization 1997/98 to 2002

7.2.5.1 Characteristics of the Constellation

This phase (see Fig. 7.6) was defined by the resolution of several legal uncertainties, political appreciation of renewable energy and the reorganization of the emancipated niche constellation – all of which led to a “wind power boom”.

Following the change of government, the social democrat – green coalition put a new emphasis on their energy policy. They approved the Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz – EEG) as well as a climate protection program, thereby signaling that wind power had a more secure future. Furthermore, building and zoning legislation were amended and the planning status issue was tackled by granting privileges to wind power. The European Court of Justice also made an important contribution to legal and investment security by acknowledging

[27] Site decisions are primarily controlled by orders from the chief planning authority of each state. To an extent, they also contain conservation-based zoning requirements (for protected areas, areas important for birds, aesthetically sensitive areas). Within the context of public consultations, conservation-based formulations of zoning requirements can end up not just coordinating events, but can also have a restrictive effect when they are involved in the planning process.



BMU = Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
ECJ = European Court of Justice
RES = Renewable energy sources
WPP = Wind power plant
* = Aktion Rückenwind

Fig. 7.6 Constellation phase 5: wind power boom and reorganization 1997/98 to 2002

that the StrEG conformed to EU law. Turbine manufacturers, operators and investors reorganized themselves both as a sector and as an initiative (Aktion Rückenwind). Technical developments – increasing capacity and scale of wind turbines and technical differentiation with specific advantages for different sites – reflected the newly won capabilities and thereby contributed to the boom.

7.2.5.2 Sector-Specific Context, Influencing Factors and Processes

Initiatives at the European Level

At the European level, greater efforts were being made to advance the expansion of renewable energy (see Section 3.3). These had great significance for the context of wind power in Germany, not only in this phase, but primarily in the phase that followed. In this way, the EnWG of 1998 (see Section 3.9.3.1) afforded wind power well-secured prospects with respect to grid access. The European Breakthrough Campaign ("Kampagne für den Durchbruch") in 1999 (see Section 3.3.2.2) made a first step toward achieving the aim of doubling the share contributed by renewables to total energy consumption from about 6% in 1995 to 12% in 2010. For the wind power sector the interim objective for 2003 was to increase installed capacity

Europe-wide from 6,400 MW in 1998 to 10,000 MW. By 2001, this target had been far exceeded, with an installed capacity of 17,200 MW (Staiß 2003).

The Sustainability Strategy of the Federal Government

In 2002, the Federal Government presented a strategy for sustainable development (see Section 3.5.5). Climate protection through the adoption of renewable energy sources was a component of this strategy, and wind power was highlighted as being one of the leading technologies. Its expansion was, however, to be carried out in an environmentally sound manner. The construction of offshore wind farms was seen as an important contribution to making the Federal Government's plans for future energy supply sustainable. The purpose behind was to reduce dependence on energy imports and to improve the sustainability of power generation (Bundesregierung 2002, 157).

Kyoto Protocol

In July 2001, the Kyoto Protocol was ratified in Bonn. Germany committed itself to reducing its carbon dioxide emissions by 21% by 2010. This target had great significance as justification for the extensive support being issued in Germany, particularly to wind power.

7.2.5.3 Governmental Guidance

Change of Government

With the change of Federal Government in fall 1998, the priorities for energy policy were shifted in favor of environmental policy priorities (see Section 3.5.2). The coalition agreement (SPD/Bündnis90/Die GRÜNEN 1998) set a target of reducing CO2 emissions by 25% by 2005, relative to 1990 levels. The National Climate Protection Program had formulated a target to double the percentage of renewable energy in Germany by 2010.[28] The enactment of the EEG in 2000 (see Section 3.7.2) was the primary measure by which the Federal Government sought to expand renewable energy.

Building Law Amendment: Privilege and Zoning

Some actors, particularly the Renewable Energy and Environment department of the Federal Environment Ministry, got involved in pushing for changes to

[28] National Climate Protection Programme. Federal Government resolution of 18 October 2000. Fifth report from the interministerial working group 'CO2 Reduction'. http://www.bmu.de/files/pdfs/ (Accessed: 6 August 2009).

building and zoning legislation to make the planning process more effective for those seeking to erect wind turbines and to reduce conflicts on the sprawl of wind power. One change to the building legislation (§ 35 para. 3 BauGB) containing the new regulations concerning privileges came into force on 1 January 1997. For wind turbines in non-urban areas without zoning there was now a right to permits as a matter of principle, unless such permission went against important public interests such as conservation, species preservation, recreation, or if the overall appearance of a landscape or townscape was at stake.

These privileges were limited by the simultaneous introduction of a so-called planning proviso. This sought to exclude undifferentiated siting of wind farms over large areas. The amendment said, by a certain deadline, municipalities had to have prepared land-use plans appointing “concentration zones” for wind power. However, only once local authorities had made such a designation in their land-use plans did the remaining areas receive a corresponding exemption from the obligation to accept new turbines.[29] These areas were to be kept free of wind turbines.

Because any change to land-use plans cost time and money, few local authorities made use of designated concentration zones, even in areas of high demand. If local authorities took the effort, they often made use of this tool to reduce wind power use in their area of responsibility. Some municipalities went too far: they deliberately designated concentration zones unsuitable for wind power use. They had to change their policy when they were accused of obstructing the deployment.[30]

The privileged position of wind power, in combination with the planning proviso, required cooperation at the regional and local levels.[31] At the regional level, so-called appropriate sites for wind power had to be appointed. This form of positive designation of areas for a certain use was a regional planning novelty. Within the appropriate sites, local authorities had to further differentiate potential sites for wind power through the designation of concentration zones and by securing those sites in the planning regulations. Through the designation of appropriate areas, the reliability of the planning process was substantially improved for wind farm operators.

[29] In this respect, this appeal had a lasting effect on the process for the approval of wind turbines (Cf. Rehfeld et al. 2001; Neumann 2001; Neumann et al. 2002).

[30] Federal Administrative Court decision 4 C 15.01 of 17 December 2002 made it clear that such a practice would be unlawful and such planning would therefore be open to legal appeal.

[31] Following the amendment of the Federal Regional Planning Act (Bundesraumordnungsgesetz – ROG) in 1997 and the corresponding amendment of the State Regional Planning laws in 1998, the utilization of wind power became a matter for regional planning. The introduction of a regulatory mechanism at the regional level was especially necessary in the case of the states of the former GDR, where there was no comprehensive legally binding land-use planning already available and so no effective possibilities for regulation at the municipality level (von Nicolai 2005, pers. comm.). Wind power production targets were prescribed in state regional planning programs and broken down to the regional level. For instance, in Lower Saxony, precise MW specifications were provided for individual administrative districts.

The Renewable Energy Sources Act (EEG 2000)

The EEG came into force on 1 April 2000 (for the political process, see Section 3.7.2). It was intended to stimulate dynamic development, mobilize private capital and thereby enable the introduction of mass production. Electricity derived from wind power was to be paid for at the rate of at least 17.8 pfennig/kWh for a period of 5 years. With the decision of the European Court of Justice[32] made on 13 March 2001, the German StrEG – which had meanwhile been continued in the form of the EEG – had been recognized as lawful. The decision ended a legal uncertainty that had lasted 3 years.

7.2.5.4 Technology and Market Developments

Technological Differentiation

During this phase, wind power was characterized by continuing rapid increase in the capacity and technological differentiation of turbines, the scale of the wind farms and the beginnings of offshore wind power.

For those wind turbines intended for use on land, two dominant turbine designs became apparent: in the case of smaller wind turbines, asynchronous grid-connected fixed-speed turbines dominated. The rotor blades for such models are fixed to the hub immovably, allowing no regulation of output. The cost of their construction, however, was lower and they required little maintenance during operation. In the case of larger wind turbines, technically more elaborate constructions with pitch regulation and variable speed operating control[33] had become established. For these turbines, it was possible to change the angle of the rotor blades and so increase the yields from the wind. Large turbines were equipped with gearbox-free concepts and multi-polar generators (Hemmelskamp & Jörg 1999, 84). Techniques allowing variable rotational speed not only made an increase in capacity possible, but also optimized the turbines' grid compatibility (Heier 1997, 95 sqq.).

This technological differentiation allowed a diversified development of wind turbines: different turbine types with specific advantages could be customized according to the site. Technological development was concentrated on corrections, improvements of details and progress with regard to turbine performance (for example, efficiency, capacity, life-span, power quality). At the same time, advances in the development of electronic components for the regulation and controlling of the turbines were of increasing significance.

[32] Cf. verdict of 13 March 2001, Rs. C-379/98 "Die Vereinbarkeit des Stromeinspeisegesetzes und des EEG mit dem primären Europarecht". Commentary in Natur und Recht 2002, p. 148.

[33] Variable speed turbines have the advantage of being able to produce electricity of the required power frequency independently of their rotation speed.

Impact on Employment and Market Access

The development of jobs in wind power showed high rates of growth during this phase. While in 1998 just 15,600 people were employed in this sector, the number had grown to 53,200 by 2002 (Edler et al. 2004). Germany now was the worldwide leader in usage of wind power, yet Germany only accounted for ca. 30% of worldwide production – a field in which Denmark was the leader with 43%. The establishment of the Renewable Energies Export Initiative[34] in 2002 sought to increase the export of wind turbines, thereby increasing or maintaining the number of jobs in the sector.

The EnWG of 1998 stipulated that a statutory order would regulate the design of grid conditions and payments. Germany thereby became the only EU member state to have chosen to implement the EU directive using "negotiated grid access", thereby doing without the adoption of a regulatory authority with the power to determine tariffs and conditions for grid access. The negotiation of tariffs and conditions for grid use took place in the context of association agreements for the electricity and gas sectors. The precise specification of grid access tariffs, however, remained the responsibility of individual grid operators. It was hence left to the businesses which were feeding power to the grid to negotiate access rights and fees with grid operators. If a grid operator violated the order demanding discrimination-free access to the grid and fair remuneration, the public trade commissions would be able to act retroactively. The result of this regulation was that, even though explicit grid access discrimination rarely occurred, transmission fees were very high – the highest in Europe (Monstadt 2004, 170). The European Commission complained that the strong market position of established power companies could hinder access to the market for new participants (COM 2003, 4).

Table 7.3 Development of turbine numbers and installed capacity in Germany 1997–2002 (Molly 2009, 9)

Year	Capacity installed/year in MW	Cumulative Installed Capacity in MW	Total turbines/year	Cumulative total turbines	Average capacity of installed turbines/year in kW
1997	533.62	2,079.97	853	5,178	628.90
1998	793.46	2,871.48	1,010	6,185	785.60
1999	1,567.68	4,439.16	1,676	7,861	935.37
2000	1,665.26	6,104.42	1,495	9,359	1,113.80
2001	2,658.96	8,753.72	2,079	11,438	1,278.96
2002	3,239.96	11,994.22	2,321	13,752	1,395.93

[34] In the summer of 2002, the Bundestag commissioned the German Energy Agency (dena) to set up and implement the Renewable Energy Export Initiative (Bundestagsantrag 14/8278). The aim of the export initiative was (and is) to support networking and activities such as support of the export of renewable energy technologies (BT-Drs. 15/1862 of 31 October 2003).

Development of Turbine Numbers and Installed Capacity

The boom in wind power during this phase becomes clear in light of the development of turbine numbers and the rise in installed capacity (see Table 7.3).

7.2.5.5 Actors in the Constellation

State Actors

The pivotal actor during this phase was the new Social Democrat – Green government. With the change that took place in fall 1998, the energy policy priorities of the Federal Government were explicitly moved to more sustainability. With the significant support of the respective departments of the Federal Environment Ministry, the government also took measures to push the realization of their energy policy goals. In keeping with these goals, the Climate Protection Program was enacted on 18 October 2000 and in the same year the German Energy Agency (dena) was founded. In fall 2002, after having established a department for renewable energy and the environment, and as a result of a decision taken by the Bundestag, the Federal Environment Ministry was put in charge of the amendment of the EEG. The department actively supported the development of onshore and offshore wind power.

On the European level, this phase saw the scene being set for a number of changes that had favorable consequences for wind power in Germany. Among these was the 2001 EU directive for the promotion of renewable energy as well as the Internal Market Guidelines for the Electricity Market from 1997. In 2001, the European Court of Justice also cleared the way for the further spread of wind power through its verdict, which attested to the legality of the German StrEG with respect to the Treaty establishing the European Community (Treaty of Rome).

With the amendments of the zoning regulations, an administrative reorganization was carried out. New actors from the zoning and planning sectors as well as from the environmental and conservation administrations of the states joined in, in order to minimize conflicts arising during the continuing deployment of wind power.

The importance of regional planning authorities and municipalities also increased significantly during this phase. Through the designation of appropriate sites, decisions were made at the regional planning level, which were intended to unfold a strong commitment of the subordinate levels and third parties (see Section 7.2.5.3).

Network Formation

The new boom period was supported by the “tailwind initiative”. A broad spectrum of actors opposed the Federal Economics Ministry’s plans for the reduction of feed-in tariffs. In September 1997, an alliance of manifold actors organized a demonstration supporting renewable energy and defending the StrEG.[35] What is more, representatives of all parties represented in the Bundestag spoke in favor of supporting renewable energy. Such an alliance for the expansion of renewable energy had never before existed in German energy politics. The protest was able to avert the proposed drop in feed-in tariffs.

In December 2001, the Offshore Forum Windenergie was founded in Hamburg. Developers and proponents, whose offshore projects had already achieved an "advanced status", were members of this forum. The aim was to represent shared interests in offshore wind power to political bodies, public authorities, trade, environmental and conservation groups as well as to the public and to advocate the improvement of legal, economic and administrative conditions for offshore wind power.[36]

Environmental Groups

For environmentalists, a persistently negative attitude to wind power was not favorable. The discrepancy between an endorsement of wind power as a contribution to climate protection and a rejection based on conservation and landscape protection continued to be seen as "wanting to have their cake and eat it too", though in the face of emerging climate change this topic was more strongly emphasized.

Energy Suppliers

Power companies continued to have a retarding effect. With their significant market power, they sought to hinder market access for new participants in the market, in particular by charging high grid access tariffs.

7.2.5.6 Interpretation of the Constellation: Driving Forces and Constraints

In this phase, all-encompassing regulations at the national and EU levels allowed the constellation to stabilize. The context – the Kyoto Process, EU directives for the advancement of renewable energy, sustainability goals and

[35] The alliance consisted of environmental and conservation organizations (Naturschutzbund Deutschland – NABU), other environmental groups, renewable energy associations, the German Farmers' Union, turbine manufacturers, protestant churches and the German Industrial Union of Metalworkers (IG Metall) (Tacke 2004, 214). The principal organizer of the event, which had 5,000 participants, was the BWE (Federal Wind Energy Association), which had only been founded a few months before.

[36] The founding members of the forum were the following companies: Energiekontor AG, Future Energy AG, GEO mbH, Neptun TechnoProduct GmbH, Plambeck Neue Energien AG, PROKON Nord Energiesysteme GmbH, Amrumbank West GmbH, 1. SHOW-VG mbH and Winkra-Energie GmbH. Cf. www.iwr.de/... (Accessed: 11 May 2009).

energy market liberalization – created an optimal combination of environmental and economic policy goals and tools which had the effect of further lowering barriers to market entry.

Legislation, financial incentives, the formation of coalitions, as well as strengthened interactions between market and state advanced the process of innovation. The EEG in particular developed far-reaching effects. In addition, amendments to planning and building regulations afforded operators a strong legal position with respect to laying claim to the non-urban area. The regulatory impetus generated by this amendment was, alongside the EEG, decisive for the boom in development. This was expressed in the further deployment of wind turbines. Wind power was now able to tap the potential of the mass market.

The convergence of climate and other environmental policies and tools with energy and economic policy goals had a special impact during this phase. The harmonization of departmental targets, which had up until then been cumulative and mostly competing (especially those of the Federal Environment Ministry and the Ministry of Economics) developed momentum. Through the EEG, actors in the traditional energy industry also gained the possibility of being able to profit from wind power.

The economics of innovation took a step forward and was above all supported by professionals, medium-sized businesses, developers and corporations. Cutthroat competition between the operators and manufacturers ("expand or die") led to a shakeout of a modest number of businesses. In comparison to the power companies, however, they exhibited only a limited level of economic power.

Unintended consequences also occurred as a result of this new dynamic, such as the sprawl of wind power facilities and conflicts of goals, particularly with respect to landscape protection and conservation. A number of nature conservation groups[37] took on the role of mediator between conflicting interests in wind power and nature conservation (wind power was endorsed, but not universally).

Though there was local resistance to this new technology, it still found broad approval within society. The societal acceptance of innovation also found an expression in the fact that more and more people were finding employment in the new sector or were investing private capital in the new technology.

During this phase, institutionalization also stabilized the innovation process. Important contributors to this were the EEG and the amendments of the planning code, as well as the change in departmental responsibility (the Federal Environment Ministry was then in charge for renewables) and the establishment of lobby groups (German WindEnergy Association – BWE).

The possibilities for integrating the new technology into the electricity grid were given differing assessments, depending on the interests involved. Thus, the transmission system acquired significance as a potential technological limitation. Problems concerning the uptake capacity of the grid had been primarily regional in the previous phases (and mostly concerned the windier northern states). With what

[37] E.g. BUND (Bund Naturschutz Deutschland); DNR (Deutscher Naturschutzring); NABU (Naturschutzbund Deutschland).

was called the dena Grid Study (dena 2005), the topic came onto the federal agenda, thus gaining a new dimension. Proponents of wind power feared that the grid's load limit might lead to a bottleneck in innovation. The discussions were technically based, but had political connotations: access to the grid presented itself as a struggle between the professionalized niche actors and the dominant industry. Last but not least, this gained significance when it came to the issue of offshore wind power.

7.2.6 Phase 6: Consolidation and Divergence of the Pathway from 2002 Onward

7.2.6.1 Characteristics of the Constellation

In the sixth phase, the deployment of wind power in Germany divided into two paths: onshore and offshore wind power (Fig. 7.7). The attitude of the wind power sector was still positive at the beginning of the phase. Though onshore expansion stagnated and declined for the first time from 2002 onward, it was still possible to compensate for declining sales through export not only to European countries, but

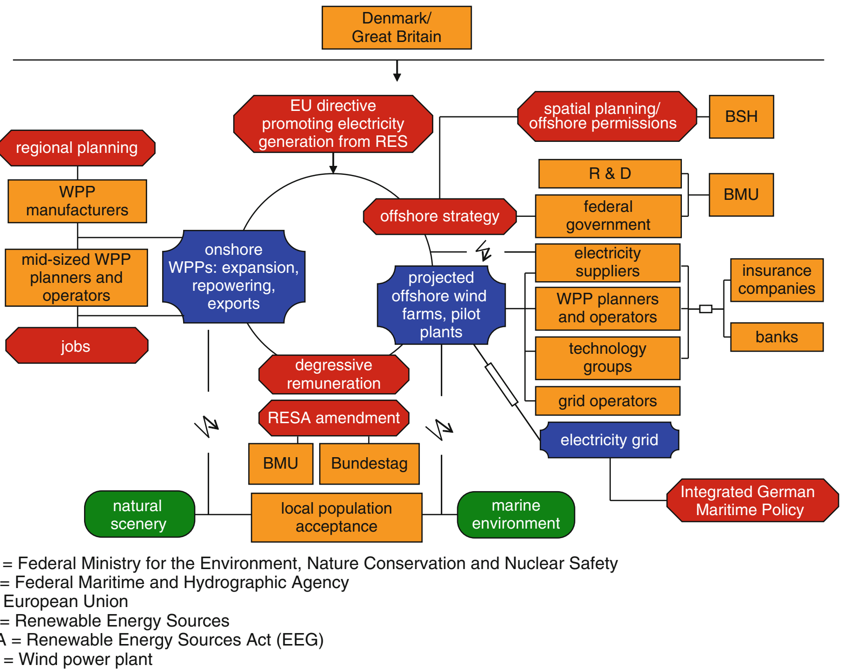


Fig. 7.7 Constellation phase 6: consolidation and divergence of the development trajectory from 2002

beyond beyond the borders of the EU. This was in addition to continuing to build turbines in the megawatt range. The start of the development of offshore wind power relied on the EEG, the economic success of onshore wind power and the positive examples in Denmark. Offshore energy was supported by an alliance of new actors (industry, power companies and the Federal Government). The alliance itself was supported by the state's commitments to climate protection.

7.2.6.2 Sector-Specific Context, Influencing Factors and Processes

Influences from Abroad

Denmark and Great Britain already had offshore wind farms during this phase. It was because of this background that the German wind power sector was motivated by the concern that it could lose the leading position it had fought for in onshore wind power to incipient technological and economic developments in offshore wind power in Denmark and Great Britain.

7.2.6.3 Governmental Guidance

EEG Amendment 2004

In August 2004, the revised version of the EEG came into force (see Section 3.7.2.2). What was significant for the wind power sector was that the next evaluation of the act was scheduled for as late as 2007. Manufacturers, developers and operators welcomed the resulting security for the financing and realization of wind farm projects in Germany.[38]

In comparison with the previous version of the law, the EEG 2004 incorporated many innovations for wind power: feed-in tariffs for onshore turbines were reduced (degression was increased from 1.5% to 2%) with the aim of increasing the pressure to lower costs and to achieve competitiveness with other technologies for electricity generation in the medium term. In the revised version, grid operators were not obliged to pay for electricity from turbines which were not able to achieve at least 60% of the respective reference yield. This was intended to make it less attractive to site turbines in less windy areas.

The revised version of the EEG was intended to increase economic incentives for repowering[39] by making it easier to calculate revenues and to prevent wind turbines in uneconomic sites. However, the reduction in compensation for wind-generated electricity also had a negative effect on the repowering.

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[38] A further amendment was implemented in 2008.

[39] "Repowering" is the term used to refer to the exchange of old turbines for newer, higher-capacity models.

The amended version of the EEG in 2004 was important for setting the future course of wind power in Germany.[40] In addition, a study commissioned by the Federal Environment Ministry “An analysis of the advantages and disadvantages of different support schemes for advancing the development of offshore wind power in Germany” (ISUSI 2005) came to the conclusion that the feed-in tariff model had proven extremely efficient compared to the rest of Europe. The strongest incentive for the expansion of wind power capacity was the feed-in model, rather than quota-based or tender-based models.

Nevertheless, for both turbine operators and manufacturers, considerable uncertainties continued to persist with regard to the future development of the domestic market. Thus, for example, from the perspective of potential investors, offshore wind farms would only be attractive if higher EEG compensation for offshore electricity was paid.

EEG Amendment 2009

In January 2009, the new amendment to the EEG came into force. Due to the 10% rise in steel and copper prices in 2004, the wind power sector requested higher remuneration for electricity generated by wind turbines. On 1 January 2009, the initial payment rate for newly commissioned land-based wind turbines was increased to 9.2 cents/kWh (from 8.03 cents/kWh), then reduced by 1% each year (previously 2%).

In order to advance the process of repowering, the initial payment for land-based wind turbines increased by 0.5 cents/kWh. However, a new turbine is required to have at least twice the capacity of the replaced one and to not exceed five times the previously installed capacity. In addition, the turbines being replaced are required to have been located in the same county or a neighboring one and must be at least 10 years old.

With the new EEG, the connection and compensation for electricity from newly grid-connected onshore wind turbines was for the first time attached to the requirement that certain technical specifications for grid integration be fulfilled.[41] The aim of the new regulation was to establish a minimum standard for integration with the transmission system and for the behavior of wind turbines should a fault occur. As the technical requirements were fixed by law, the issue of the grid integration of wind turbines acquired special importance. With these amendments, the EEG was reacting, among other things, to the need for action specified in the dena Grid Study (dena 2005).

The connection requirement is now a device on the wind turbine which permits a remotely controlled reduction of the feed-in output in the event of grid overload.

[40] Cf. the regulations affecting offshore wind power in EEG 2004 in Section 0.

[41] Cf. www.eeg-aktuell.de (Accessed: 2 February 2009).

If the turbines fulfill these grid requirements, they receive a system service bonus (0.5 cents/kWh) in addition to the EEG compensation. New turbines which fail to fulfill these requirements have no entitlement to EEG compensation. From 1 January 2011, the requirement will also apply to old turbines, which will then have to be upgraded.[42] In the case of smaller individual turbines the upgrading costs could be uncomfortably high. In the case of turbines with stall regulation emergency stops are possible, but a smooth reduction in output is not.

The System Service Ordinance

In June 2009, the Federal Government enacted the System Service Ordinance for Wind Power ("Verordnung zu Systemdienstleistungen durch Windenergieanlagen" – SDLWindV), which was intended to increase the security and stability of transmission systems despite the growing proportion of wind power. This enactment corresponded to the requirement that wind turbines take on some of the characteristics of conventional power plants and thereby assume more responsibility for grid security. SDLWindV does not prescribe the use of any specific technology, but rather relates to the characteristics of the power being fed into the grid at the point of connection. For newly installed wind turbines, remuneration will become a condition of the requirements of SDLWindV from the middle of 2010 onward. In order to cover the extra costs, a higher initial compensation will be granted.

From Generation to Feed-in Management

Electricity from renewable sources is to be given priority by grid operators (§ 8 EEG). One legislative innovation is the introduction of what is referred to as feed-in management in order to deal with bottlenecks in the grid in § 11 EEG 2009. The regulation established requirements under which grid operators only in exceptional cases had the right to reject or partially reject offers of sustainably generated electricity (Reshöft & Sellmann 2009, 142). The amendment has improved investment security, as it limits opportunities for grid operators to exclude or cut off inputs to the grid and minimizes loss of income for operators. A financial improvement also came about in that grid operators are now required to pay compensation for any power that has not been accepted within the framework of feed-in management.[43]

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[42] § 66 para. 1 clause 1 EEG.

[43] Additionally, grid operators are, according to the new EEG, expressly required not only to carry out grid expansion, but also optimization and enhancement of existing transmission networks.

Ordinance for the Further Development of the EEG Equalization Scheme

Those quantities of power that were paid for according to the EEG had so far been divided up between all power companies in Germany (the EEG equalization scheme – EEG-Ausgleichsmechanismus). Particularly in the case of small and medium-sized power companies, this could lead to considerable excess costs. From January 2010, the Equalization Scheme Ordinance ("Verordnung zur Weiterentwicklung des bundesweiten Ausgleichsmechanismus" – AusglMechV) simplified the process in that electricity from renewable sources no longer had to be physically passed on to the distributors. Instead, a financial equalization took place for the EEG electricity that was brought onto the electricity market. The restructuring of the equalization scheme is intended to reduce effort, risks and excess costs for those taking part. Whether this new regulation does indeed develop the expected momentum to further develop wind power remains yet to be seen. Critics fear that the equalization scheme could have a negative effect on the future development of wind power (Jarras & Voigt 2009).

7.2.6.4 Development of Onshore Wind Power

Techno-economic Development Onshore

The expansion of installed capacity reached a peak of ca. 3,200 MW/year in 2002. Following this, the rate steadily sank to about 1,800 MW/year by 2005 (see Fig. 7.8). The reason was that zoning restrictions were having an increasingly limiting

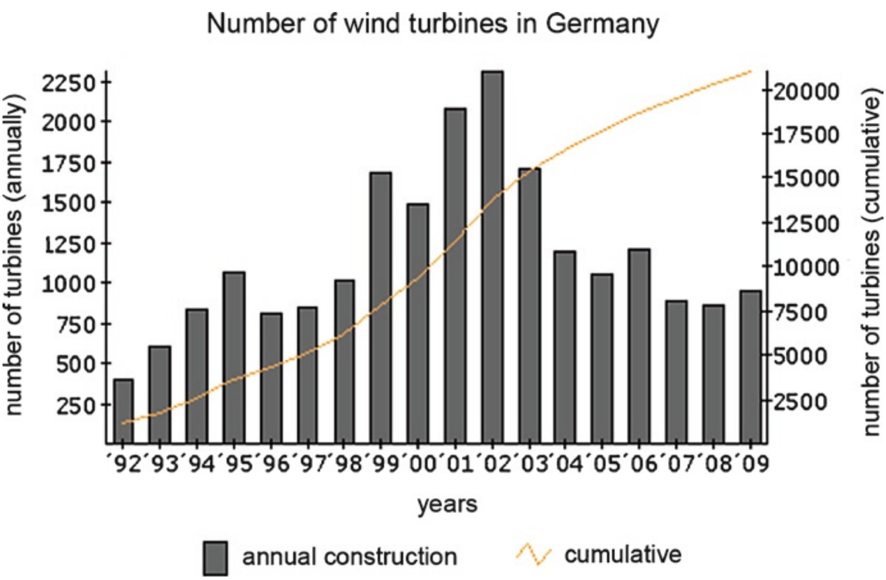

Fig. 7.8 Number of wind turbines in Germany, cumulative and annual expansion (BWE 2009)

effect on the deployment of wind turbines. The annual expansion rate of newly installed capacity dropped because economically viable sites without planning restrictions were decreasing. Thus, the potential for the development of wind power in Germany was being limited by zoning.

In 2006, another temporary increase to 2,250 MW/year occurred. In 2007 and 2008, expansion stabilized at ca. 1,600 MW/year (1999/2000 levels). Despite having decreased in relation to the boom years, installation rates are still high. At the end of 2008, a total of almost 24,000 MW of capacity had been installed, and the number of turbines amounted to some 20,300. According to Ahmels (2009, pers. comm.), the construction of onshore wind farms constituted, as it previously had done, the core business of the German wind power sector. With around 240 turbines and an installed capacity of around 460 MW, the process of repowering (see below) had only achieved a low level of significance.

The Influence of Planning Restrictions

This was caused by the coming into effect of planning regulations through the designation of appropriate areas on the regional and municipal level. Limitations on the choice of sites arose from clearance and no-go criteria. These were specified in state wind power ordinances and applied by regional planning authorities, and were aimed at avoiding conflicts with residents and conservationists. The Habitats Directive specifications had an especially restrictive effect on wind power as a result of the large areas involved, particularly those that applied to the habitats of protected birds and bats. The impacts on birds had turned out not to be as grave as had been feared. In conjunction with intensifying opinions concerning species protection, from around 2005 the effects of turbines on bats began to take center stage.[44]

As in the previous phase, an emphasis was put on approaches to achieve a spatial concentration of wind power via the designation of suitability and priority in regional plans and through the concentration zones specified by local authorities. In contrast to the previous (fifth) phase in which appropriate areas temporarily produced reliability in planning as well as in available sites for wind farms, in this phase, the zoning had an increasingly restrictive effect. The annual expansion rate of newly installed capacity fell.

Particularly in the north-western states of Schleswig-Holstein and Lower Saxony, the targets set in the 1990s for expanding the use of wind power had already been met and even, in some regions, significantly exceeded.[45] In the discussions concerning the designation of additional sites, this success in turn served to

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[44] Cf. inter alia BUND 2004; Hötker et al. 2004; Sprötge et al. 2004.

[45] In Schleswig-Holstein, at the end of 2003, ca. 25% of electricity consumption was covered by wind power (Rohwer 2004). By the end of 2003, 2,547 wind turbines, with an installed capacity of around 2,000 MW and a productivity of some 3,000 Gigawatt hours had been installed. The energy concept of Schleswig-Holstein, written in 1992, had aimed to achieve this amount by 2010.

justify a negative attitude to the further expansion of wind power on the part of the state governments of Schleswig-Holstein and Lower Saxony. If further expansion of wind power use was to take place on land, it was not to be achieved through further sprawl. Increase in capacity was instead to be achieved through repowering and the intensified use of offshore turbines (Voigt 2006).

Permit Requirements

The legal basis for the approval of turbines was changed in 2004. As a basic principle, from 2004 it was required that all wind turbines receive approval in accordance with the Federal Immission Control Act ("Bundesimmissionsschutzgesetz" – BlmSchG). The responsibility for approval was transferred from local authorities to the immission control authorities. Planning permission was thus integrated into immission control permission. For the proponents of wind power this presented an improvement. On the one hand, this freed local authorities from the pressure to grant permission, but on the other hand, they lost their decisive role in granting approval for the construction of wind turbines. Local authorities now took on the role of a – still important – party in the process. It sometimes required a number of years to adjust regional or zoning plans to the new legal situation as well as to the increasing size of the turbines. This inertia restricted both expansion and repowering.[46]

Repowering Wind Turbines

Repowering was not just promoted as a way of achieving increased capacity.[47] The associated reduction in turbine numbers was (and is) regarded as advantageous from the perspective of limiting environmental and visual impacts. Single and widely scattered turbines outside designated concentration zones were to be eliminated during the course of repowering and the new turbines would then be subject to planning regulation (cf. e.g. Fritsche 2003; Wustlich 2007, 20). Zoning and regional planning representatives from the north-eastern states pointed out that the

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[46] In the turbine approval guidelines according to the Federal Immission Control Act (BImSchG; cf. Index of Legal Sources), the required maximum noise levels and minimum distances to residential areas play the most important role. Further grounds for restriction such as conservation issues are brought in when respective public stakeholders are involved. On the one hand, one reason for restrictions (bird protection) became weakened and seen in a different light while, on the other hand, new reasons for restrictions (bat protection) came into play.

[47] Replacing old turbines with new, higher capacity turbines was intended to generate a significant potential for further growth in installed wind power capacity. Potential analyses for the north German coast led to expectations of a significant increase in installed capacity (Deutsche WindGuard 2005a), even when taking into account limitations derived from siting criteria (Deutsche WindGuard 2005b).

designated appropriate sites definitely still had potential for development and should be used before any new approvals should take place.[48]

However, the replacement of old turbines progressed only very slowly during this phase. This was partly due to economic reasons (Köpke 2004 und 2005a). To a large extent, the turbines erected had not yet completely amortized. Furthermore, if the investment costs of a turbine had not yet been refinanced (10 years after raising the credit at the earliest), it was then difficult to raise the required capital investment for the new turbine. The degression of feed-in tariffs came on top of all this. High capacity turbines may not spend enough time benefiting from high compensations to be able to refinance themselves within a certain time period. As a consequence, repowering was regarded as financially unpromising during this phase (Köpke 2004). DEWI expected that economic constraints alone would mean that appreciable repowering will only be able to occur from 2010 onward in Germany.[49]

Planning and building regulation presented repowering with another obstacle, in that permission for turbines situated outside areas covered by zoning laws lapses as soon as the old turbines have been demolished (Maslaton & Kupke 2005). If these areas were not part of designated appropriate areas for wind power, then a renewal of permission to build a turbine in the same place was unlikely. A significant restriction came about as a consequence of the height limits and siting regulations for wind turbines established several years before in the context of zoning. The restriction of turbine height to below 100 m was no longer consistent with the dimensions of new turbines (Wustlich 2007, 20). However, a corresponding readjustment of municipial and regional plans would be a time-consuming exercise.

Some states, such as North-Rhine Westfalia systematically introduced height restrictions in order to limit possibilities for repowering to take place. The introduction of a new wind power order,[50] which contained restrictive limitations on height and spacing demands, severely limited turbine operators' leeway.[51] At the same time, the state of North-Rhine Westfalia proposed a motion to abolish the regulations granting privileges to wind power.[52] Both attacks against the increase of wind power capacity significantly prejudiced the wind power market's attitude to repowering.

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[48] Increasing competition between operators was partly the cause of the as yet incomplete exhaustion of appropriate areas. According to von Nicolai (2005, pers. comm.), operators, fearing a reduction in wind yield, are taking legal action against constructions planned on the windward side of existing wind farms. This would also account for unutilized areas.

[49] Cf. Molly (2005, pers. comm.); Deutsche WindGuard GmbH (2005a).

[50] Cf. Joint circular order of the Ministry of Building and Transport, the Ministry for the Environment and Conservation, the Ministry of Agriculture and Consumer Protection and the Ministry of Economics, Medium-sized Businesses and Energy in North-Rhine Westphalia "Grundsätze für Planung und Genehmigung von Windkraftanlagen – WEA-Erlass" of 21 October 2005.

[51] BWE press review, 4 October 2005: "Abstandserlass für Windräder gibt falsches Signal". Cf. (Köpke 2005b).

[52] Cf. Motion by North-Rhine Westphalia put forward to the Bundesrat on 30 September 2005 (Bundesrats-Drs. 718/05) for changes to the Building Code. The motion was not successful.

Besides obstacles in planning and building law (not only height restrictions, but also clearances to residential areas due to immission control thresholds), the capacity of the grid also hindered the process of repowering. The grid needs to be capable of accepting sporadic spikes in current. However, the construction of new turbines often runs into transmission bottlenecks. Areas where this is of particular concern are the coastal regions of Lower Saxony und Schleswig-Holstein, in which the development of German wind power had started 20 years before.

Pressure of Competition and Increasing Focus on Export

By the mid-1990s, the wind power market was already increasingly export-focused.[53] Development over the previous years, with decreasing numbers of turbines being erected in Germany, increased the pressure of competition among manufacturers. Despite decreasing rates of turbine construction, Germany was a vigorously fought-over market and was regarded as being increasingly saturated and "to a large extent subdivided" (Köpke 2005b). A concentration into large providers, partly through mergers (Nordtank and Micon 1997, Vestas and NEG 2004), the bankruptcy of smaller providers (Südwind, Frisia, Lagerwey, Tacke) or take-over by global corporations (Enron, GE, Siemens) had led to considerable changes in the market. In this situation, smaller enterprises seeking new markets in Germany had little hope of success. At best, they were seen as having a chance as local niche providers on the international market (Twele 2005).

Manufacturers were therefore anxious to compensate for falling sales on the German market by increasing export. The export share of German manufacturers was able to increase annually from 2000 onward (12% in 2000, 59% in 2004, 74% in 2006, 83% in 2008).[54] However, just as is the case for offshore wind power, capital-rich vendors are essential for export (Twele 2005). The increased efforts of German manufacturers to assert themselves in the export market came (and still come) into competition with strong Danish and Spanish providers.

In the wind power sector, it is expected that once an export market has developed, the production of turbines is also transferred abroad in the course of knowledge transfer. It is also being emphasized that efforts need to be made in order to maintain wind power technology-related services as well as research and development activities in Germany (Voigt 2005, pers. comm.).

[53] In 1990 there was a special export subsidy for manufacturers, the "ELDORADO program", which had the aim of making the entry of German manufacturers into the world of export easier by supporting the large-scale production of turbines.

[54] Cf. Ender & Molly (2004); BWE 2008: Data sheet 2008 (accessed: 4 March 2009); see also press release from BWE and VDMA in January 2009: http://www.wind-energie.de/de/aktuelles/... (Accessed: 24 February 2009).

Wind Turbines for Export

The rise in exports sometimes required considerable technological developments, since many models had been constructed for the German market and were therefore not necessarily suitable for export. The required changes consisted on the one hand of those needed in order to transport the turbines, and on the other, of those related to operating conditions in the target country. As far as markets within Europe were concerned (Spain, Austria, Italy, Greece), the differences in technical requirements were limited. In contrast, in Asia (India, China, Japan) very different conditions had to be taken into consideration (Twele 2005).

Employment and Regional Value Creation

The continued rise in employment in the wind power sector and opportunities for regional value creation demonstrated the success of the sector. At the end of 2004, ca. 61,600 people were employed in the wind power industry. Of these ca. 23,500 were jobs in the manufacturing of wind turbines for the domestic market, ca. 9,100 were associated with the management and maintenance of turbines that were in operation within Germany and ca. 29,000 jobs were in the manufacturing of turbines for the export market.[55] According to the BWE, the number of jobs created within the sector as a result of the strongly growing world market had risen to over 90,000 by the end of 2007.[56] With this, a renewed and appreciable increase occurred in comparison with the previous phase. The effect of the wind power sector on the job market and its contribution to regional added value were no longer in question.

The sector is still defined by a predominance of medium-sized companies. It is particularly those areas with poor infrastructure which benefit from the employment opportunities. In northern Germany, the share of regional revenue is relatively high at ca. 50%, while in eastern Germany it is at its lowest at ca. 20% (ZSW et al. 2006, 6). In the coastal states of north-western Germany, where the stimulus to the local economy through the use of onshore wind power was already declining, hopes were set on the expansion of offshore wind power. A regional creation of value was also expected in that some ports would be expanded into support points for large building equipment and service ships.

Insufficient Grid Capacity

Limited grid capacity led in some cases to the shutting off of 20% of the turbines that were feeding power into the grid. The wind power sector complained of insufficient

[55] BWE (n.d.); see also http://www.wind-energie.de/de/statistiken/... (Accessed: 31 August 2009).

[56] http://www.wind-energie.de/de/statistiken/... (Accessed: 11 February 2009).

grid optimization and delayed grid expansion. The economic viability of the turbines affected drop significantly as a result of the long periods of being shut off (Weinhold 2008).

Actors in the Onshore Subconstellation

The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and the Bundestag

The most important actor during this phase was the Federal Environment Ministry (BMU). In 2002, the Bundestag had decided that the responsibility for renewable energy should be transferred from the Federal Ministry of Economics to the Federal Environment Ministry. In this way wind power experienced an institutionalization at the highest ministerial level – though it was limited in terms of personnel.

On amending the EEG, the Federal Environment Ministry and the Bundestag had to deal with the attacks from the traditional energy sector, whose representatives based their arguments on the high costs for the equalization of fluctuations in wind power as well as the costs of preparing the grid. In contrast, the Federal Ministry for the Environment and members of the Bundestag, especially those from BÜNDNIS 90/Die GRÜNEN[57] and the SPD faction argued that, in the course of repowering, grid operators could significantly reduce costs through better forecasting, more efficient grid management and more flexible power stations.[58] They also said that grid operators would receive payments corresponding to the grid usage tariffs in return for the balancing power.

Manufacturers, Planners and Operators

For many manufacturers, planners and operators in the wind power sector, this phase was one of consolidation. Businesses had to make an effort to remain internationally competitive (Weinhold 2009, 51). Because of the declining German market, they concentrated on the growing global market and the export of wind turbines overseas. The replacement of smaller turbines with large turbines of higher capacity proceeded hesitantly. Though the market for wind power was growing globally, the situation was tense as a consequence of the onset of the economic crisis in 2008. In many cases, the financial crisis meant that projects had to be delayed.

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[57] Bündnis 90/Die Grünen, the German Green Party was founded in the late 1970s. Since 1998, Bündnis 90/Die Grünen were part of the coalition government on the national level.

[58] Speech by Federal Minister for the Environment Jürgen Trittin on 28 January 2003 at the New Year's reception of the associations BWE (Federal Wind Energy Association)/Fachverband Biogas/VDMA in Berlin.

States

The German states played a decisive role when it came to restrictions in planning law. The parliament of Lower Saxony decided that “the landscape in some areas is heavily dominated by wind turbines and that on land, a considerable degree of saturation has been reached” (LT-Drs. 15/1615). The responsible authorities for state and regional planning announced that with the currently designated areas and their potential for development, the limits of the environmental and social acceptance had been reached. “It’s now enough – we cannot expect the citizens here to tolerate more” (Kegel 2005, pers. comm.). The state of Schleswig-Holstein also made a reference to limits to the population’s tolerance, saying that the then designated proportion of 1% of the land area could not be exceeded (Püstow 2005, pers. comm.). In terms of zoning, the cap was justified by a lack of tolerance within society. Above a certain density of wind farms, this would no longer be possible.

7.2.6.5 Development of Offshore Wind Power

Offshore Technological and Economic Development

Multi-megawatt turbines appropriate for offshore use are the center of technological development. Offshore wind turbines need to fulfill high technical requirements in order to guarantee safe operation and a low rate of failure. They are consequently more expensive than onshore turbines. Due to the higher costs of investment, larger turbines with higher capacities are required. Both their spatial extent and the number of turbines per wind farm exceed those of the units built on land until then. At present, a new generation of offshore wind power technology is being researched. The research spectrum extends from small 6 kW vertical-axis models to the vision of the 20 MW turbine, from the revival of stall technology for lower failure rates and research into new materials up to new transport concepts for the immense components of the large turbines (Weinhold 2008).

In many cases, there is uncertainty about the construction of offshore wind farms. The projects involve a high level of geotechnical and civil engineering challenge. Firstly, the conditions of the substratum of the heterogeneously structured seabed in the North Sea and the Baltic Sea have to be explored (BSH 2008). Precise knowledge of subsurface geotechnical properties is very important for the design of the foundations, which are constructed individually and which account for 25% of costs. After successfully surveying the site, the parts (under-water structure with foundations and anchoring to the sea bed, tower, generator, rotor blades) need to be assembled on the coast, transported across the sea, and installed on-site. The dimensions and weight of the parts present a challenge that can only be met by large floating cranes – however, there is a shortage of such specialist ships. A further challenge is the selection of materials and load-bearing structures appropriate to the on-site exposure to sea and wind. Unlike the situation in Britain, it is not possible for manufacturers in Germany to draw on already developed offshore technologies from the oil and gas sector. In addition, wind turbines in the 5 MW and 6 MW class are not yet in serial production. Furthermore, a lack of service concepts, increased costs of raw materials and the fact that the connection to the high-voltage direct current transmission grid (HVDC grid) has yet to be made have an impeding effect on offshore expansion.

According to BWE estimates made in October 2005, the requirements of German offshore wind power are disadvantageous in comparison with the rest of Europe, as projects are supposed to take place at a distance of 30 – 100 km from the coast and in depths of water up to 40 m (BWE 2005, 1 sqq.). The standard of construction and foundation technology required for such projects are correspondingly higher than those in shallower waters just offshore.

Strategy for the Expansion of Offshore Wind Power

In January 2002, the “Strategy for the expansion of offshore wind power”[59] (“Strategie zum Ausbau der Windenergienutzung auf See”) was published. It became part of the Federal Government’s national sustainability strategy that was enacted in April 2002. The aim was to increase the share of wind energy contributing to power consumption to at least 25% within the next three decades (BMU 2001, 8). It was assumed that offshore wind power alone would cover 15% of Germany’s electricity needs. Using this strategy, which was prepared by the Federal Environment Ministry and interdepartmentally agreed on, it was possible to establish an important incentive for the development of offshore wind power. It prescribed that the expansion of offshore wind power should take place in a sustainable manner i.e. avoiding possible risks to the marine environment. This premise was to be met using an innovative concept involving several stages (pilot turbines – monitoring – decision on final extent of construction). In this sequence, the attainment of subsequent levels requires a positive and resilient outcome with respect to sustainability. In order to improve the standards for the assessment of environmental impacts, an accompanying ecological research program[60] was initiated. Up-to-date research findings could thereby continuously influence the permission processes.

In the first phase, which was scheduled for the years 2001–2003, appropriate sites for offshore wind power were to be identified, the relevant research activities were to be carried out and preparations were to be made for the initial phase of implementation.

For the initial phase from 2003/04 to 2007, the building and operation of the first pilot wind farms with an installed capacity of 500 MW was planned. The practical experience gathered during this process was then to be evaluated. The aim of the expansion phase from 2007 to 2010 was the installation of a capacity of 2,000 to 3,000 MW. In later phases, increasing economic efficiency was expected to result in the installation of up to 25,000 MW (BMU 2001).

[59] Cf. http://www.erneuerbare-energien.de/inhalt/... (Accessed: 11 August 2009).

[60] 4.2 million euros were dedicated to the offshore wind power sector.

It later emerged that the expansion targets of the Federal Government's offshore strategy, which had stood at 20,000 MW by 2025 and 25,000 MW by 2030 were unattainable. Experts of the sector considered 16,000 MW to be a more realistic aim for this timeframe.

Modified Conditions for Offshore Wind Power

The amended version of the EEG, which came into force on 1 August 2004, increased remuneration for offshore wind power. The coming into force of the new version saw the initial compensation rate increased to 9.1 cents/kWh and guaranteed it for at least twelve years, in contrast with the previous guarantee of nine years, as long as the turbines entered operation by 2010 (previously the limit had been 2006). However, the benefits only apply to turbines that are not situated within protected areas (respectively in bird sanctuaries) of the German Exclusive Economic Zone.

In view of the increased rates of compensation, investors became more interested in claiming sites for wind farms. In opposition stood the designations of special protection areas for the European NATURA 2000 network. The planned private wind farm of Butendiek, for example, was positioned in a Special Area of Conservation and had already been given permission. This situation was, from the perspective of nature conservation, irreconcilable with the goals of the Habitats Directive[61] and the Birds Directive.[62] A fundamental decision was to be made which would decide the way future applications for offshore wind farms in European protected areas would be dealt with. Opinions on this issue varied. It became apparent that the protected areas were not vital in order for the expansion targets to be reached. This led to a line of argument that claimed that the protected areas should as a matter of principle be kept free of wind farms (Kaiser 2009, pers. comm.). In this way, the right to compensation of turbines situated within protected areas as defined in the amended version of the EEG was removed – a measure that significantly reduced the attractiveness of investing in wind farms situated in such areas.

Faced with the high investment costs determined by their site, the amended version of the EEG deferred the degression rates for offshore turbines to 2008 and introduced a higher initial compensation rate, which was linked with the parameters of water depth and distance from the coast. The twelve-year initial payment grace period was increased for turbines erected at a great distance from the coast or in very deep waters.[63]

[61] Council directive 92/43/EEC – Habitats directive; cf. Index of Legal Sources.

[62] Council directive 79/409/EWG – Birds directive; cf. Index of Legal Sources.

[63] For every nautical mile in excess of twelve nautical miles, the grace period increases by 0.5 months and for every additional meter of depth, it increases by 1.7 months. Cf. www.offshore-wind.de/... (Accessed: 5 February 2009).

The high costs of offshore turbines were regarded as a major reason for the slow progress in the development of offshore wind power in Germany. Because of this, the compensation rate was again increased in the EEG amendment of 2009 – to a level comparable with that of other EU member states. The initial compensation for offshore wind power was raised to 15 cents/kWh, with the rate remaining valid until the end of 2015. In return, the final compensation was lowered: after 2015, electricity from new turbines would be paid for at a rate of 13 cents/kWh, and this rate would be decreased by five percent per year.

Offshore Research Support by the Future Investment Program

In the Federal Government's Future Investment Program (ZIP) around 30 million euros were made available to the Federal Environment Ministry from 2001 to 2003.[64] Offshore research became the main area of focus within wind power research (Welke & Nick-Leptin 2005, 5).

The aim of the accompanying ecological research within the context of the ZIP[65] was to figure out the environmental effects of offshore turbine installations on, for example, marine mammals, seabirds, fish, benthos and bird migration. This was supplemented by the Federal Ministry for Economics that financed two wind measurement platforms – one in the North Sea and the other in the Baltic Sea.

During this phase, support for research helped to allay the fears of both experts and the public concerning negative consequences in the marine ecosystem by providing objective information concerning the impacts of offshore wind power. This resulted in improved acceptance of offshore projects.

At approximately the same time the effects of offshore wind power in Denmark were investigated and determined on a case-by-case basis. These investigations took place in the course of a monitoring program that accompanied the construction and operation of the two large offshore wind farms and so were of an empirical nature. There was repeated international exchange of respective experiences (Köppel et al. 2002; Zucco & Merck 2004, Zuccho, et al. 2006).

Research Platforms FINO I, II and III

The construction of three research platforms in the North Sea and the Baltic[66] was also intended to study the effects of offshore wind power on marine mammals,

[64] This support encompassed solar thermal power stations, geothermal electricity generation and ecological research to accompany the development of offshore wind power, biomass and fuel cells.

[65] The "Zukunftsinvestitionsprogramm 2001-2003" (ZIP) was financed using income generated by the auctioning-off of UMTS (Universal Mobile Telecommunication Systems) mobile licenses.

[66] 2002: erection of FINO I, near the Borkumriff; 2007: erection of FINO II in the Baltic Sea, near to Kriegers Flak; 2009: erection of FINO III 80 km west of Sylt.

seabirds, bird migration, the fauna of the sea bed and fish. Since 2002, various institutes have carried out meteorological, hydrological and biological research on these research platforms. The results are intended to serve as a basis on which power companies, planners, operators, certification organizations and regulatory bodies will be able to evaluate offshore projects technically and ecologically. The public support of these research platforms is part of the offshore strategy and is intended to contribute to the elimination of knowledge gaps that stand in the way of the implementation of offshore wind power.

Marine Spatial Planning

To begin with, it looked as if conflicts with nature conservation, which inevitably would have occurred as a consequence of claiming national park areas,[67] could be avoided by siting offshore wind farms in the German Exclusive Economic Zone (EEZ[68]). There was also the hope that fewer conflicts would arise from other entitlements of use in the EEZ. These hopes proved to be illusory, however.

Firstly, at the same time as first areas appropriate for offshore wind power were being designated, the appointment of Natura 2000 sites – including within the EEZ – was taking place in accordance with the European species protection regulations (Bruns et al. 2008). Together with the national categories of protected area (Wadden Sea National Parks, national Marine Protected Areas) this resulted in a narrowing of possibilities to find appropriate sites for offshore wind farms, all the more so since restrictions on other uses of the EEZ (e.g. shipping, military use, sand and gravel extraction) already meant that large areas were already out of the question. In view of all this, it seemed that – as on land – the basic conflict between nature conservation (particularly biodiversity) and climate protection (Byzio et al. 2005) persisted.

With the amendment to the Federal Planning Act ("Raumordnungsgesetzes des Bundes" – ROG) in 2004, the incorporation of § 18a ROG created the legal conditions for the zoning of the sea. The principle of spatial concentration was to be applied to the sustainable planning of offshore wind farms, too. The regulation of site selection was to be achieved via the designation of appropriate areas.[69] To this

[67] The large areas of the Wadden Sea National Parks in Schleswig-Holstein and Lower Saxony as well as the Western Pomerania Lagoon Area National Park in Mecklenburg-Western Pomerania were regarded as off-limits for the utilization of wind power.

[68] The EEZ extends seawards from coastal waters (the twelve sea-mile zone) and stretches up to a maximum of 200 sea miles from the baseline. It does not constitute part of the territory of the coastal state.

[69] Appropriate areas in terms of the Marine Facilities Ordinance § 3a (Seeanlagenverordnung - SeeAnlV) and § 18a para. 3 ROG; the legal effect of these is not identical to that of the sites specified in the regional plans of the states. In terms of zoning, they have the status of priority zones and have the effect of an expert opinion when it comes to the selection of a site.

end, the approach which was already in use on land,[70] was nearly replicated for use in the EEZ. The aim was to rapidly attain legal and planning certainty for the development of offshore wind farms (Wolf 2003). The Federal Ministry for Transport's regulations concerning the EEZ were authorized by the cabinet on 16 September 2009.[71]

The zoning plan for the EEZ was intended to secure an initial tranche of ca. 11,000 MW, which equates (assuming 5 MW per turbine) to ca. 2,200 individual wind turbines (more than 8,000 MW in the priority zones specified in the zoning plan for wind power and ca. 2,800 MW in wind farms outside the priority zones, which had already received permission).[72]

Furthermore, the attractiveness of areas of importance for conservation was reduced by the reduction of compensation rates within these areas in the EEG of 2004: according to § 10 para. 7 entitlement to payments for turbines did not apply within areas that had been declared to be protected natural areas or landscapes under federal[73] or state conservation law.

Permission for Offshore Wind Farms

The legal basis for permits is the Offshore Installations Ordinance (SeeAnlV) of 1997, in which the responsibilities and processes associated with the issuing of permission are stated.[74] The BSH was also chosen to be the responsible body for permission procedures in the EEZ to simplify thus the implementation of offshore wind farms.[75] The 2003 amendment of the Federal Nature Conservation Act (BNatSchG) brought about important revisions for the designation of protected areas in the EEZ as well as for appropriate areas for wind turbines (BMVBW 2002) and for the permissions process in accordance with the SeeAnlV. From 2003, the first respective permission routines began.[76]

At the beginning of this phase, there was a "run" on what were regarded as the best sites on the principle of "first come – first served". What resulted is that some permit applications were made for the same sites. In such cases, priority was granted to those whose application was the first to be ready for approval. By way

70 Here: especially appropriate areas for wind turbines according to § 3a of the SeeAnlV.

71 The Federal Office for Navigation and Hydrography (Das Bundesamt für Seeschifffahrt und Hydrographie - BSH) in Hamburg had begun to compile a zoning plan for the EEZ in 2004.

72 Cf. http://www.bmv.de/... (Accessed: 15 September 2009).

73 Cf. § 38 in conjunction with § 33 para. 2 of the BNatSchG.

74 The SeeAnlV was developed by the Federal Ministry of Transport, Building and Urban Development (BMVBW).

75 The responsibility for the construction of power lines in coastal regions remained with the states however, as did the effort involved in coordinating between the relevant decision-makers.

76 Cf. Dahlke (2002). For the permission process cf. Köller et al. (2006), Bruns et al. (2008) for more information.

of precaution, a number of applicants handed in applications for several sites, which ended up obstructing the process for each other. In order to remedy the situation, the procedure was changed in 2004: with the acceptance of an application, a site would only be reserved for the operator for a certain period. The permit application then had to be completed within this period; otherwise the claim to the site would no longer apply.

Offshore wind farms required an environmental impact assessment that had, in comparison with other countries, ambitious requirements in terms of the comprehensiveness of the analysis.[77] For operators, this was a time-consuming and costly challenge. To make things easier for applicants, a regulation was sought according to which requirements for wind farms in designated appropriate areas would be lowered (BMU 2007, 16).

Due to the fact that strategic offshore wind farm planning and regulation occurred in the wrong sequence, wind farm sites today are occasionally outside the appropriate areas (Kruppa 2007), demonstrating the limited success of regulatory efforts until now.

In November 2009, 24 wind farms in the North and Baltic Seas had been granted permission[78] (see Table 7.4). As specified in the Federal Government's offshore strategy, permission issued by the BSH was generally for up to 80 turbines with a capacity of up to 5 MW, meaning that during the first phase of expansion, wind farms have an average installed capacity of 400 MW per site. At present, plans for more than 50 proposals are in progress.

Besides wind farms in the EEZ, for which the BSH is responsible, an offshore wind farm in the coastal waters of Mecklenburg-Western Pomerania was also granted approval. In this case, the respective state is responsible. Baltic I is the first commercial German offshore wind farm in the Baltic.[79]

Given the delays to implementation that had already occurred, the new situation, whereby applications for permission expire if construction has not begun within a certain period, constitutes an obstacle for planners and operators.

Reference Project Alpha Ventus and the RAVE Research Initiative

Following a few delays, in April 2009, the offshore wind farm test site alpha ventus was installed. This is a demonstration project for providing basic experience for the future commercial use of offshore turbines.[80] Since August 2009 wind power from

[77] The requirements were based on the 'Standard research concept' of the BSH ("Standarduntersuchungskonzept", BSH 2002). Portman et al. (2009, 3596–3607) offer a comparison of the political and legal factors influencing offshore wind power in Germany and the USA.

[78] Two wind farms in the Baltic have failed to be approved on nature conservation grounds.

[79] Baltic I is around 16 km north of the Darß/Zingst peninsula and should ultimately have a total capacity of 48.3 MW. Siemens Energy and EnBW Energie Baden-Württemberg AG have signed a contract for 21 wind turbines of the type SWT 2.3–93.

[80] http://www.alpha-ventus.de/… (Accessed: 11 August 2009).

Table 7.4 Overview of approved offshore wind farm projects in the EEZ as of November 2009[a]

No.	Wind farm	Approved
North Sea		
1	"Delta Nordsee 2"Offshore-Windpark Delta Nordsee GmbH (E.ON Climate & Renewables Central Europe GmbH)	31.08.2009
2	"MEG Offshore I"Nordsee Offshore MEG I GmbH	31.08.2009
3	"Veja Mate"Cuxhaven Steel Construction GmbH	31.08.2009
4	"Gode Wind II" PNE Gode Wind II GmbH	27.07.2009
5	"Borkum West II", Prokon Nord Energiesysteme GmbH	13.06.2008
6	"Hochsee Windpark He dreiht", EOS Offshore AG	20.12.2007
7	"Meerwind Ost"und "Meerwind Süd", Meerwind Südost GmbH & Co Rand KG und Meerwind Südost GmbH & Co Föhn KG	16.05.2007
8	"BARD Offshore 1", BARD Engineering GmbH	11.04.2007
9	"Godewind", Plambeck Neue Energien AG	28.08.2006
10	"Hochsee Windpark Nordsee", EOS Offshore AG	05.07.2006
11	"Global Tech I", Nordsee Windpower GmbH & Co.KG	24.05.2006
12	"Nördlicher Grund", Nördlicher Grund GmbH	01.12.2005
13	"DanTysk", Gesellschaft für Energie und Oekologie mbH	23.08.2005
14	"ENOVA Offshore Northsea Windpower", ENOVA Offshore Projektentwicklungsgesellschaft mbH & Co. KG	11.02.2005
15	"Sandbank 24", Sandbank 24 GmbH & Co KG	23.08.2004
16	"Nordsee Ost", WINKRA Offshore Nordsee Planungs- und Betriebsgesellschaft mbH	09.06.2004
17	"Amrumbank West", Amrumbank West GmbH	09.06.2004
18	"Borkum Riffgrund West", Energiekontor AG	25.02.2004
19	"Borkum Riffgrund", PNE2 Riff I GmbH	25.02.2004
20	"Butendiek", OSB Offshore Bürger- Windpark Butendiek GmbH & Co. KG	18.12.2002
21	Test area "alpha ventus"(formerly "Borkum West", Prokon Nord)	09.11.2001
Baltic Sea		
1	"Ventotec Ost 2", Ventotec Ost 2 KG	16.05.2007
2	"Arkona-Becken Südost", AWE Arkona-Becken-Entwicklungs-GmbH	15.03.2006
3	"Kriegers Flak", Offshore Ostsee Wind AG	06.04.2005

[a]Source: Bundesamt für Seeschifffahrt und Hydrographie, www.bsh.de/de/Meeresnutzung/... (Accessed: 11 August 2009)

the North Sea has been fed into the German electricity grid for the first time. The project constitutes the construction of twelve wind turbines, of which six are of the type Multibrid M5000, as well as a transformer platform. Together, the turbines have an installed capacity of 60 MW. The test area is being jointly run by the power companies E.ON, EWE and Vattenfall.

The Grid Integration of Offshore Wind Farms

Besides the development of multi-MW offshore turbines, this phase was dominated by problems of integrating offshore power into the grid. The uptake capacity of the electricity grid in coastal areas is limited, and so the planned offshore wind farms make an expansion of the grid necessary (Kuxenko 2003, 337). According to the dena grid study, 850 km of high-voltage lines need to be built and 400 km need to be enhanced in order to transport wind-generated electricity to the user. The expansion of junctions near the coast would also be necessary. The Federal Environment Ministry pointed out that until the necessary expansion takes place, temporary technical solutions would be available, which could optimize grid operation and thus create additional network capacity (BMU 2007, 20).

In windy areas close to the coast, the problems with grid integration were already noticeable.[81] To meet the challenge an energy management system was therefore required (Ramesohl et al. 2002, 36 sqq.), as well as a willingness to cooperate on the part of the traditional energy economy and the grid operators (Mautz & Byzio 2004, 124).

The grid connection of offshore wind farms presented an infrastructural and financial bottleneck and new submarine cables had to be planned and granted approval.[82] The bundling of various submarine connections proved to be difficult at first due to the diverging interests of the competing wind farm operators. The cable connection of the first offshore wind farm with a total capacity of 3,000 MW, which involved crossing the island Norderney for the alpha ventus test area, was debated for a long time. In autumn 2006, facilitated by the Federal Environment Ministry, the requirements for the construction of the cable route were established, allowing permission to be granted in 2007 (see Table 7.5).

In 2006 a legal ruling was enshrined in the Act for the Acceleration of Infrastructural Planning[83] (InfraStrPlanVBeschlG), which removed a financial burden from wind farm operators. According to this, grid operators – as was already the case on land – now had to bear the investment costs for grid connections (cables between wind farms and land)[84] (Bauchmüller 2006, 20). Investment could thus be reduced by around a third. The sector expected that the financial viability of the projects and the interests of banks and investors in financing these projects would thus increase.[85]

In February 2007, the BSH approved cable connections for another three offshore wind farms.

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[81] During strong winds, the high voltage cables, particularly those in northern Germany, reach the limits of their transmission capacity. What is needed are substations which allow the use of high and extra high voltages. The growing quantity of wind power feed-ins also requires new high voltage cables in order to allow the broad distribution of wind-derived electricity to urban centers.

[82] The issuing of permission for the laying and operation of power cables is subject to the German Federal Mining Act (Bundesberggesetz - BBergG). The responsible authority in the EEZ is the BSH, while in coastal waters, the German states are responsible.

[83] The Act for the Acceleration of Infrastructural Planning was enacted on 27 October 2006 by the Bundestag and came into force on 16 December 2006.

[84] However this required that the wind farms should have already started to be built by 2011.

[85] WindForum extra. Newsletter of Energiekontor AG April 2007. www.energiekontor.de (Accessed: 1 October 2009).

Table 7.5 Approved grid connections in the North Sea, as of November 2009[a]

Project	Connection	Year	Funding provider	Technology
Windnet	"Borkum-West" wind farm	2007	Prokon Nord	110-kV high voltage three-phase connection (three-wire cable)
Multikabel	"Nördlicher Grund" wind farm	2006	Multikabel GmbH	High Voltage Direct Current transmission system (bipolar HVDC cable system)
Sandbank 24	"Sandbank24" wind farm	2007	Sandbank Power GmbH & Co KG	High Voltage Direct Current transmission system
OTP	"Amrumbank West" wind farm and pilot phase of the "Nordsee Ost" wind farm	2007	Offshore Trassenplanungs-GmbH (E.ON)	Four three-phase three-wire sea cables of 200 MW each as well as a cross-connection between the two wind farms with two three-phase three-wire cables of 200 MW

[a]Source: Bundesamt für Seeschifffahrt und Hydrographie, www.bsh.de/de/Meeresnutzung/... (Accessed: 27 November 2009)

Integrated Maritime Policy 2008

On 1 October 2008, at the suggestion of the Federal Minister for the Environment, Siegmar Gabriel, the Federal Cabinet enacted a national strategy for the sustainable use and protection of the sea.[86] Complementing the legal adjustments undertaken in the realm of planning regulation and approval for wind power at sea, this strategy emphasized the importance of the mitigation of possible risks to the marine environment. This meant that cables, especially when they run through protected areas, should be laid in bundles. Disturbances to sea mammals, such as the underwater noise generated during the building, operation and dismantling of wind turbines are to be kept to a minimum.

Expansion of the Extra-High Voltage Network

The "Act for the Acceleration of the expansion of the extra-high voltage network" (Energieleitungsausbaugesetz – EnLAG), which was initiated at the end of 2008, is a reaction to the long periods required for the planning and approval of a land-based high-voltage grid. In Article 1, EnLAG establishes an urgent need for new constructions. Whether these proposals were going to take place was thus no longer in question. Article 2 of the Act changed the EnWG. For the approval of connection cables from offshore turbines, a more focused permit

[86]The Federal Government was thereby acting in accordance with the requirements of the European Marine Strategy Framework Directive (2008/56/EG).

procedure was introduced. It replaced the previously necessary time-consuming individual approvals and is to have the effect of accelerating the process. Despite this measure, the question remains of whether grid capacities will be ready on time or if this bottleneck in offshore expansion will prove to be a significant hindrance.

Conflicts Concerning Grid Expansion

The topic of grid expansion and the capacity of existing high-voltage lines gained increasing importance in political debate, especially in the coastal areas of north-western Germany. Questions concerning the ability of the grid to bear larger quantities of wind-generated electricity as well as security of supply and the question of transmitting electricity to centers of consumption no longer solely affected single regions or grid operators. The aspects of grid integration and the required long-term expansion of the grid, which were presented by the dena (2005), have become a topic of heated discussion throughout the country.

The construction of new high-voltage lines is particularly controversial, since the adverse effects on residents cannot be compensated for by some kind of regional or personal benefit. The controversial wind farms in the North Sea had not yet been built when resistance against the consequences on land started building up – especially in Lower Saxony. The Lower Saxony Association of Towns and Municipalities regarded the construction of eight new power lines at a height of 60 m, with two to three pylons per kilometer of line, to be unrealistic (Haack 2005, 23). Due to the controversy, the duration of the planning process for the proposal increased up to ten years, as the variety of involved stakeholders meant that coming to an agreement became very time-consuming.[87]

With the expansion of wind power and the linked increase in market share for turbine operators, conflicts played an increasingly important role: one of them concerned the grid access regime in Germany (Ohlhorst et al. 2008, 57–58). The operators of the grid were accused of not being transparent concerning actual cost structures and of siphoning off monopoly profits by levying excessive grid access tariffs. The focus on the large-scale generation and transmission of power caused a tendency toward centralization and the development of monopolistic structures. Control over the power grid is closely connected to having influence on the entire power supply system.

These conflicts concerning the distribution of costs, the technical integration of wind power into the grid as well as the expansion of the grid are closely connected to the manifold interests involved in the electricity market.

[87] Coming to agreement with representatives of public opinion in the case of controversial issues such as high voltage lines is given a lot of attention, since potential legal cases which might affect the realization of such proposals can draw out or delay the process even more.

Actors in the Offshore Subconstellation

The Federal Government and the Federal Environment Ministry

The central actor in the offshore subconstellation was the Federal Government with its offshore strategy. The Federal Government and the Federal Environment Ministry hoped to take advantage of the economic potential as well as the environmental advantages of offshore wind power. The aims of energy policy and climate policy were thus to be combined in a win-win solution which would reduce dependence on imported power and make a significant contribution to the energy supply. They envisaged that offshore wind power would also have positive effects from the points of view of economic and employment policy.

Turbine Manufacturers

In this phase, the national onshore market was declining since fewer and fewer sites for wind turbines were available. The establishment of wind farms was further impeded by the tightening up of regulations concerning siting and height limits. The decline in the wind power industry on the national market stood in contrast to an increase in export quotas. The world wind power market expanded in line with an increase in foreign demand. During this time, exports became increasingly important for the German wind power industry. Especially because of the dynamic of the national onshore market, German companies had been able to gain technical knowledge in previous years, which allowed them the benefit of a head start. The EEG created investment security, meaning that Germany, in contrast to the USA and Great Britain, was able to develop an export-oriented wind power industry and lower costs through technological progress.

The national wind power industry developed and was now testing multi-MW turbines for offshore use. However, it appeared that it would only be possible for Germany to enter the international business of offshore wind power if it also got on with setting up pilot projects. Denmark, Sweden, Great Britain, the Netherlands and Ireland had already been gathering years of experience in offshore wind power through nearshore wind farms and therefore had a head start in comparison with the German wind power industry.

Companies Involved in Developing Multi-MW Turbines for Use Offshore

In Germany it was initially the companies Enercon and REpower Systems AG (REpower 5M) that were active in the development of multi-MW turbines suitable for offshore use – though Enercon later pulled out of offshore development. A large proportion of the turbines built for offshore application are now produced by the companies Areva-Multibrid (Multibrid 5000[88]) and Bard

[88] Multibrid produces wind turbines for offshore projects (M5000) in Bremerhaven. The company, which is part of the PROKON Nord group, was founded in 2000. In October 2007 the French energy company AREVA joined in. The prototype of the M5000 was put into operation onshore in April 2005. In 2006 and 2008 further turbines were erected on offshore foundations (also onshore), giving a total of four turbines which are in test operation.

(BARD VM[89]).[90] Both enterprises are manufacturers as well as wind farm operators. Many of the founders of the Offshore Forum that was established in 2001 (see Section 7.2.5.5) do not appear anymore.

Planning Authorities

In terms of administration, the Federal Office for Navigation and Hydrography (BSH) established a new area of responsibility. During this phase, this particular actor took on a very important role in the design of a new regulatory mechanism for the marine realm.

Operators

The feed-in tariffs guaranteed by the EEG as well as the considerable potential of wind power at sea attracted the interest of many investors in offshore wind farm projects in the North Sea and the Baltic Sea. Once sites and consent were available, German power companies such as E.ON and RWE began to take part in offshore wind farms.[91] They generally bought into projects that had already been granted approval.

The financial capacities required for offshore projects had an effect on the nature of those investing. The planning and future implementation of turbines for use at sea lay primarily in the hands of medium-sized stock corporations and operator companies, international corporations and large power companies.[92] This was due to the fact that the amount of risk and investment capital required in the offshore wind power business could only be summoned up by such large businesses, with the support of banks and insurance.

The largest proportion of approved projects in the North and Baltic Seas are in the hands of power companies.[93] While it is possible for large companies to finance projects using their own money, other businesses prioritized project financing, i.e. regaining their investment through profits from the wind farm. The present situation on the financial markets, however, is such that capital providers only hesitantly enter into such arrangements.[94] It is therefore to be assumed that primarily strategic

[89] The prototypes of the BARD VM, which were produced in Emden, were installed as nearshore turbines and connected to the grid in 2007 at the Rysumer Nacken. In 2008 this offshore turbine model went into serial production with 5 MW. The special offshore foundations are produced in Cuxhaven. The offshore installation of this turbine model was planned for 2009.

[90] BARD Engineering GmbH also possesses numerous permits for offshore wind farms in the North Sea.

[91] RWE entered the wind power market in 2007. From 2008 onward Siemens has been building wind turbines exclusively for E.ON.

[92] A special example of this is the Bürgerwindpark Butendiek (BUTENDIEK GmbH & Co. KG, n.d.).

[93] Cf. www.handelsblatt.com/unternehmen/... (Accessed: 11 May 2009)

[94] Price Waterhouse Coopers: Gegenwind für Offshore-Windparks. Press release 4 December 2008. Cf. http://www.pwc.de/portal/pub/... (Accessed: 15 September 2009).

investors, like power companies, on a corporate financing basis will carry out the first stage of expansion of commercial offshore wind farms.

Offshore Foundation

At the Federal Chancellor's fourth National Maritime Conference, which took place in Bremen in January 2005, the request to construct one or more offshore test areas was delegated to the Federal Government. Risks were to be evenly spread between political and economic actors through the establishment of a foundation. The Offshore Wind Energy Foundation (Stiftung der deutschen Wirtschaft zur Nutzung und Erforschung der Windenergie auf See) had the rights to an approved offshore wind farm (alpha ventus) and made it available to the test area operators. The construction of this offshore wind farm consisting of twelve 5 MW turbines 45 km from the island of Borkum was intended to jump-start the expansion of wind power on the North and Baltic Seas.[95] The Federal Environment Ministry made 50 million euros available for research and development on the test area over a period of five years.

Grid Operators

The operators of the electricity grid, who are in a position of market domination, are criticized for not being open with regard to actual cost structures, for not having fulfilled their obligations to expand the grid and for already having on several occasions refused to connect wind farms to nearby feed-in points. The current energy management system could be replaced by one that handles bottlenecks more effectively. In this context, up to 20% of possible power production is not being fed into the grid, resulting in loss of income for turbine operators. Not only that, but grid operators generally only begin with the planning of grid expansion once a wind farm has received approval, part approval or a preliminary building permit (required according to § 4 para. 2 EEG). This can lead to lengthy delays in wind farm construction and connection. Currently, claims for compensation cannot be made in the case of losses to potential suppliers resulting from insufficient grid capacity (BWE 2007).

The dispute concerning what constitutes grid connection as opposed to grid expansion often ends up in the courts, and this also results in delays. Moreover, in order to determine the technically and financially optimal connection point, certain data concerning the grid are required, which are generally not available to turbine operators (BWE 2007).

[95] Cf. www.offshore-stiftung.de (Accessed: 11 August 2009).

Critics of Offshore Wind Power

With the arrival of offshore wind farms, the idea of small-scale decentralized power generation was given up. Wind power is now to be increasingly centralized and industrialized and is to contribute to the national energy supply at a magnitude thus far unknown. Critics of this development fear or complain of the unintended consequences and of the fact that the scaling up of the phenomenon has led to it taking on a life of its own, with a resulting reduction in the ability of the public to have an influence (Byzio et al. 2005).

Though the siting of offshore wind farms at a significant distance from the coast helps to reduce conflicts with local residents, the fact that offshore wind power is associated with the impacts caused by the expansion of the electricity grid on land means that even those wind farms distant from the coast are subject to controversy.

7.2.6.6 Interpretation of the Constellation: Driving Forces and Constraints

In the sixth phase, the constellation broke up into two subconstellations. On the one hand was the divergence and formation of the land-based subconstellation. Due to the ever decreasing availability of appropriate areas – the appropriate sites defined in regional plans and the concentration zones of municipal plans had come to a restrictive effect – the continued deployment of wind power on land became more difficult. At the core of the constellation lay the opening up of new business areas (repowering and export). These were needed in order to maintain the stability of the wind power sector.

On the other hand, the offshore wind power constellation was forming. Both targeted regulatory mechanisms (EEG and the Federal Government's strategy paper) and the economic and technical success of land-based wind power were driving forces for offshore development. The subconstellation consisted of a new alliance of actors from the dominant subconstellation (the energy sector and industry) and public actors (the Federal Government and the Federal Environment Ministry), as well as banks and insurance companies. Without actors possessing financial clout, offshore wind power would not have been possible. The motivation of the Federal Government's strategy paper for the utilization of offshore wind power was to attain climate policy targets as well as a substitute for energy imports. A Federal Environment Ministry-supported alliance of manufacturers, planners and operators, as well as power companies and large businesses drove the implementation of the plans. The EU directive for the support of renewable energy added to this momentum. Offshore wind farms were to replace energy imports, make a significant contribution to national energy supply and be integrated into the centralized structures of the energy sector and power stations. However, the high investment funds involved in offshore wind power and the resistance of grid operators hindered the process. Furthermore, the deployment of wind turbines at sea, far from the coast and in very deep waters, involving great technical challenges which still have not been comprehensively overcome, also led to delays.

The development of prices for fossil fuels as well as discussions concerning security of supply and independence from energy imports was a driving force in both constellations. However, the land-based wind power subconstellation was defined by predominantly impeding forces: ever fewer suitable areas, competition from biomass and photovoltaics and sluggish repowering induced a phase of consolidation. The reformulated EEG was supposed to provide incentives for repowering, but economic, planning regulatory and technical factors had an impeding effect. Initiatives in some states also had a negative effect. In contrast, the export of wind turbines proved to be a success and managed to compensate for the limited domestic market. The driving force behind export was the market leadership demonstrated by German manufacturers, who are, however, facing strong competition from Denmark and Spain.

While new and larger wind turbines with higher capacities are being planned, technical restrictions persist locally in the uptake capacity of the electricity grid. Experts anticipate that the solution to this will lie partly in the expansion of infrastructure and partly in changes in organizational measures.

7.2.6.7 Future Prospects

Despite the targeted progress in the implementation of offshore wind farms, a certain resignation with respect to the German offshore wind power spread through the sector (Waldermann 2007). Besides unanswered questions concerning finance and insurance as well as technical challenges, the onset of the financial crisis in 2008 also contributed to the fact that offshore expansion took place at a significantly slower pace than had been planned. For several projects, the start of construction was delayed by the reticence of banks and investors. Exploding steel prices also worried the planners of offshore wind farms, as this significantly increased the financial requirements for their projects. In the development of both offshore technology and special technologies for construction and maintenance, actors within the sector feared losing their competitive advantage to other countries. Even so, wind power is generally regarded (see e.g. Nitsch 2008) as a future mainstay of German energy security.

In view of DEWI's statistics for 2008[96] and against the background of the new EEG that came into force at the beginning of 2009 and the associated reliability in planning, BWE president Hermann Albers and the VDMA Power Systems managing director Thorsten Herdan expect more growth in the wind power sector, despite the financial crisis. Figure 7.9 makes it clear that offshore wind power will form the greatest proportion of this growth. Rather than stagnation, the prognosis of the BEE is one of continued growth.

[96] In 2008, 866 new wind turbines with a capacity of 1,665 MW were installed, thereby maintaining approximately the same rate of expansion as the previous year (2007: 883 turbines, 1,667 MW). By the end of 2008, a total of 20,301 wind turbines with a combined capacity of 23,902 MW had been installed.

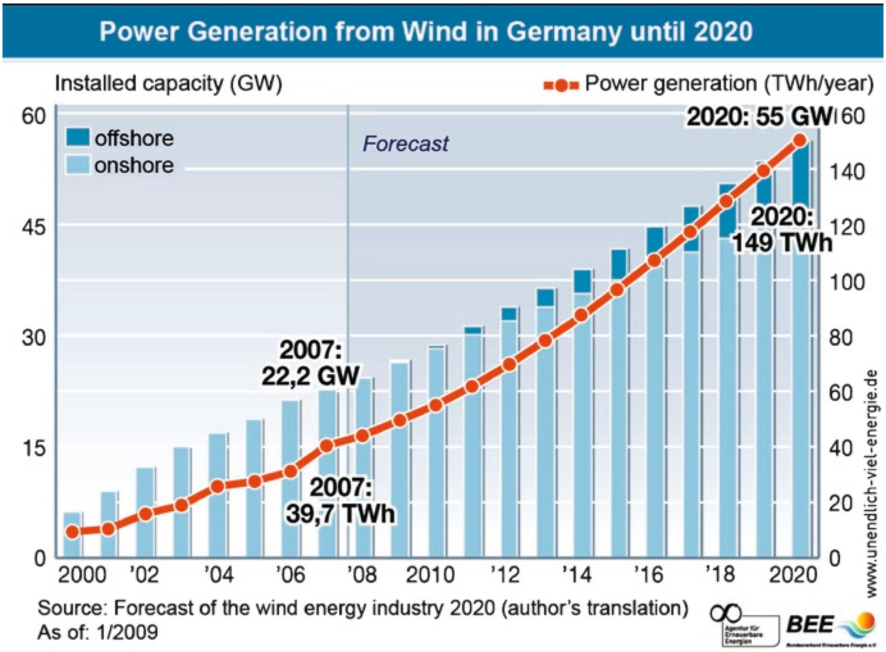

Fig. 7.9 Predicted German power generation from wind until 2020

Current findings point out that the future deployment of wind power will very much depend on whether the transformation of the power generation system as a whole is going to be successful. A high proportion of renewable energy means that the conventional base load power generation has to be reduced to a large extent. The remaining fossil fuel power stations will then have to make their capacity exclusively available in order to ensure a reliable power supply (Nitsch 2008). Power companies also recognize this problem. In a statement addressed to the British government in May 2009, E.ON and Électricité de France made it clear that they consider high proportions of renewable energy to be incompatible with the construction of capital intensive base load power stations and that they consider the acceptable upper limit of renewable energy to be between 25 and 33%.

Due to seasonal and weather-dependent changes in wind intensity, the supply of wind power is subject to short- and long-term variability. Without the deployment of power storage, a significant expansion of the grid and easily controlled power stations with rapid start-up times (like gas-fired power stations), a higher proportion of contribution of wind and solar power in the electricity supply will not be possible. In order to be able to thoroughly cover electrical demand at all times, a combination of wind farms, power stations with easily adjustable output and power storage capacity are necessary in order to compensate for the difference between the supply of renewable electricity and electricity demand (SRU 2009).

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Chapter 8
Innovation Framework for Generating Electricity from Hydropower

Abstract The technology of harnessing hydropower is regarded as the pioneer among the renewable energies. Electricity generation from hydropower was in its maturation phase as early as the mid-twentieth century. The degree of technical sophistication depended on the framework conditions at the particular location (amount of water, gradient, capacity range). With environmental awareness increasing in the 1970s and 1980s, public response to hydropower, which had hitherto been positive, began to change, with concerns regarding the environmental effects on rivers and streams growing. In response to this, the subsequent phase saw corrective measures that were intended to allow for the implementation of hydropower use under ecologically compatible conditions. This means that the modernization of hydropower plants is subject to noticeable restrictions with regard to the limited ecologically compatible potential at the respective locations. Species protection as codified in European law was taken into account to a greater degree in approval decisions as a result of EU legislation being implemented in national law.

The current state of the technical development is characterized by incremental innovations in the fields of electric current transformation and system control technology. Longevity of the technical components, long replacement cycles and long approval periods contribute to the fact that processes of modernization in hydropower use occur within long time intervals.

Keywords Hydropower • Renewable energy sources • Innovation • Corrective measures • Environmental impacts • European legislation

8.1 Preliminary Remarks

Of all renewable energies, hydropower has the longest history in electricity generation, more than 120 years. In the early years its importance as a source of power was surpassed only by that of the steam engine. There was a time when hydropower accounted for the largest share of the power supplied by renewable

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energies in Germany, where there were several large power plants (with capacities of several MW) and numerous small and mid-sized plants (with capacities from multiple kW up to a few MW). More recently (as of 2008), it slipped to second place, having been outstripped by wind power. From today's perspective a review of hydropower´s innovation story is something of a historical endeavor, since turbine technology was developed from the waterwheel well before the twentieth century, as Giesecke and Mosonyi (2005, 4) point out. Already at the time of the Industrial Revolution techniques for exploiting the energy potential of water located at an elevation above the site of utilization were available, for instance, by using dynamic pressure.[1]

At the start of the period under consideration for this book, the individual components of hydropower technology had already been both developed and used to a great extent – from hydraulic plants, catchments and pipeline systems through to generators and transformers and systems for controlling water.

The development of hydropower use in Germany, which reached its peak in that period can be divided into three phases (see Fig. 8.1), which are described in more detail in Section 8.3, below.

Due to the fact that small hydropower plants[2] had long been widely distributed and because hydropower technology had already reached a level of maturity that was quite high by the 1960s, the more recent pace of innovation in this sector was fairly low compared to that in other sectors. That is also reflected in the relatively small number of phases identified in the period since then.

8.2 Hydropower in the Pioneering Phase (Before 1930)

The phase leading up to 1930 we called the "pioneering phase." Since it predates the period considered here, the pioneering phase is not shown in Fig. 8.1. However, familiarity with this earlier history is important for understanding the developments

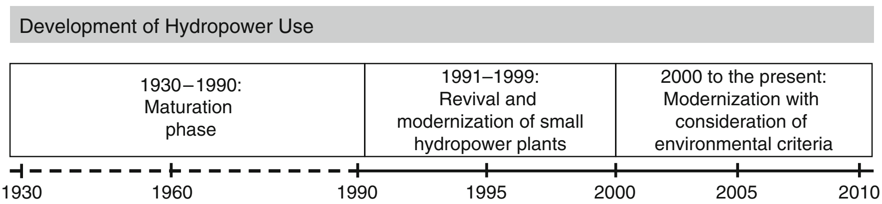

Fig. 8.1 Phases of the development of hydropower use in Germany

[1] At first with the use of low and medium pressure power plants, from 1827 (Fourneyron turbines) with high-pressure hydropower plants as well.

[2] In Germany, plants with capacities of up to 1 MW count as small hydro, plants with >1 MW as large hydro.

that occurred during our focus period, which begins with the technology already in the maturation phase. The pioneering phase coincides with the first electrification projects. Key technological developments and pilot applications of turbine technologies, power conversion technologies and plant construction introduced the period of “modern hydroelectricity conversion.” The previous phase had been characterized mainly by mechanically utilized, traditional hydropower.[3] At the time, due in no small part to the global economic crisis, there was growing recognition in Germany that industrialization would require electricity.

8.2.1 Turbine Technology

In this phase, the water turbine[4] producing hydropower energy was already almost a century old. The key steps in the development of turbine types had already been taken in the previous century.

The development of Fourneyron’s turbine, a type of reaction turbine, dates all the way back to the 1830s. Fourneyron’s turbine is a propeller turbine with an interior runner through which water passed in a radial outward flow. This invention had an efficiency of about 80%. The first Fourneyron’s turbine was installed in 1835 in St. Blasien in the Black Forest (Southwest Germany), where it generated around 4.5 kW of power. It laid the groundwork for designs to come, some of which are still in use today.

Improving on the design of Fourneyron’s turbine, the Anglo-American engineer James B. Francis introduced the Francis turbine in 1849. It achieved an efficiency of about 90%.

In 1873, the firm Voith delivered Germany’s first Francis turbine to the C.F. Ploucquet weaving mill in Heidenheim. His family business being a factory that built paper mill machinery, Friedrich Voith had recognized the breakthrough features of this originally American invention. He added his own improvements to it, e.g., the use of movable guide vanes to regulate the turbine. In 1893 the company began to build free-jet turbines as well. In 1902, it received an order to build what were to be the world’s largest turbines at the time: 12 12,000 hp Francis turbines for the power plant at Niagara Falls (USA/Canada). By 1917, 50 years after the company was founded, it had built 6,000 water turbines.

The Francis turbine is the type of turbine most commonly used today. It is found primarily in storage power plants and pumped-storage power plants with 50–800 m heads (drop heights) and large water volumes.

[3]Heimerl (2009, pers. comm.) describes this process as “away from the clanking mills – on to the technological structure.”

[4]The term “turbine” (from the Latin word “turbo,” whirlwind) was coined in 1824 in connection with a public competition held by the Societé d’Encouragement pour l’Industrie Nationale.

In 1910 Prof. Victor Kaplan (1876–1934), an Austrian, made another improvement to the design of the propeller turbine. The use of adjustable guide vanes allowed the Kaplan turbine to reach a greater efficiency. This turbine is used in run-of-river power plants with low to medium heads. The first Kaplan turbines were installed in 1919 in a textile factory in Velm, Austria. With a head of only 2.3 m, it was capable of generating 19 kW.[5] In 1922, the Voith firm began building an early Kaplan turbine in the 1,100 hp capacity range.

The turn of the century saw the design of early forms of the cross-flow turbine, by the Australian Anthony Michell (patented in 1903), the Hungarian Donát Bánki and the German Fritz Ossberger (patented in 1922), among others. Ossberger turbines, still manufactured today, are primarily used in small power plants serving factories or small communities. A single turbine can produce up to 1,000 kW.

The Pelton turbine, which is also a cross-flow turbine, takes its name from the mining engineer Lester A. Pelton (1829–1908), who began working on the construction of water wheels in around 1870. When a jet of water accidentally hit only the outermost part of the curved bowl of a wheel, the wheel's speed increased to an extent that caused it to fly apart. After many experiments, Pelton came up with a design consisting of two shallow cups joined together in the middle: the Pelton wheel. It is said American engineers coupled one of these "free-jet" turbines with a generator for the first time in 1882 at a plant at a Wisconsin dam.

The Pelton turbine, in an improved and up-dated form, is still used in power plants with heads of 200–2,000 m and low water volumes. It remains the classic turbine type for power plants in high mountains even today.

The rim-type generator turbine (Harza turbine), developed by Leroy Harza in 1919, is used for high capacity ranges. Between 1937 and 1950, the Swiss company Escher Wyss AG installed a total of 73 turbines based on Harza's prototype in power plants on the Iller, Lech and Saalach rivers. The Harza turbine entered into a period of revival in 1980, when Escher Wyss connected enhanced Harza-type turbines, of 5.5 MW each, to the public grid, three in the Belgian Ardennes and four in Lixhe. In 1982, two additional turbines, each with a capacity of 8 MW, were installed in Weinzödl, Austria. This turbine design is of particular interest, because it was also going to be installed in a pilot plant for a tidal power plant in Canada.

In summary, turbine technology had been well-established by the start of the 1960s.

[5] In the 1940s an interesting modification of the Kaplan turbine was developed in Germany. This consisted of a conventional Kaplan turbine that was situated in a streamlined casing downstream of a generator. Both units were built on a horizontal plane into horizontal tunnels of the power plant.

8.2.2 Hydropower Plants

In Germany, hydropower use is concentrated in the southern states of Bavaria and Baden-Württemberg. It was there that the first electricity plants were built toward the end of the nineteenth century. Companies in the crafts and trades sector, local governments and regional power suppliers operated those plants. There were also over 10,000 micro hydropower stations (average capacity of 14 kW per station) in Bavaria for instance, operated for the most part by farmers and small-scale craftsmen. Bavaria's first hydroelectric plant was built by Oskar von Miller in Schöngeising in 1884.

In addition to the conventional low-pressure run-of-river plants, the early twentieth century also saw the construction of the first storage power plants. One well-known example is the Walchensee plant in Kochel am See, which started operation in 1924. The Walchensee high-pressure storage power plant remains one of the largest of its kind in Germany, with an installed capacity of 124 MW.[6]

The era of reconstruction that followed World War II saw a rapid increase in the demand for electricity, triggering another wave of hydroelectric power plant construction.

8.3 Phase-Based Analysis of the Course of Innovation

8.3.1 Phase 1: Hydropower Maturation Phase (1930–1990)

8.3.1.1 Characteristics of the Constellation

The constellation was characterized by the use of, already largely mature, turbine technology in both of the application ranges (large and small hydropower) (Fig. 8.2). At the time, power supply companies, then still highly regionalized, operated hydropower stations in both the large and small-scale capacity ranges. Hydropower plants were seen as better than merely compatible with the electricity industry: as pumped storage power plants, in particular, they fulfilled an important function by compensating for variability, allowing for regulation in the supply grid. During a phase in which river valleys were increasingly industrialized, no controversy was associated with their use for power generation. One highly visible indication of that acceptance was the architectural design of the hydropower plants, which tended to take the form of towering industrial structures that were visible for miles.[7]

[6]It now belongs to E.ON Wasserkraft GmbH in Landshut.

[7]Heimerl (2009, pers. comm.) cites the Rheinfelden hydropower plant built in 1896 as a typical example for this period. In the 1970s awareness of hydropower plants and, with it, the style of hydropower plants changed; influenced by the increasingly powerful environmental awareness, the Säckingen hydropower plant, for example, was designed as a low-construction-type, very compact structure. At that time people's associations with hydropower were no longer unambiguously positive (ibid.).

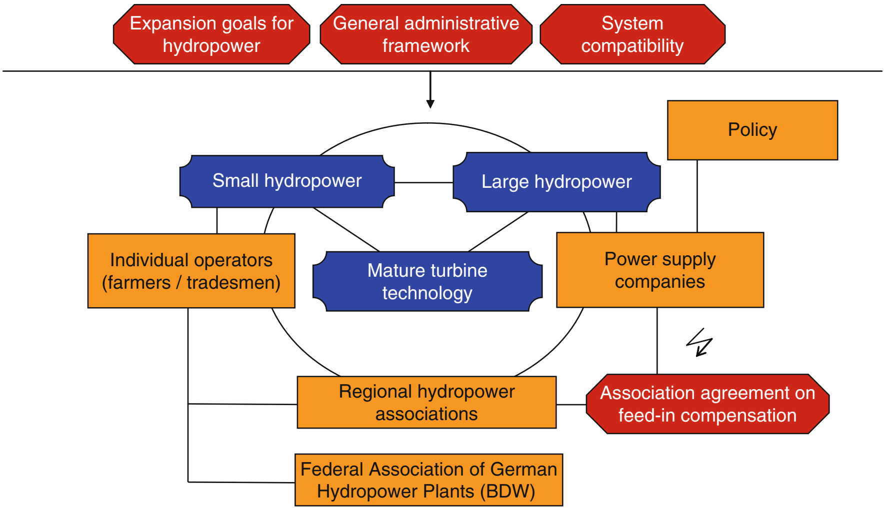

Fig. 8.2 Constellation of Phase 1: Maturation phase 1930–1990

A fundamental conflict of interest did arise, however, between private hydropower plant operators and power utilities. The power utilities operated the grid into which the hydropower plant operators fed their electricity and they took advantage of that position to dictate the price for electricity. It was only with the support of state-based operator associations that operators were finally able to win "association agreements" that provided contractual protection for compensation for electricity fed into the grid. Only once those agreements were in place was it possible for operators to obtain adequate compensation from the power utilities.

8.3.1.2 Sector-Specific Context, Influencing Factors and Processes

Hydropower Expansion Aims

In the post-war period, the expansion of hydropower was a consensual political goal. Individual measures were enacted to facilitate the sitting of new hydropower plants, for example, the payment of abandonment premiums for the "dismantlement of surplus mill capacities" (BT-Drs. 11/5025, 7/8). But by the 1960s it was already clear that there were only a limited number of suitable sites available.

With the oil crisis in the 1970s, increased emphasis was placed on expansion of hydropower use at the political level (BT-Drs. 8/3468 1979). However, as low as they were, the rates paid by the energy suppliers at the time, at about 8 pfennigs/kWh,[8] could hardly have offered much incentive for further expansion, at least for small hydropower (ibid).

[8] Approximated 0.025 USD/kWh at the time. www.history.ucsb.edu/faculty/marcuse/projects/currency.htm#infcalc (accessed 29 March 2010).

The German government believed that the country's potential was nearly exhausted by the beginning of the 1980s (BT-Drs. 11/5025 1989, 1). Nevertheless, referring to studies of hydropower potential at that time, Germany's political parties still considered hydropower an environmentally friendly alternative and called for its further expansion (BT-Drs. 11/5025). However, assessments of the economic and technical potentials of hydropower did vary. For example, the results of the 1982 Jülich Nuclear Research Centre (KfA Jülich) study promised considerable enhancement of reserves, amounting to around 33 TWh. Obviously, that study took legal, technical and economic restrictions into account to only a limited degree. In contrast, a DIW/ISI[9] (1984) study found a potential for technically and economically utilizable hydropower of around 21.3–22.5 TWh.

With the growing environmental concerns against the expansion of hydropower use during the 1980s, the Federal Government concluded in 1989 that the concerns of nature conservation and environmental protection would frequently prevent further exploitation of the remaining potential (BT-Drs. 11/5025). Protection of natural water courses represented a considerable impediment to the attainment of higher expansion objectives. Thus there were early signs of a "capping" effect caused by the conflicting objectives aiming at the protection of natural waters and their ecosystems.

Regulatory Framework

According to Heimerl (2009, pers. comm.), most of the plants operating in the 1950s held permits that had been issued in the 1920s or 1930s for a term of up to 80 years. In 1957 the first Federal Act on Managing Water Resources (Wasserhaushaltsgesetz – WHG)[10] came into effect. It incorporated regulations governing licenses, but they could only be applied to new hydropower plants. The states then created their own requirements for the permit procedures. Thus each state developed its own principles about what it considered to be reasonable restrictions for hydropower plant operators.

In the 1970s, ongoing environmental legislation led to greater requirements for nature conservation and environmental protection. In 1976 the Federal Nature Conservation Act (Bundesnaturschutzgesetz – BNatSchG) introduced a new requirement when water management decisions were made: concerns of nature preservation and landscape protection had to be taken into account explicitly.

The "impact mitigation regulation" of the BNatSchG required operators to minimize negative impacts and compensate for ecological damage to waterbodies.[11]

[9]The German Institute for Economic Research (Deutsches Institut für Wirtschaftsforschung – DIW) & The Fraunhofer Institute for Systems and Innovation Research (Fraunhofer-Institut für System – und Innovationsforschung – ISI).

[10]The sources for the legal information used in this chapter are given in the Index of Legal Sources.

[11]Operators must prepare a Landscape Management Plan (Landschaftspflegerischer Begleitplan) that describes the adverse effects on the ecosystem and mitigation requirements (Klinski 2005, 78).

Requirements of that kind resulted in additional costs for operators. However, there is no way to quantify whether, or rather, to what extent the construction of hydropower plants was influenced by the nature conservation regulations.

Entering into force in 1986, the fifth amendment to the Federal Act on Managing Water Resources had a positive effect on the renewal of expiring permits. A simplification of the permit procedure (BT-Drs. 11/5025, 5) reduced the number of required approvals from four to one.

Requirements for the assessment of the environmental impact of hydropower plants grew more specific in the late 1980s, when the European Environmental Impact Assessment Directive (European Directive 85/33/EEC) was implemented into national law. The EIA law ultimately enacted in Germany in 1990 (Gesetz über die Umweltverträglichkeitsprüfung - UVPG)[12] mandated (No. 6 of the Annex to §3 UVPG) that an EIA be performed for projects that required planning approval under §31 of the Federal Act on Managing Water Resources. More detailed regulations that specified which hydropower plants required an environmental impact assessment and which not, were set in the states' EIA acts, enacted at a later date. Those acts contained different rules concerning the conditions under which a general EIA as opposed to a site-specific EIA was required. While Bavaria and Baden-Württemberg required a general assessment only for plants producing 1,000 kW or more and a site-specific assessment for smaller plants, in the early 1990s the states of Thuringia and Saxony-Anhalt introduced a mandatory EIA for plants of any size.

System Compatibility

There was little conflict over the integration of hydropower in the energy supply system. Since hydropower plants provided a continual feed into the grid, they did not cause upsets in the network. Plus, pumped storage plants allowed energy to be stored in times of surplus. So, from the perspective of the energy industry, hydropower was associated with certain advantages and it was therefore accepted, despite its marginal significance as an energy source. That acceptance secured the support of political actors as well.

Hydropower in the Former German Democratic Republic (GDR)

Hydropower was the only technology that contributed in any appreciable extent to the production of renewable energy in the GDR (Weidenfeld and Korte 1992, 289). The existing plants were built long before the war. Due to a very low price of electricity there was practically no incentive to expand the existing plants as an alternative to lignite-based electricity generation.

Those plants that survived the war were often used by state-owned enterprises (Volkseigene Betriebe – VEB) to ensure that their factories did not draw more

[13]The compensation model is based on a model for the feed-in of surplus electricity from the

energy from the grid than the quota allotted to them. In addition, hydropower plants were used in certain cases to generate reactive loads (to improve grid quality) and as emergency suppliers when the public electricity supply failed (Richter 2008, pers. comm.). Some pumped storage plants were used to balance out peak loads, whereas the generation of electricity was viewed more as a by-product.

According to Richter (2008, pers. comm.), plant operators could not prevent the ongoing decline of their plants, as it was impossible to get adequate replacement parts from West German manufacturers. The plants ran until they collapsed and then they were shut down (ibid.). By the time the Berlin Wall came down, the number of East German hydropower plants had fallen from 500 to 50.

In the wake of reunification, development opportunities for proponents of small hydropower in upland areas in former East German territory improved. The plant sites and unused dams (see Section 8.3.2.5) were to be reactivated.

8.3.1.3 Governmental Guidance and General Economic Conditions

Until the end of the 1980s, the state exhibited little interest to promote small hydropower through the adoption of specific strategies or laws. It saw no reason to become active in adopting national legislation to regulate compensation for electricity from hydropower, for instance.

Permission to feed into the grid and the compensation for feed-in continued to be matters that individual operators had to negotiate under private law with the energy suppliers. Plant operators had a weak negotiating position and were frequently placed at a disadvantage. The energy suppliers paid less for one kilowatt hour from hydropower than it cost them to produce their own electricity (Berchem 2006). This unsatisfactory situation left hydropower operators with little means to pursue their claims for compensation. They were also unsuccessful at creating a political lobby strong enough to press for legal regulation.

It took some time for operators to establish an appropriate body to represent their interests. In the end, they sought support from among their own. Regional associations stepped up to negotiate what was called an "association agreement" with the energy supply companies. The compensation stipulated therein provided a reference figure for contracts with energy suppliers.

Actively supported by the Federal Government, the association agreement compensation model was renewed in 1988.[13] Finally there was a model for feeding electricity into the grid that was binding for both sides, one based on voluntary contractual agreements between individual energy suppliers and those feeding into the grid. Once a long-term agreement was in place, small plant operators had some degree of security for investment. The compensation was based on the long-term average costs that could be avoided in the public supply.

co-generation of heat and electricity to which the electricity industry agreed (BT-Drs. 11/5025, 5).

The Federal Government believed that the association agreement compensation model had also considerably improved the general economic conditions of small hydropower (<1 MW). For many plant operators though, compensation under the association model often failed to even cover the costs of minor repairs, resulting in the closure of plants into the 1990s. Yet as the 1980s drew to a close, the Federal Government continued to see no reason for regulatory intervention in the compensation issue beyond the voluntary compensation model of the association agreement (BT-Drs. 11/5025, 6). Rather, it hoped that tax advantages for hydropower plants would provide incentives in particular to the operators of large-scale hydropower plants.[14] According to Heimerl (2009, pers. comm.), however, this did not play a key role in decisions on new construction or modernization.

One additional administrative incentive, though a selective one, came in the 1980s in the form of the Investment Allowance Act (Investitionszulagegesetz). Under that Act, commercial enterprises received a tax-free allowance of 7.5% of the amount invested in construction of run-of-river hydropower plants. Applications for an average of around 12 million German marks were submitted each year between 1975 and 1988.

8.3.1.4 Technology and Market Developments

Scope of Hydropower Use

It is difficult to find statistical data on the use of small hydropower in the individual states or in Germany as a whole, particularly data concerning the scope of that utilization. Those statistics that are available are based to some extent on estimates, particularly in the case of plants with capacities of less than 1,000 kW. In the mid 1980s, hydropower generated around 18.5 GWh, corresponding to 4.7% of total electricity generation. Bavaria led the country in the generation of hydropower, with 10.8 GWh, followed by Baden Württemberg (almost 5 GWh) and Rhineland-Palatinate (with around 1 GWh) (BT-Drs. 10/4272 1985).
In terms of numbers of plants, small hydropower accounted for the vast majority, at around 93% of all plants. They produced only a small portion of the electricity generated by hydropower however (around 7%).

According to data from the German Electricity Association (Verband der Elektrizitätswirtschaft – VDEW), approximately 3,300 plants existed in Germany at the end of 1980. Between 1988 and 1994 the number of small hydropower plants increased by 900, causing a capacity increase of 68 MW (see Table 8.1).

[14]Under the Regulation on the Favorable Tax Treatment of Hydropower Plants Insurance Agreement (Verordnung über die steuerliche Begünstigung von Wasserkraftwerken Versicherungsvertrag – WasKwV) hydropower plants received preferential treatment in conjunction with corporate taxes and income taxes, property taxes and business taxes for 20 years after the start of operations (BT-Drs. 10/4272). Specifically, this was intended to benefit plants that went into operation by 1990.

Table 8.1 Installed capacity at small hydropower plants, 1988–1994[15]

Year	Plants	Installed capacity (MW)
1988	3,300	280
1990	3,691	310
1992	3,881	318
1994	4,200	348

This trend was probably supported at first by the slightly improved compensation conditions created by the association agreement and later by the Electricity Feed-in Act (Stromeinspeisungsgesetz – StrEG).

Technological Developments

Although turbines and other technical components of hydropower plant construction had reached market maturity, meaning that operators had access to individual components for the various types of hydropower construction models, plant parts were not mass-produced. Hydropower plants cannot be planned and produced "off the rack" with no reference to location because the selection and combination of modules and components must always reflect the requirements of a particular site. In fact, individual model tests are sometimes conducted for large plants in order to develop and optimize the hydraulic geometry (Heimerl 2009, pers. comm.).

Another special feature of hydropower plants is their long lifetime. The cycles of technical refurbishment are determined in part by the equipment's need for replacement or upgrading and in part by the periods for which licenses are granted. Since plant equipment has an exceptionally long life, long periods of time elapse between improvements in design of the technologies used (incremental innovations) – unless there is an economic incentive for early replacement or modernization of the equipment.[16]

8.3.1.5 Actors in the Constellation

Private Operators: Farmers and Members of the Crafts/Trades

In the rural regions of southern Germany, operators tended to fall into three groups: farming or trades-related operators of small and micro plants, municipalities and energy supply companies. Farmers and tradesmen were considered "traditional users" and were also seen as the pioneers of small hydropower. At the beginning of this phase, water turbines were often the only source of electricity at remote sites where there was no public energy supply.

[15] Source: BR-Drs. 705/95.

[16] According to Heimerl (2009, pers. comm.) hydraulic structures depreciated over a period of between 50 and 80 years.

Energy Suppliers and Industrial Enterprises

Expanding electricity-consuming industrial operations also used hydropower, though usually in the mid-range capacity segment. For instance, the company Carl Zeiss in Jena Burgau built its own power plant as early as 1910; the plant went on-line in 1912 and was modernized once again in 1938. In the end, the installed capacity was 1,700 kW.[17] Large hydropower plants were operated by industrial enterprises and the large energy supply companies. Small hydropower plants were originally operated by local and regional energy suppliers. Through regional and supra-regional mergers over the course of consolidations processes at the beginning of the century they found their way into the ownership of the large energy supply companies.

Federal and Regional Associations

Initially, the operators – mainly private individuals – evinced a low degree of networking and organization. After the war, small power plant operators organized themselves at the level of the state, in Bavaria, for instance, beginning in 1948 with the Society of Bavarian Small Power Plants (Gemeinschaft Bayerischer Kleinkraftwerke), the predecessor association to today's Association of Bavarian Hydropower Plants (Landesverband Bayerischer Wasserkraftwerke e. G.).[18] That association struggled vehemently for a better electricity price from the OBAG.[19] Ultimately, in 1952, it succeeded in getting the Bavarian Ministry for Economic Affairs and Transport to issue a directive on regulation of the electricity price.[20] That regulation was later supplemented by more far-reaching individual association agreements (see Section 8.3.1.3) and was eventually superseded by the StrEG.[21] In addition to the Bavarian association, Baden-Württemberg's Coalition of Hydropower Plants (Arbeitsgemeinschaft Wasserkraftwerke) was also an active state-based association.

[17] See http://www.wasserkraft-thueringen.de/Wasserkraftanlagen/ (accessed August 04, 2009).

[18] The State Association of Bavarian Hydropower Plants (Landesverband Bayerischer Wasserkraftwerke) currently has around 600 members and exerts substantial influence on association policy at the federal level.

[19] OBAG, established in 1908, was the largest regional power supplier in Bavaria in terms of territory covered, supplying the Upper Palatinate, Lower Bavaria and parts of Upper Bavaria. More than 20% of its electricity came from hydropower. In 2001, it merged with other regional power suppliers to become E.ON Bayern AG.

[20] Regulation No. By 2/52 on Regulation of the Price of Electricity for Small Hydropower Plants (Verordnung Nr. By 2/52 zur Regelung des Strompreises für Kleinwasserkraftwerke) of March 03, 1952 (Bavarian State Gazette [Bayerischer Staatsanzeiger] of March 03, 1952 p. 3), last amended by a regulation dated February 02, 1963 (Gesetz und Verordnungs Blatt, GVBl. p. 31).

[21] The state association also worked actively on behalf of the subsidy program of the Ministry of Economics for the expansion and reactivation of hydropower plants sites. It made substantial contributions to the Residual Water Guide (Restwasserleitfaden), which was published by the Bavarian State Ministry for Development and Environmental Affairs in 1996 and 1999.

Several associations represent the interests of hydropower plant operators. These include the Federal Association of German Hydropower Plants (Bundesverband Deutscher Wasserkraftwerke – BDW),[22] which represents mainly the interests of small hydropower plant operators. The president of the BDW from 1978 to 2002 was Matthias Engelsberger, a member of the CSU party (Member of the German Bundestag, 1969–1990), whose efforts were substantially responsible in 1990 for the passage of the StrEG in the context of the regulations for compensation for electricity from hydropower. The BDW ultimately became a member in the German Renewable Energy Federation (Bundesverband Erneuerbare Energien - BEE) and represents its members through that association today. In addition, the German Association of Energy and Water Industries (Bundesverband der Energie – und Wasserwirtschaft – BDEW) represents the interests of energy suppliers active in the hydropower sector, primarily at the municipal level. There is also a coalition of state-based hydropower groups, the AWD (Arbeitsgemeinschaft Wasserkraftwerke Deutschland), which represents private and for-profit smaller and mid-scale hydropower plant operators at the federal level.

Thus the variety of associations has evolved historically. To a significant extent the variety is also due to the federal distribution of duties and responsibilities in laws relating to water.

Hydropower Sector Companies

Market-leading companies with proven skills in plant construction emerged primarily in Bavaria and Baden-Württemberg. Many of those companies were family businesses, with traditional experience in agricultural and mechanical engineering to draw on.

Some firms, such as Voith Hydro, have a long tradition in the construction of small and larger hydropower plants (see Section 8.2). In the company's "glory days" between 1917 and 1942, it more than doubled the number of turbines it built.[23] The majority of hydropower plants in GDR territory dated to that period (see Section 8.3.2.5).

Another example of a family-owned business is Ossberger GmbH,[24] a company that started in the field of mechanical engineering, specifically, in the manufacture of agricultural machines. Fritz Ossberger, a son of the company's founder obtained a patent in 1922 for the development of the Ossberger free-jet and one in 1933 for the cross-flow turbines. In the post-war era, the company continued to manufacture agricultural machinery while at the same time developing into one of the

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[22] The BDW is the umbrella association of the states' hydropower coalitions. It was a founding member in the German Renewable Energy Federation (Bundesverband Erneuerbare Energien – BEE), and is a member of the European Small Hydropower Association (ESHA) and of the European Renewable Energies Federation (EREF).

[23] From 6,000 in 1917 to 12,600 in 1942.

[24] See http://www.ossberger.de/ (accessed August 04, 2009).

leading manufacturers for small hydropower plants under the business name "Ossberger-Turbinenfabrik."

One of the younger companies that developed from a local micro-operation into a market-leading firm is Wasserkraft Volk AG.[25] That company started in 1979 in a barn at Gernhansen Farm in Simonswald (Southern Black Forest), designing and building hydropower stations. The small company grew steadily over the next years, became a limited liability company in 1986 and converted into a joint stock company in 1997. Its activities include the full planning and manufacture of hydropower plants. The firm developed a complete service portfolio that sets it apart in its sector: it produces four types of turbines (Pelton, Turgo, Francis and cross-flow turbines), designs and builds plants according to individual case requirements and offers maintenance and control systems for plants in operation.

The company Escher Wyss, founded in Zurich (Switzerland) in 1805, was purchased by Sulzer in 1969 but continued to operate under the old name, due to its reputation as a well established firm branded in tradition.[26]

8.3.1.6 Interpretation of the Constellation: Driving Forces and Restraints

The first phase was characterized by a restrained development. Although expansion of hydropower was seen as a political good, restrictions on that expansion were already making themselves felt in the 1970s. The 1980s put in focus the competing objectives between renewable energy production and environmental protection, which functioned as a barrier to expansion.[27] The conflicts over the objectives and necessities of protecting surface water resources were not the only obstacles: claims relating to other sorts of utilization (e.g. shipping) also put restrictions on hydropower generation. Evaluations of potential and expansion goals varied according to what extent ecological restrictions were taken into account. The lack of clarity regarding unexploited potential inhibited the state's ability to promote expansion.

In this phase the goals of environmental protection were assigned a relatively greater weight than hydropower expansion, but there was no public debate about the legitimacy of those goals. During this phase small hydropower did not benefit from any support in the form of overarching government incentives. It is likely that the imbalance in the distribution of hydropower utilization among the German states had an impending effect on hydropower's growth.

Hydropower technology was considered largely mature by this time, so further development of that technology was not pushed forward. State subsidies for the maintenance and modernization of plants sustained the status quo, but failed to stimulate any new potential.

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[25] See http://www.wkv-ag.com/ (accessed August 04, 2009).

[26] For more information see Section 8.3.2.5.

[27] For a presentation of the conflict of aims see UBA (1998).

8.3.2 *Phase 2: Revitalization of Small Hydropower, 1990–1999*

8.3.2.1 Characteristics of the Constellation

The core of the constellation is formed by the StrEG,[28] with its statutory minimum compensation for electricity from hydropower as the central government incentive, in conjunction with revitalization, modernization and optimization in the technical arena which was instigated after some delay following the legislation (Fig. 8.3). Small hydropower operators profited from the feed-in tariff, and especially from its increase under the 1994 amendment to that legislation. The section of modernization of small hydropower plants and revitalization of old sites saw the latter concentrated on the states in the former GDR.[29]

New potentials opened up in the wake of reunification. At the same time, permit requirements were becoming stricter: the 1992 EU Habitats Directive[30] on the conservation of natural habitats and of wild fauna and flora lent visibly more weight to the conservation of certain species and aquatic habitats. In conjunction with the river protection programs of the states, aimed at migratory fish species and

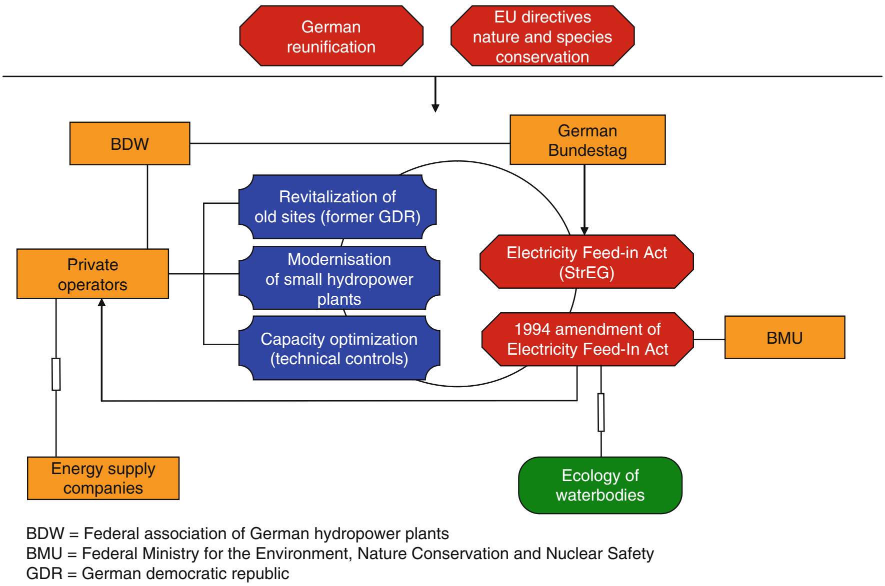

Fig. 8.3 Constellation of Phase 2: Revitalization of small hydropower 1990–1999

[28] Cf. Index of Legal Sources.

[29] See Staiß (2000, I–33).

[30] Directive 92/43/EEC of May 21, 1992. Cf. Index of Legal Sources.

preserving river basin ecosystems, these ecological programs and regulations functioned as a “cap” to hydropower plant expansion and renewal.

8.3.2.2 Sector-Specific Context, Influencing Factors and Processes

Reunification

By the time of the German reunification, a great many of the hydropower capacity in the territory of the GDR had fallen into ruins. While there were more than 1,000 plants in Thuringia about a century ago, at the time of reunification there were less than 30.[31] The number of plants in Saxony fell from over 3,000 in 1950 to 222 in 1999 (Rolle 2001, 492).

In 1991, the Federal Government adopted a general program for an “Energy Policy for the United Germany.” Hydropower played a role in that program. In the new East German states, the revitalization of old mill sites promised a certain growth potential for hydropower.

EU Directives on Nature Conservation and Species Protection

The implementation of the Habitat Directive in Germany[32] led to a stronger protection of habitats and species listed in the appendices to the Habitat Directive. After thorough mapping, representative areas were designated as special protected areas after the Habitat Directive (so called “FFH-areas”),[33] which then were part of the European Natura 2000 network. This new European protection regime proved to be stricter than the national nature conservation law. In cases where an impairment of a FFH areas caused by the re-erection of hydropower plants could not be excluded, the approval of this project was in question.[34]

Programs for River and Stream Protection

In the early 1990s, some states (e.g. Lower Saxony, North Rhine-Westphalia) introduced programs to encourage river restoration by dismantling dam barriers. These programs, supported by environmental groups, contributed to the cap on a hydropower expansion furthermore.

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[31] http://www.wasserkraft-thueringen.de/ (accessed August 04, 2009).

[32] Implementation of the Habitat Directive (Council Directive 92/43/EEC of 21 May 1992 on the Conservation of Wild Habitats and of Wild Fauna and Flora) occurred through the expansion of the BNatSchG to include §§ 19–21 of that act (cf. Index of Legal Sources).

[33] FFH is the abbreviation of Flora–Fauna–Habitat.

[34] See Klinski (2005, 78) on the conduct of impact assessments after the Habitats Directive and – in the event of non-compatibility – reasons for exceptions that must be present pursuant to BNatSchG in order to acquire a permit despite that incompatibility.

Preference for Small Hydropower Under Building Law

Section 35(1) no. 5 of the Town and Country Planning Code (Baugesetzbuch – BauGB)[35] grants privileged building law status to plants located in non-urban areas (*Außenbereich*)[36] that serve the purposes of research or the development or use of hydropower. This had already applied before the code was amended in 1996 (BGBl. I p. 1189), so from the perspective of hydropower, the 1996 amendment can be seen as merely a legislative clarification rather than an innovation (Maslaton & Zschiegner 2005, 95). However, the privileged status was more symbolic in nature and did not really promote hydropower use.

8.3.2.3 Governmental Guidance and General Economic Conditions

Electricity Feed-in Act (StrEG) 1991/1994

In the 1980s, the voluntary compensation agreements in Bavaria (see Section 8.3.1.3) were insufficient to ensure progress in the expansion of old plants or, above all, the replacement of old plants with new, higher-capacity plants. The enactment of the StrEG[37] represented the central incentive that drove plant construction in the small hydropower section. The Bavarian association agreement model considerably influenced the terms for feed-in tariff set out in the StrEG.

Mainly private operators took profit from a legally binding compensation rule, since it applied to hydropower plants with a capacity up to 5 MW that were *not* operated by an energy supply company. Following the enactment of the StrEG in 1991, a minimum compensation of approximately 7 cent/kWh[38] (14 pfennigs/kWh) was in force for plants with capacities of up to 500 kW and one of about 6 cent/kWh (12 pfennigs/kWh) applied for plants with capacities between 500 kW and 5 MW (Table 8.2).[39]

The first amendment to the StrEG was enacted in 1994.[40] The payment for electricity from small and micro hydropower plants (up to 500 kW) was raised from

[35]Cf. Index of Legal Sources.

[36]The term *Außenbereich* comes from German zoning law and describes a category of areas which are not within the area designated by a binding land-use plan and which are not part of the already built-up area (*Innenbereich*); see Section 35(3) of the Federal Building Code (Baugesetzbuch – BauGB).

[37]Electricity Feed-in Act (Stromeinspeisungsgesetz – StrEG) of December 07, 1990, Federal Law Gazette (Bundesgesetzblatt – BGBl.) Part I p. 2633. See Section 3.7.1 for discussion in more depth.

[38]Cent in this section always refers to euro cent.

[39]Berchem (2006) refers to a minimum of 13.84 pfennigs paid for each kilowatt-hour of green electricity fed into the grid.

[40]See Article 5 of the act dated July 19, 1994 (Federal Law Gazette I, p. 1622), see Index of Legal Sources.

Table 8.2 Compensation rules under StrEG 1991–1998

	StrEG 1991	StrEG 1994 and 1998
Maximum limit	5 MW	5 MW
Rate for ≤500 kW	75% of average earnings/kWh, (ca. 14 pfennigs/kWh)	80% of average earnings/kWh (ca. 15 pfennigs/kWh)
Rate for >500 kW	75% for capacities of up to 500 kW (ca. 14 pfennigs/kWh); remainder with 65% of average earnings (ca. 12 cent/kWh)	80% for capacities of up to 500 kW (ca. 15 pfennigs/kWh; remainder with 65% of average earnings (ca 12 cent/kWh)
Degression	../..	../..

75% to 80%. Thus the rates remained at between 7 and 8 cent/kWh (nominal prices) until the Renewable Energy Sources Act (Erneuerbare Energien Gesetz – EEG) was introduced in 2000. The increase provided the incentive necessary for modernization and the replacement of turbine equipment. Between 1990 and 1998, the number of private plants rose from around 3,750 to 5,100 (Staiß 2000, I–33). Conditions in the former East German territory were particularly favorable for the reactivation of old plants. Fifty years before reunification there were around 3,500 hydropower plants in GDR territory, of them, less than 200 were still in operation at the time of reunification. By 1998 the figure had climbed back to 300 (Staiß 2000, I–33).

In the amended version of the StrEG enacted in 1998, compensation rates continued to be coupled to average prices. Due to falling electricity prices, compensation for electricity from hydropower fell as well. That trend put an end to the "temporary peak" at the close of the 1990s.

Financial Support

Concurrently, hydropower plants received an indirect subsidy by credit lending commitments from the German Equalization Bank between 1991 and 1993.[41] These added up to around 33.5 million German marks, which were issued under the ERP[42] Energy Conservation Program. However, according to Heimerl (2009, pers. comm.) this support did not create any real drive for development – particularly as there was considerable bureaucracy associated with applying for such a loan.

In Bavaria, the incentive provided by the StrEG feed-in tariff was accompanied by the "Program for the Promotion of Small Hydropower Plants in Bavaria" from 1990 to 2005.[43] By 2005, that program had supported around 680 investment projects. This initiative shows that state promotion programs could have a positive effect.

[41] Deutsche Ausgleichsbank, now integrated within the Reconstruction Loan Corporation known as the Kreditanstalt für Wiederaufbau.

[42] European Recovery Fund, also known as "Marshall-Plan".

[43] It was discontinued consolidating the budget in April 2005.

Privileges Granted to Small Hydropower Plants

The 1996 amendment of the Town and Country Planning Code (BauGB) provided for a privileged status in permit procedures for wind and hydropower plants (see Section 8.3.2.2).

At the same time, the Act on Managing Water Resources (WHG) was being amended. Under Article 31 of the amended act, hydropower use was explicitly identified as a priority interest of the general welfare that ran counter to the projects aimed at ecological restoration. After strong protests from the nature conservation groups,[44] seeing this as giving carte blanche to hydropower (Mayr 1996, 190), an improvement of the status of hydropower in the Federal Act on Managing Water Resources was no longer pursued.[45] Thus, although the building law requirements were eased, certain restrictions on the (re-)utilization of small plant sites remained.

8.3.2.4 Technology and Market Developments

The numbers of plants built at *new* sites continued to be very few, in part because compensation rates were not high enough to cover investment costs and in part because water and conservation regulations made it difficult to carry out such projects. Modernization work led to an increase in capacity of small hydropower plants of not more than 150–200 MW (Staiß 2007, 90).

The number and capacity of large hydropower plants remained practically constant throughout the 1990s. About 90% of the electricity generated from hydropower came from run-of-river plants. The remainder came equally from storage hydropower plants and natural in-flows into pumped storage power plants.

There were no developments in hydropower technology associated with turbines worthy of note in this phase – apart from very few exceptions.[46]

Converter technology, already familiar in other application areas (e.g. wind power, photovoltaics), was introduced into small hydropower plants in this phase on a larger scale for the first time. That technology made plants less dependent on water levels, allowing variable speed operation without the need for expensive and often vulnerable gear units between generator and turbines.

In 1994 hydropower contributed 4% of the energy supply (BR-Drs. 705/95).[47] Installed capacity rose continually following the introduction of higher compensation rates through the StrEG in 1991 and its 1994 amendment, but the proportion

[44]Conservation groups argued that the negative environmental impacts caused by hydropower exploitation were not appropriate compared to gain of electricity production which is only marginal (Mayr 1996, 190).

[45]The parliamentary group of the SPD also objected an amendment of the wording granting privileges to hydropower utilization in the Act on Managing Water Resources.

[46]In the case of Francis turbines (which are of no significance to small hydropower, however) a considerable increase in efficiency was achieved with the use of permanent magnet-excited synchronous generators with innovative converter technology.

[47]For comparison: in 1984 hydropower accounted for a 4.7% share of overall electricity generation.

Table 8.3 Installed capacity and generation of electricity from hydropower, 1990–1999[48]

Year	Installed capacity (MW)	Generated electricity (million kWh)
1990	4,403	17,000
1991	4,403	15,900
1992	4,374	18,600
1993	4,520	19,000
1994	4,529	20,200
1995	4,521	21,600
1996	4,563	18,800
1997	4,578	19,000
1998	4,601	19,000
1999	4,547	21,300

of total generated electricity could not be increased to any noteworthy extent relative to 1984 in the following years (Table 8.3).

Developments in the market were relatively minor, with a capacity increase of an average of 15 MW per year. As a result, the significance of hydropower in the electricity sector did slightly increase, but it continued to lag considerably behind wind power, which grew at a rapid pace over the same period. The major markets for suppliers of hydropower technology continued to lie abroad.

8.3.2.5 Actors in the Constellation

Apart from the explicitly highlighted German Bundestag, many other actors influenced events in the constellation, although not playing a leading role.

Bundestag and Its Members

The impetus for the Bundestag's move to enact the StrEG (see Section 3.7.1) was provided by politicians and political associations who wanted to improve the situation of private hydropower plants. Among those actors Matthias Engelsberger, CSU, stood out. As a member of the Bundestag he strongly advocated legally based compensation. He himself was a hydropower operator and also served as president of the BDW. It was due to his efforts that the issue received support from the CDU/CSU parliamentary group.

Private Operators and Companies

In the early 1990s, replacement parts and new plant components manufactured by West German companies like Voith were once again available in the newly formed German states, as were the services of those companies as engineers. The fact that

[48] Source: BMU 2007a, 14–15.

Voith[49] actually still had the technical plans for plants built before the war turned out to be helpful, as they could be used as a basis for maintenance or plant conversion (Richter 2008, pers. comm.). Prerequisites for putting plants back into operation were that the old water rights still existed and that property rights issues could be clarified. When that was not the case, projects tended to be delayed for unforeseeable periods (Richter 2008, pers. comm.).

In the 1990s, the sector was characterized by extensive processes of acquisitions. Escher Wyss had owned Sulzer since 1969 and was renamed Sulzer Hydro in 1995. That company was purchased in turn by VA TECH in 1999 and integrated into the VA TECH Hydro Group. VA TECH Hydro was then purchased in 2006 by the international ANDRITZ GROUP, a conglomerate with businesses all over the world. That shows the internationalization of the sector and serves as the antithesis to the "family business" with its middle-sized orientation, which yet continued to exist (see Section 8.3.1.5).

Environmental Groups

The effort to bring expired plants back into operation triggered an outburst of the conflict familiar in the old West German states between the concerns of environmental groups and operators' interests in hydropower generation. The conservation associations (e.g. BUND Sachsen) criticized the published figures on hydropower's potential contribution to the energy supply, which were derived from calculations of potential and expansion scenarios, as "exaggerated" or "manipulated." They went on to say that hydropower, as measured by its minor contribution to the country's final energy supply (0.4%) caused disproportionate amounts of environmental damage through the construction of hydropower plants. Rivers and streams, they said, had already been segmented by dams (with and without hydropower).[50] Hence, they concluded that the construction of additional barriers was unacceptable.[51] The environmental groups demanded that water authorities in the states on GDR territory place more emphasis on ecological requirements and proceed restrictively with issuing new permits to old plant sites. Along with fishing associations, environmental groups can be considered as powerful opponents of hydropower operators in this phase.

Companies

The StrEG's economic incentives for the modernization of small hydropower plants resulted in the establishment of some new companies that specialized in providing complete packages in this segment. To that extent, the StrEG did result in a kind of

[49] Voith Siemens HydroPower Generation GmbH & Co. KG, Heidenheim.

[50] For instance, the Zschopau river has 83 weir systems on a 120 km stretch of flowing water alone. That means that on the average there is a weir installed every 1.4 km. http://www.bund-sachsen.de/ (accessed August 06, 2009).

[51] For impacts barriers on the habitats in rivers and streams see Dumont (2006, 122–124).

revival in the hydropower sector, although to a considerably lesser degree than in the area of wind energy for instance. Despite the technical improvements in plant performance and system controls, these initiatives did not become a driving force for hydropower in this phase.

Hydropower Lobby Groups

Following reunification and the adoption of the StrEG, associations were set up in the newly formed states, for the purpose of promoting the reactivation of small hydropower plants and to influence the formation of political will for hydropower. In 1990/1991 in Thuringia for example, the Working Group of Thuringian Hydropower Plants (Arbeitsgemeinschaft Thüringer Wasserkraftwerke e.V. – ATW) was established by committed hydropower operators. After an initial boom in the early 1990s though, organizations in the newly formed states were not able to get a firm foothold for their issues to make the revitalization process permanent.

8.3.2.6 Interpretation of the Constellation: Driving Forces and Restraints

Offering state promotion to hydropower, the StrEG of 1991 was the central government incentive in this phase. Small hydropower profited from the tariff fixed by law, which provided for higher compensation for the small capacity range in particular. This allowed operators to make long overdue investments for rehabilitation and repairs and to take steps to relaunch operations at old plant sites.[52] Modernization and revitalization led to a revival in the segment of small hydropower. Expansion, i.e. the opening of new sites, was restrained by the competing objectives of natural water courses' protection. Hence financing under the StrEG allowed only a "capped" increase of capacity, limited to a large extent to existing hydropower sites.

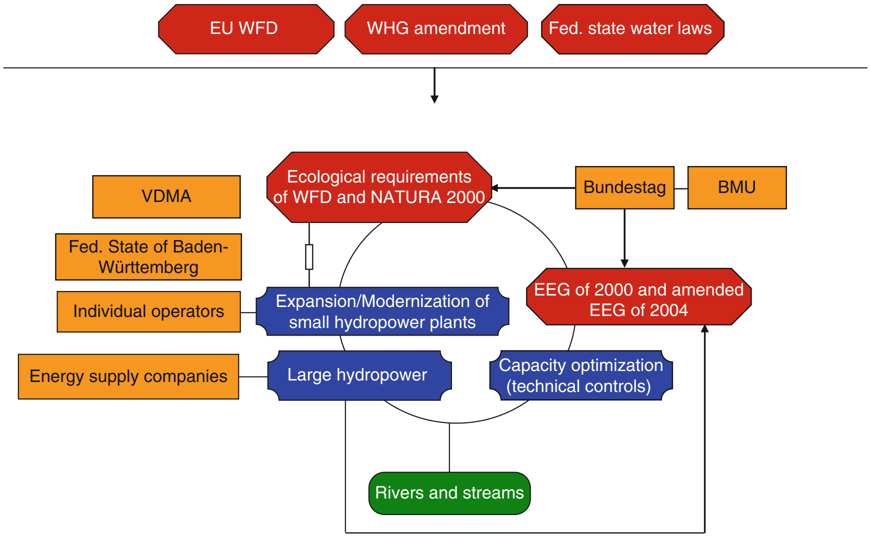
8.3.3 Phase 3: Modernization Under Environmental Constraints, 2000 to the Present

8.3.3.1 Characteristics of the Constellation

The adoption of the Renewable Energy Act (EEG)[53] by introducing a fixed tariff marked the beginning of this phase, reversing the trend seen since 1998 of decreasing compensation. The most significant government incentive was provided – an attempt to ensure the economic viability of small hydropower and create incentives for technical modernization and a better performance (Fig. 8.4). Operators of large

[52]This occurred primarily in the East German states.

[53]Cf. Index of Legal Sources.



BMU = Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
EEG = Renewable Energy Sources Act
EU WFD = EU Water Framework Directive
NATURA 2000 = Network of nature protection areas
VDMA = German Machinery and Plant Manufacturers' Association
WHG = Act on Managing Water Resources

Fig. 8.4 Constellation of Phase 3: Modernization under environmental constraints

hydropower plants, representatives of their associations and the state of Bavaria formed a coalition to lobby for extension of the tariff regulations to include plants with capacities greater than 5 MW in the 2004 version of the EEG.

The protection of natural water courses strongly advocated by environmental groups in the previous years, succeeded in taking up a place in the constellation, strengthened by the implementation of EU conservation regulations (Habitat Directive) concerning specific protection sites (Natura 2000 areas). The environmental requirements emerged at the core of the constellation, exerting a restrictive influence. Those restrictions were supported by the EU Water Framework Directive (WFD) and its implementation in the states.

8.3.3.2 Sector-Specific Context, Influencing Factors and Processes

Development of Permit Requirements

The Water Framework Directive adopted in 2000, led to strengthening of water-related environmental concerns (Heimerl 2005). It was implemented in German law through a 2002 amendment to the Federal Act on Managing Water Resources. The states amended their water acts to reflect the federal WHG; states with traditionally many hydropower sites took care to ensure that the changes did not lead to stricter permit requirements.[54]

According to Richter (2008, pers. comm.) however, the legal situation of hydropower plant operators was weakened in Saxony by a clause in that state's water act that undermined the legal status of the holders of water rights. The enlargement of sites subject to old water rights and new construction practically came to a halt there in 2002.

8.3.3.3 Governmental Guidance and General Economic Conditions

Electricity prices were low at the beginning of the third phase. The wholesale prices for electricity had fallen considerably since the opening of the electricity market in 1998, and were around 3 cent/kWh.[55]

Economic analyzes revealed that the construction of new small hydropower plants (with capacities of under 100kW) was economically feasible only under highly favorable site conditions. This also applies for the reactivation and modernization of plants of that size.[56] Cost advantages did emerge with increasing plant size due to decreasing specific investment costs but even the construction of new hydropower plants or the modernization of large plants was exposed to financing risks. In order to ensure the continuing existence of the plants, government incentives were directed at improving remuneration conditions.

In 2004, new cost factors emerged that also called the economic viability of hydropower into question: costs for meeting environmental requirements such as the inclusion of rakes and upstream and downstream fish passage technologies. According to the operators, despite the increase in the tariff (see below), the 2004 EEG did not adequately cover these additional costs.

Extension of EEG Support to Include Large Hydropower

An early draft of the 2004 EEG made large hydropower plants eligible for the support that had until then been offered only to small hydropower.[57] Without this

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[54] Thus it is reported that no adverse effects were seen in Baden-Württemberg. See Printed Paper of the State Parliament (Landtagsdrucksache, LT-Drs.) 14/2819 of June 06, 2008 "Facilitation of the Construction of Small and Middle-Scale Hydropower Plants" ("Erleichterung der Errichtung von kleinen und mittleren Wasserkraftanlagen").

[55] The situation has since altered: large hydropower plants can in some cases obtain higher prices on the energy market (exchange) than they can with the EEG tariff. The average wholesale electricity price in 2008 was more than 6 cent/kWh. The large power plants therefore did not make recourse to the feed-in tariff at all.

[56] In this context the Renewable Energy Sources Act 2007 (BMU 2007b, 61) cites over 5,000 full load hours/year and low specific investment costs (<4,000–4,500 euro/kWh) for instance.

[57] In doing so, the Federal Ministry for the Environment was yielding to pressure from the state of Baden-Württemberg, where there were large plants in need of modernization. The VDMA and individual companies, including EnBW, also lobbied vehemently for the inclusion of large hydropower in the support scheme.

support, it was thought that necessary modernization of existing run-of-river plants would not be economically feasible.[58] This attempt to support large plants was highly controversial.[59] The conflict it triggered dominated the process of drafting and enacting the 2004 version of the EEG. In a compromise draft, in November of 2003, the German Environmental Ministry limited the entitlement to the compensation for large plants to that for additional power output attained through modernization. The compensation would also only be available for plants that were completed by the end of 2012 and that achieved a performance increase of 15%.

Adjustment of Compensation Under the Renewable Energy Sources Act

The StrEG's coupling of the compensation rate to the average prices, which were falling, had pushed hydropower to the limits of economic viability. By introducing a fixed rate (7.67 cent/kWh; see Table 8.4) for hydropower plants with capacities of up to 500 kW, the EEG of 2000 created relief for running small hydropower plants and, in some cases, made it possible to reactivate deactivated plants. However, the compensation rates in the EEG 2000 were at no point sufficient to function as an incentive for the construction of new plants.

While drafting of the amended version of the EEG of 2004 continued, its authors formulated conditions under which small hydropower would also be entitled to increased compensation. During consideration of the draft EEG in the Bundestag, hydropower advocates were able to push through added improvements. The rate for electricity from small hydropower plants with capacities of 500 kW or below was increased by 2 cent/kWh to 9.67 cent/kWh (see Table 8.4). That was intended to ease the specific plant costs and additional costs for environmental measures (see below). The lengthening of the compensation periods represented another improvement.[60]

For power from medium-sized plants (500 kW–5 MW), compensation remained at the 6.65 cent/kWh level. The payment of the increased compensation of 9.67 cent/kWh was tied to the fulfillment of environmental requirements (EEG §6

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[58] Specifically, at issue was the modernization and/or new construction of the run-of-river power plant in Rheinfelden (operated by EnBW), which is why insiders also referred to the inclusion of large hydropower as "lex Rheinfelden". Many plants would not otherwise have been economically viable in view of the looming relicensing requirements and the far-reaching modernization and retrofitting measures, with no feed-in tariff and the electricity prices at the level they were on the market (at the time 3–4 cent/kWh), meaning that the continued operation of plants was at risk (Staiß 2007, 94).

[59] Private hydropower operators organized within the Federal Association of German Hydropower Plants (BDW) rejected the inclusion of large plants belonging to the energy industry, reasoning that large hydropower plants did not need support since they were far more profitable than the small plants run by medium-sized companies and could earn more through the direct sale of electricity than was stipulated in the EEG. See the press release connected with the member assembly in Frankfurt on May 05, 2003: http://www.wasserkraft.org/ (accessed August 06, 2009).

[60] The compensation period was intended to be unlimited for plants that began operating before January 01, 2004, while the claim to compensation was increased from 15 to 30 years for younger plants. In view of the long amortization periods of plants, Heimerl (2009, pers. comm.) believes that long terms of that order were justified. In the case of plants of > 5 MW the compensation period was limited to 15 years though.

Table 8.4 Overview of compensation rates for hydropower under EEG 2000, 2004 and 2009

Content	EEG 2000	EEG 2004	EEG 2009
Maximum capacity	5 MW	150 MW	omitted
Rate (in cent/kWh)	≤500 kW: 7.67	≤500 kW: 9.67	New plants of expansions of up to 5 MW
	>500 kW: for share of electricity up to 500 kW output: 7.67	≤5 MW: 6.65	(new/modernized) ≤500 kW: 12.67/11.67 ≤2 MW: 8.65
	Remainder with 6.65	> 5 MW and ≤ 150 MW in cases of performance increase of at least 15% or new construction:	≤5 MW: 7.65/8.65 New plants with cap. >5 MW Performance share
		≤500 kW: 7.67	≤500 kW: 7.29
		≤10 MW: 6.65	≤10 MW: 6.32
		≤20 MW: 6.10	≤20 MW: 5.80
		≤50 MW: 4.56	≤50 MW: 4.34
		>50 MW: 3.70	>50 MW: 3.50
Period	../..	≤5 MW: 30 years	≤5 MW: 20 years
		>5 and ≤ 150 MW: 15 years	>5 MW: 15 years
Degression	../..	1% for plants > 5 MW from 2005	1% for plants > 5 MW from 2010

subsection 1). The attainment of a good environmental status or improvement of the status relative to the past also applied to small plants with capacities of up to 500 kW that were newly built at existing barriers or weirs. In contrast, small plants of 500 kW capacity or less that were not built in connection with existing barriers or weirs were eligible for the increased compensation only if they were completed within a certain period; i.e., licensed by December 31, 2007, unless they were built without a transverse structure that stretched completely across the waterbody.[61] That regulation represented an important goal for the nature conservation groups: the linkage of the feed-in tariff to improvement of the environmental conditions of waterbodies. They viewed this as a step toward environmentalization of the feed-in tariff.[62]

[61] With that, a balance was struck between the nature conservation issues and the interests in energy-related use of rivers, while, it was thought, additional interference in small rivers and streams still in their natural state could be avoided.

[62] See press release of Nature and Bio-Diversity Conservation Union (Naturschutzbund Deutschland – NABU) of July 20, 2005. http://www.nabu.de/ (accessed: August 06, 2009).

However, it must be said that rehabilitation or conversion of existing hydropower plants occurred only rarely in a scope that allowed the construction of “detours” or fish passage aides actually to be stipulated during the permit procedure.

The 2009 amended version of the EEG did not change the compensation rates for large plants with capacities of more than 5 MW. Since there were no longer any specific cases of application certain conditions affecting large plants were deleted: The compensation period for plants with capacities of less than 5 MW was adjusted to match that for other sectors in the EEG, decreasing from 30 to 20 years. To make up for that, the rate was increased by 1 cent/kWh. The incentive for the construction, expansion and modernization of smaller new plants was enhanced by raising the basic compensation to 12.67 cent/kWh for new plants and 11.67 cent/kWh for plants with capacities of up to 500kW that are modernized after January 01, 2009.

Despite criticism of the additional costs associated with environmental requirements, the compensation was not increased in the 2009 version of the EEG for expansion and modernization of existing plants.

8.3.3.4 Informal Ex-Post Management to Prevent Harmful Environmental Impacts

The rules set out in the water acts of the states intended to make sure that environmental requirements were confirmed within the licensing procedures, were not sufficient to ensure adequate protection of rivers. The link created in the 2004 EEG between the payment of higher compensation for the fulfillment of environmental requirements also appeared inadequate for ensuring that this form of tariff support conformed with national and European aims – the creation of a good environmental river status. From a conservation standpoint, what was missing was a link between the environmental criteria set out in §6 of the EEG and the permit criteria under water legislation.[63] To avoid conflicts, it was thought, technical criteria were required to underpin the riverine ecological concerns.

Guideline for Environmental Hydropower

The 2004 EEG said that compensation will only be paid provided that – after installation of a hydropower plant – the respective watercourse is in an improved environmental state. Some states, including Baden-Württemberg, began to set out their own directives and enactments.[64] To ensure that environmental requirements are

[63] For example, one cannot assume that the issue of a permit is sufficient evidence that an improvement in river ecology has been achieved.

[64] Due to the high status that hydropower utilization enjoys in Baden-Württemberg, the government of that state was probably more willing to make concessions in this matter, according to Heimerl (2009, pers. comm.).

applied consistently the Federal Ministry for the Environment released a guideline on the compensation for electricity from hydropower in 2005.[65] It specified criteria to assess improvement of the environmental conditions of a waterbody.

Using a demonstration project, the hydropower plant in Farndau on the river Fils in Baden-Württemberg, the guide showed how it was possible to render the construction or modernization of hydropower plants compatible with the requirements set out in the EEG through appropriate measures.[66] Critics claimed, however, that the standards for the riverine environmental assessment were too high and that their implementation would be unrealistic in a substantially less flexible economic environment.

The guide and the demonstration project were considered to be “soft” or “informal” governing instruments with which the statutory requirements could be operationalized and thus more effectively implemented. The Federal Ministry for the Environment used them to show that hydropower use was possible even under the water-ecology-related conditions that had been stipulated.

8.3.3.5 Technology and Market Developments

Currently, it is assumed[67] that there are a total of about 7,000–8,000 hydropower plants in Germany, with Bavaria and Baden-Württemberg still home to more than 80% of them. Large plants account for over 90% of overall installed capacity. Small hydropower does account for 95% of all plants, but represents only around 7% of installed capacity, or electricity generation (Heimerl & Giesecke 2004).

In 2003, construction of the Rheinfelden run-of-river power plant[68] (100 MW) on the section of the river Rhine known as the “Hochrhein” began. The plant is scheduled to begin operation by 2010/2011. The expansion of the German-French plant Rheinkraftwerk Iffezheim (38 MW) is also scheduled to start operating in 2011. There are also plans for a new hydropower plant on the Weser near Bremen (10 MW).[69]

According to Laubach (2004, 18), almost half of the licensable expansion potential is on the Rhine. The share of new construction or expansion potential for what are called “border” power plants is very high there. The inter-governmental

[65] Cf. BMU (2005). The Federal Ministry for the Environment was instructed by the legislature to prepare this guideline in connection with the EEG amendment (BT-Drs. 15/2864).

[66] A more compact construction method was thought to lessen the environmental impacts on the waterbodies, upstream and downstream fish movement technologies would improve passage and the installation of side channels would create additional spawning beds. In 2006 the Federal Ministry for the Environment earmarked 570,000 euros from the Environmental Innovation Program for the hydropower project (BMU 2006).

[67] Since small hydropower is found only in patchwork fashion outside of Bavaria, estimated figures are used often in compiling statistics on this subject.

[68] This project included an exemplary fish ladder installation. On the construction project/progress of construction up to 2007 see http://www.energiedienst.de/ (accessed August 06, 2009).

[69] This is intended to be a “citizens’ hydropower plant” – a novelty in the hydropower sector with respect to its operator structure.

and inter-company coordination required in such cases may represent a substantial impediment (ibid.).[70]

Only around 7,000 plants were operating in the small hydropower segment in 2005. Installing additional capacity would have to involve the removal of licensing barriers, the issue of new water rights and the use of high-performance technology. New plants at new sites would probably be eligible for permits only in exceptional cases (Laubach 2004, 18). As the "prime cuts" among hydropower sites have long since been allocated, the only sites that might come into consideration are primarily old watermills. Those old mill sites frequently offer individual capacities of only 10 kW or below. Sites in the micro-capacity range have a variety of application areas for waterwheels.[71] Since technological development in that area has also advanced,[72] such wheels are superior to turbine technologies for those sites. However, they offer only a very limited increase in capacity.

Employment estimates reveal that the hydropower sector provided ca. 4,900 jobs in Germany in 2008 (O'Sullivan et al. 2009, 6).

8.3.3.6 Actors in the Constellation

Engineers and Operators in the Former East German States

At the start of the new millennium, operators in Thuringia and Saxony felt the full impact of the restrictions affecting the recommissioning and/or expansion of small hydropower sites. Political will for the expansion of small hydropower of up to 100kW for example in Saxony (Rolle 2001, 493) was missing. Furthermore, costly requirements for operating in an environmentally friendly fashion, such as compliance with minimum residual flows, installation of fish ladders and continuous measurement of water levels led to decreased profitability (ibid.). Conflicts between the water mill operators, conservation groups and fishermen, who saw their fishing rights jeopardized, grew more heated. From the perspective of mill operators, it was illogical that an activity that they had practiced for decades without, in their view, was suddenly no longer acceptable. Frustration set in and many potentially suitable sites were left unused.

Nature Conservation and Environmental Protection Groups

Conservation and environmental protection groups played a significant role in the negotiation process concerning the environmental management of hydropower utilization.

[70] An expansion project can only be implemented when both the environmental and the economic conditions in both border countries involved are favorable (Laubach 2004, 18).

[71] Waterwheels should be seen more as a niche product, but they are currently experiencing something of a renaissance in the micro-capacity sector. See http://bega-wasserkraft.de/Wasserrad/ (accessed August 08, 2009).

[72] Modern planetary gears and transmissions from 1:100 can achieve efficiencies of over 90%.

Addressing the need to protect riverine ecosystems, the environmental organization BUND published a position paper on the use of hydropower under the premises of protecting riverine ecology. The stance taken by conservation groups like NABU, BUND and WWF[73] on hydropower use was largely positive but included some reservations. Negative impacts on populations of aquatic species in rivers and streams were a major concern. Taking ecological aspects into account by conditioning the support on the fulfillment of certain ecological obligations in the EEG 2004 was regarded as a progress. However, opinions have varied with respect to whether it was appropriate to enact those regulations in the EEG or whether the regulations in the water management legislation (WHG) might have been sufficient.[74]

Companies

The companies in the hydropower sector still see an expansion potential of around 2,000 MW (EE-Branche 2009, 15–16). However, the exploitation of this potential is currently not being pushed at the political level. Many German companies in the sector have been highly active in other countries for many years.[75] Corporate mergers and restructuring to adjust to market developments are continuing. For instance, Voith Hydro and RWE Innogy have formed a joint venture, Voith Hydro Ocean Current Technologies, which is set to develop tidal energy as a new area of business.

Environmental Authorities of the States

The reasons that expansion in the sector has lagged behind technological and economical potentials are predominantly thought to lie in the political and legal arena. In many cases, old usage rights were deemed not to cover the conversion of a site from mechanical operations to electricity generation. Policies on water resources in the states were directed far more toward the revocation of old water rights. The water authorities used their discretionary powers accordingly, ensuring that the conversion of old watermills into privately operated micro-power plants running parallel to the grid remained restricted to a small number of cases.

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[73] According to the WWF (2003), the substantial damage caused by small hydropower plants is disproportionately great relative to plant capacity. For that reason the WWF advocates including large hydropower plants with over 5 MW capacities in the EEG support, whereby the support would go only to additional capacity.

[74] The conservation organization BUND criticized the link in the public hearing on the EEG 2004 in the Bundestag and considered the arrangement in the WHG to be adequate in that respect.

[75] For instance, Wasserkraft Volk AG cited its export quota as over 90%. Wasserkraft Volk AG's chief sources of revenue are primarily emerging countries. By contrast, their German business, they report, is continually declining due to the high bureaucratic hurdles. See http://www.iwr.de/ (accessed August 06, 2009).

8.3.3.7 Interpretation of the Constellation: Driving Forces and Restraints

The realizable potentials of hydropower in Germany are considered to have already been exhausted to a great extent. At present, there is not a high level of activity with respect to development processes and the constellations of actors. A certain equilibrium has been established in the constellation, one which is unlikely to provide new incentives for change. Technological innovations apply to incremental improvements in turbines, generators and plant management and in trials of new technology such as fish movement equipment intended to facilitate passage through water bodies. The compensation rules set out in the EEG of 2000 and 2004 did contribute toward stabilizing small hydropower, but performance increases in that segment were primarily due to modernization, and had less to do with the construction of plants. Large hydropower also profited from its inclusion in the EEG support from 2004. Modernization and capacity expansion would not have been possible at that time without that support. Potentials for revitalization at old sites in the states in the former GDR have not been exhausted because of restrictive interpretations of the regulations concerning river protection.

Beginning in 2004, modernization and repowering of small plants were subjected to stronger requirements concerning environmental compliance. The European regulations on the protection of rivers promoted environmental criteria required for licensing of hydropower plants, Tariff payments in the EEG 2004 were also tied to the fulfillment of environmental criteria. Hence the 2004 EEG was, at least from the perspective of hydropower utilization, expanded to include an “environmental management component.” The operationalization of that component was pushed forward by the Federal Government (Federal Ministry for the Environment) by the publication of a guide and a demonstration project. With that the hydropower sector took on a trailblazing role for informal approaches to reduce conflicts between renewable energies and nature conservation.

8.3.4 Prospects

Hydropower has already reached a high technical degree of development. According to the Federal Ministry for the Environment (BMU 2008a, 6), there are a wide range of opinions about the potential of small hydropower for growth that is sensible from an economic and environment perspective. Environmental groups believe that ecologically compatible sites have already been exhausted to a great extent. In contrast, the hydropower sector still sees opportunities for expansion. Taking environmental criteria into account, future projects will have to concentrate chiefly on *existing* transverse structures. Capacity increases will thus primarily be achieved through repowering (replacement, modernization and reactivation of existing plants).

In near future, hydropower plant operators will face another challenge: a large proportion of existing water rights allowing to run a hydro power plant will expire. They then have to submit applications for their renewal. Again, the water rights will then be limited to a term of 30 years. Under the aspects of amortization periods of hydropower plants that period is too short.

Accordingly, the sector has called for a prolongation, both of the permit periods and the support periods set out in the EEG, to reflect the particularly long-term planning horizon of hydropower operators.

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Chapter 9
Cross-Sectional Comparison

Abstract The innovation biographies of renewable energies allow us to draw conclusions about the particular course of each individual process as well as about the respective influencing factors. The analysis shows that each innovation process is individual, but that, at the same time, certain phase types occur in all processes examined. Despite such typical phases in innovation biographies, each process pursues its own dynamic and has its own distinctive features. On the other hand, the constellations revealed that the innovation processes are complex and that they are affected by a high degree of interaction and interdependency between the influencing factors. Renewable energies developed as a result of the interplay between technical, socio-economic and environmental driving forces. The processes can only be explained as resulting from the interaction of a variety of factors within the particular context of action. Governance plays a key role, but it cannot be isolated from other factors.

Keywords Innovation process • Cross-sectional approach • Typical phases • Key driving forces • Interdependency

The objective of this research was to trace the impressive development of renewable energy in Germany over the past 20–30 years, and to review and add to the results of previous studies. A lot has happened in Germany and other parts of the world since around 1970 that has affected all renewable energy sectors examined here. These influential interventions, events and processes have been summarized in Chapter 3, and they are subsequently drawn on for the analysis of the individual innovation processes (Chapters 4–8), depending on their respective relevance.

Although these overall processes were significant, scrutiny of the individual sectors showed that each one of them has its own individual history (Chapters 4–8). The analytical approach of Constellation Analysis helps to reflect the uniqueness of the five innovation tracks. At the same time this approach allows for comparability, albeit only to a certain extent. The technologies examined here have different

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characteristics, for example, with regard to technological concept and manufacturing complexity, the necessity of pooling know-how from various fields of knowledge, possibilities of integration into existing patterns or systems of usage, the duration of their development and innovation cycles, social acceptance, spatial requirements, etc. Each innovation process, i.e., each technology and its implementation, has a specific, individual nature.

Following, we examine the differences and similarities between the innovation conditions of the various renewable energy sectors. We will outline and systematize key promoting and inhibiting influences, while at the same time scrutinizing the innovation processes for typical phases and patterns. Are there any significant cross-sectoral impulses, principles or interdependencies that can be generalized for the innovation processes of renewables?

Finally, this comparison will shed light on the role of public policy in the innovation process and provide insights into a possible focus and strategic application of policy approaches in innovation processes (Chapter 10).

9.1 Key Driving Forces in the Innovation Biographies

The innovation processes were driven by government interventions and incentives, such as legislation and subsidies (see Sect. 9.1.4), as well as a number of non-governmental factors that defy direct control (technological specifics, overall social and economic conditions, crisis-like contextual events). The following section describes the most important driving forces that are crucial to the innovation's success.

9.1.1 Civic Activities, Creative Environment and Pioneers

In the case of renewable energies, the strong anti-nuclear power movement and the considerable engagement of environmentalists greatly fueled the process of innovation. The actors of this scene, who were frequently organized in citizens' initiatives, created a setting that encouraged the development of alternative ideas. The respective community developed innovative technical ideas resulting from the desire for a less heteronomous life and a world that is less threatened by technological risk, the desire for independence from the system and for self-sufficiency, and an attitude of resistance toward both the political establishment and the predominating power supply system. In this way, the members of the environmental movement, who were searching for alternatives to fossil and nuclear energy generation, did the pioneering work for the development and first application of wind power technology. The continuity of the PV development was in no small part due to strong civic engagement as well (investments in private PV systems). In the field of biogas idealistic farmers committed to environmental protection who initiated and advanced the use of biogas technology, based on learning by doing.

The decisive factor in the technologies' successful breakthrough was that individual business people from the wind, photovoltaic and biogas sector managed to professionalize their idealistic ideas and succeeded in creating structures that were compatible with the market. In this, they were able to build on the acceptance and favorable attitude of large proportions of the population.

In particular, the expansion of wind power technology, which requires vast areas, was to a large extent made possible by farmers. As landowners they held the key resource for the erection of wind turbines.

Geothermal power missed such a process of social embedding during the 1980s and 1990s. For this reason the circle of active proponents and users is considerably smaller in this case. In its initial phase, the geothermal sector therefore depended more strongly on governmental action.

Unlike geothermal power, the concept of hydropower had evolved over the years. Having been viewed as a technological forerunner, its acceptance was extremely high at the beginning of the nineteenth century. A large number of private operators, businesses and power utilities were interested in hydropower. Its loss of acceptance began with the growing environmental movement in the 1980s, when it became clear that hydropower was being used at the expense of river basin ecosystems. Support by civil society actors gradually led to broad political and social acceptance, which is what present-day support for renewable energies – provided by associations, politicians and the public – builds on. Surveys have repeatedly substantiated the high level of public acceptance toward renewables. Social acceptance – an overall positive attitude of the population toward renewable energy – is an important prerequisite for diffusion and expansion (see Sect. 9.3.4). The more a technology is accompanied by (unintended) negative environmental effects and visible changes to people's environment, the more acceptance problems are likely when it comes to actually planning its implementation. The stronger the expansion and the less regulated it is, the more likely it is to lose acceptance, at least at the local or regional level. In this case it is important to find a balance between opportunities for the development of the sector and the burden perceived by the population.

9.1.2 Advocacy Coalitions

Individual actors hardly manage to assert their interests without the support of other actors, preferably already established ones. These so-called advocacy coalitions[1] can turn into a driving force for the innovation process. For this to occur, concerns must be raised to individuals or institutions with political relevance and power to act. Leading promoters or "change agents", who manage to initiate the formation of actor alliances, are particularly successful at this.

[1]The term "advocacy coalition" was coined by Paul A. Sabatier (1993). Advocacy-Koalitionen, Policy-Wandel und Policy-Lernen: Eine Alternative zur Phasenheuristik? A. Héritier (Ed.), *Policy-Analyse. Kritik und Neuorientierung* (pp. 116–148). PVS-Sonderheft 24, Opladen.

Alliances may form at identical or at different public policy levels (macro-level: e.g. EU; executive: states, local authorities), but also between actors of various domains such as the state, market or civil society.

An example in the innovation process of renewable energy was the Tailwind Campaign (Aktion Rückenwind) that formed at the end of the 1990s. In 1997 the Federal Ministry of Economics had announced reductions of the feed-in tariffs specified by the Electricity Feed-in Act,[2] which provoked a protest by a broad range of actors. At the initiative of the still young German WindEnergy Association (BWE), an alliance of various different actors (total of 5,000) organized a demonstration for renewable energy in defense of the Electricity Feed-in Act in Bonn in September 1997. The alliance consisted of environmental associations (NABU) and environmental groups, associations from the field of renewables, the German Farmers' Association, plant manufacturers, the Protestant Church and the German Industrial Union of Metalworkers (IG Metall). In addition, representatives of all parliamentary groups in the German Bundestag argued in favor of continuing support for renewable energy. The protest voiced by this unusually broad advocacy coalition was substantial in abandoning the idea of reducing the feed-in compensation.

Examples from wind power and photovoltaics show that alliances of business interests and labor market interests are relevant to the development and diffusion of the technologies. Most wind turbine manufacturers and their contractors are based in the northern, windier regions of Germany. The jobs created here not only provide income from owner-operated municipal enterprises, shares in operating companies or leasing yields, but also serve to secure the population's purchasing power and the economic prospects in the regions, while at the same time strengthening the social acceptance of wind power. With respect to photovoltaics, many manufacturers and research institutions are headquartered in the eastern German states which have an above-average unemployment rate. The state and local governments are very much interested in supporting the photovoltaics business clusters as one of the few dynamic sectors. A network formed by local government authorities, enterprises, investors, a state-owned holding company, a planning and coordination office as well as research institutions and universities has allowed the east German "solar valley" to grow into a model region.

The probability of an innovation becoming established and diffusing through society increases when the number of participating actors from various arenas grows and cooperation and communication among them is intensified. Positions of power and strength of the participating actors play an important role (see Sect. 9.2.2).

[2]The sources for the legal information used in this chapter are given in the Index of Legal Sources.

9.1.3 Political Window

A comparison of the processes showed that all of the sectors (except for geothermal) had entered an inception phase and dynamization in the 1990s. Processes of societal and political rethinking had been sparked off by the 1986 Chernobyl reactor catastrophe. This triggered a fundamental environmental crisis that called into question the nuclear power policy pursued up to that point in time. In addition to dealing with the consequences of the accident, politicians were now faced with providing preventive strategies. Alternative energy supply concepts started to gain ground in the course of this societal rethinking process. The Chernobyl accident also opened up a window for political action, resulting in the institutionalization of environmental politics by creating dedicated environmental departments (e.g. environmental ministries in the Federal Government and the states).

This example shows that critical events outside of governance activities may assume a trigger function in the context of actor constellations. They point to the need for action and force politicians to reconsider and adjust objectives and strategies.

9.1.4 Political Strategies and Lead Principles

In Germany the path toward the establishment of renewable energy was paved by strategies for climate protection, the dedicated promotion of renewable energy and the paradigm of sustainability. However, the lead principles, goals and expectations that were associated with the technologies of renewable energy in question varied during the innovation process. In the early phases, cultural orientation patterns and the lead principles of social subgroups that strove for a paradigm shift in energy supply played an important role. These principles can be regarded as a crucial driving force in the development of renewable energy, especially in the pioneering phases.

The emergence of wind power and photovoltaics, for instance, was initially motivated by environmental issues. The pioneers wanted energy resources to be used more efficiently and fossil sources to be replaced. In the further course, the principle of sustainable development became increasingly important as a justification for renewable energy. With the new generations of technology, such as offshore wind energy or solar power stations, the objectives seem to be increasingly aimed at the economic profitability of renewable energies as lead markets and at climate protection; the latter significantly driven by the EU climate protection policy, but also by ambitious national CO_2 reduction targets. On the other hand, nature and biodiversity protection are faced with the threat of being taken less seriously. It seems as though climate protection measures are being pushed at the cost of nature and biodiversity protection.

The federal offshore strategy from 2002 gathered momentum for preparing the realization of the planned wind facilities. However, reality could not keep up in time with the goals originally set, so the goals had to be corrected.

Despite the offshore development did not yet meet the expectations, the strategy acts as a driving legitimation background for continued efforts to reach the targets.

All of the sectors demonstrate that various strategies, objectives and motives were linked to each other and geared toward the technology in the course of the innovation process. They legitimized and initiated government action in the innovation processes of renewable energy. The political strategies and respective policies were an important context of justification that spurred the development. It is important to note, however, that the focus areas of the policies shifted in the course of the process.

9.1.5 Institutionalization and Market Incentives

A key success factor in the growth of renewable energy in Germany is the institutional framework. In the cases examined here, this is made up of an effective research and development policy and demonstration programs both at federal and state level and far-reaching federal legislation which, based on sophisticated and long-term financial incentives, creates security for investment within the young sectors. Furthermore, the transferal of administrative responsibility for renewables to a professional and committed key actor – the Federal Ministry for the Environment – fostered the process.

9.1.5.1 Feed-In Compensation as the Trigger of Dynamization

It was a strong, central governance stimulus that proved to have a great impact on the dynamization of the innovation process – the Electricity Feed-in Act (Stromeinspeisungsgesetz – StrEG) which was passed in 1991. In the field of electricity it marked the beginning of a new phase for all renewable energy sectors, except for deep geothermal energy.[3]

At the time when the StrEG was passed, the individual sectors were undergoing different phases of the innovation process. The wind energy sector, for example, was in its inception and pioneering phase. The changes in energy policy, which ultimately affected all the sectors, accelerated the inception phase. Due to its stage of development and sociopolitical embedding, the wind energy sector benefited from the feed-in tariffs of the StrEG more than any of the other sectors.

The use of hydropower, whose proponents had significantly encouraged the enactment of the StrEG, was already in the maturation phase with respect to its

[3]Deep geothermal technologies were still in the making during the 1990s. The feed-in compensation could *initially* not induce any innovation in this sector though.

technological development. There was no more impetus for technical innovation to be expected. What followed was rather a phase of modernization of the small-scale hydropower stations, which served as a temporary stimulation of the market.

The biogas pioneering phase took place in farming businesses. Receiving payments for electricity spurred biogas production from liquid biomass (liquid manure) with an increasing proportion of solid biomass (bio-waste, crops), which led to a first start-up phase. Due to a quite diverse range of technological applications, both its expansion and technological growth did not proceed as rapidly as in the wind power sector.

The promotion of research and development in photovoltaics had cleared the way for a pioneering phase in the mid-1980s, yet the dynamic plummeted soon after. Both, the 1,000 Roofs Program (1,000-Dächer-Programm) and the StrEG provided a stimulus for solar power generation, but the influence of the StrEG was rather small in this case, and did not manage to leverage the technology at this point.

The StrEG proved to be a key instrument in launching the technologies onto the market. It accelerated innovation processes if the technologies were already in the pilot or demonstration stage. However, the feed-in tariff did not have this accelerating effect if these stages of development had not yet been reached.

9.1.5.2 The EEG as the Key Instrument in Market Launch

Even more than the StrEG, the subsequent Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz – EEG) effected extensive growth of renewable energy in Germany. Depending on the development stages of the technologies, it initiated or consistently supported their development, creating several internationally competitive sectors. When the EEG superseded the StrEG in 2000, which had been a central project of the new Red-Green[4] government coalition that had come to power in 1998, the StrEG was comprehensively revised and expanded. In order to improve security for investment, fixed tariffs were now introduced based on the status of pilot plants' cost development. The introduction of *fixed* compensation rates in the EEG was also closely linked to the liberalization of the electricity market 1998, because as a consequence declining electricity prices had harmed the interlinked feed-in-tariffs of the StrEG, too.

9.1.5.3 Liberalization of the Electricity Market

Following the amendment to the German Energy Industry Act (Energiewirtschaftsgesetz – EnWG)[5] in 1998, the EU regulations aimed at breaking up the regional monopolies that had been in force protecting the power

[4] An alliance of the Social Democratic Party and the Greens who were in power from 1998 to 2005.

[5] Cf. Index of Legal Sources.

utilities since 1935, thus permitting competition on the electricity market. Despite the establishment of the Federal Network Agency (Bundesnetzagentur – BNetzA)[6] in 2005 and a second amendment to the EnWG (2005), there were still shortcomings in the implementation of the liberalization efforts. In exceptional cases it is still possible to deny alternative electricity feeders access or connection to the grid. Still, along with the feed-in and compensation regulations, liberalization was one of the key political and legal frameworks for the diffusion of renewable energy sources.

9.1.5.4 Transferal of the Political and Administrative Responsibility to the Federal Ministry for the Environment

While renewable energy had lived a shadow life in the energy portfolio of the Ministry of Economics, its transferal to the Ministry for the Environment gave it a noticeable push. With the gradual establishment of a relevant subordinate department, renewable energy was for the first time represented by a federal-level portfolio. The Federal Environment Ministry introduced the targets of climate protection and expansion of renewable energy at the national level, while establishing the important connections with the European renewable energy sources policy. It pooled the different partial strategies (R&D, market launch, framework conditions, governance stimuli) in order to create a consistent overall strategy of renewable energy.

9.1.5.5 Founding of Renewable Energy Advocacy Groups

The renewable energy sector experienced a further consolidation of the institutional framework with the formation of a number of relevant advocacy groups. Initially their work frequently encompassed exchanging technical experience (e.g. Fachverband Biogas e.V. – the *German Biogas Association*). As the represented sector gained in significance, the advocacy groups' tasks began to expand and included political representation of interests as well. These lobby groups pointed out certain developments to decision-makers at an early stage, and in doing so influenced their decisions. In the field of biogas, for instance, they propagated the use of renewable primary products as fermentation substrates in order to allow the sector to grow further. In addition, they drew attention to the necessity of regulations for gas feed-in.

In the solar sector the lobby groups contributed to the raise in the 350 MW subsidy cap in 2002 (see Sect. 5.3.5.5). The completion of the 100,000 Roofs Program (100,000-Dächer-Programm) created a gap in the photovoltaics sector subsidization. But unlike what had occurred after the expiry of the 1,000 Roofs Program, the advocacy groups of the solar industry were able to prevent a sharp

[6]The Bundesnetzagentur is intended to ensure that the monopolized part of the grid is separated from the competitive energy sectors, thus guaranteeing fair conditions for competition and grid access. Its tasks cover the control of abusive practices as well as ensuring that the regulations for grid unbundling and system responsibility are complied with.

decline in the sector and at least to cushion the lack of follow-up support thanks to the Interim Photovoltaic Act (PV-Vorschaltgesetz).[7]

The sectoral associations have been represented by the cross-sectoral association Erneuerbare Energie e.V. (BEE) at the federal level since 1991. It coordinates the activities of the individual groups. A similar function at the European level is adopted by the European Renewable Energies Federation (EREF).

9.1.6 Multi-Level Policy as the Driver

The renewable energy biographies show that, depending on the political field and the problem at hand, the role of the spearhead or leading part switches between the European, national, regional or even municipal level. This includes the European structure of competencies, different political power constellations and different competencies and expertise. Switching between the national and the European level proves to be advantageous if this allows circumventing barriers, such as those resulting from established power structures.

At the global level, international climate agreements (Kyoto protocol) were pushed forward. These were aimed at raising awareness of the problem back in the home countries and at encouraging the relevant commitment to tackle it.[8]

At the European level, a large number of actions were initiated that introduced structural change to the energy supply system. One of these was the organization of the European common market. Liberalization of the energy market was not feasible because of the power structure at the national level. It was not until the EU's liberalization regulations that structural change of the energy market was enforced at the national level.

Federal renewable energy policy focuses on various supporting measures and on the regulations governing feed-in compensation. This set of policies sets Germany apart, lending it an exemplary role that affected not only its own energy industry but also that of other European countries.

In Germany, the policies provided by the various decision-making and implementation levels frequently interlocked. In the case of wind energy, the "old" north-western German states served as trailblazers for the development and application of siting criteria (clearance decrees). Regional and local land-use planning and the practice of approving permits influenced the federal government's amendment to the building and land zoning legislation in the mid-1990s.

In the case of photovoltaics it was the cost-covering compensation for alternative electricity granted by ca. 40 municipalities that closed a gap in the federal government's supporting policy. In the case of hydropower, the state of Bavaria took on the pioneering role in creating the association agreement as an informal compensation regulation before it was finally raised to the federal level with the adoption of the StrEG.

[7] Cf. Index of Legal Sources.

[8] Currently this concerned a Kyoto follow-up agreement with adequate targets and emission budgets.

9.1.7 Technology-Bound Driving Forces

Whether the performance of a technology is trusted and whether it experiences broad acceptance within society depends in no small part on its image. The technologies for solar power generation benefited in particular from their high-tech image ("space technology"). This was linked to high-flying hopes concerning the government's readiness to provide early and comparatively wide support in the form of subsidies and industrial commitment.

The wind power sector benefited from a high-tech image as well, albeit not to the same extent. It was able to enhance its positive image after it had become possible to integrate German mechanical engineering with know-how from the field of aerodynamics and modern construction methods and materials. The wind power turbines developed certain high-tech aesthetics and a performance capacity that made them qualify as a "technology of the future".

Biogas engineers, by contrast, initially suffered a low-tech image. The technology was considered simple and rugged, which is why it failed to provide ambitious researchers with a promising field for achieving recognition. In practical terms, the image also suffered because of the odor as well as setbacks resulting from the hardship to control fermentation process.

Power generation from deep geothermal heat had long been considered a dream of the future. The procedure was originally not associated with the high-tech segment. The two high-tech research projects for the utilization of "hot dry rock" technology of significantly higher temperatures were hardly known except to researchers of this specific field. So despite the introduction of compensation for power from geothermal sources with the EEG 2000,[9] this had no noteworthy incentive on the sector. This effect occurred only after the compensation rates were significantly raised in the EEG of 2004. In recent years, microseismic earthquakes and tremors that occurred in the context of geothermal exploration wells created image problems.

The "prestige" of a technology, and its degree of acceptance in research, society and politics, determines the liability for government support and its willingness to help overcome obstacles. Technologies with a high-tech image are more liable to be granted research promotion, because innovation research prefers high-tech technologies.

9.1.7.1 Technical Integration

Photovoltaics and deep geothermal systems are examples that it requires considerable effort to make a technology marketable and competitive if their integration degree with already existing technologies is relatively low.

[9] Cf.: Index of Legal Sources.

In the field of photovoltaics, it was not only the technology itself but in part also the production methods that had to be developed from scratch, with no possibility of drawing on already existing structures. It is true that the silicon and wafer production process required for the manufacture of crystalline solar cells is largely identical with the manufacturing technology used in cell production, and that because of its low material requirements the cell sector was able to draw on "silicon waste" from the semiconductor industry. Still, because of the low sales rates, solar cells and modules were largely produced manually and therefore quite expensive. It was only when the demand increased (even globally) that it became worthwhile to automate these manufacturing steps. Unlike crystalline solar cells, thin-layer solar cells represented a stand-alone technology. Their breakthrough on the market had become possible only after new production technologies from the field of substrate coating and plasma screen manufacture were used in large-scale industrial manufacturing.

The development of deep geothermal systems essentially uses modified oil drilling or gas drilling technologies. Countries with their own gas and oil resources have a competitive edge here since domestic drilling companies have the relevant drilling know-how. However, the interest in promoting technologies designed to explore and encourage the use of deep geothermal energy was not and still is not very pronounced in the oil and gas producing countries. From a German perspective, competing oil and gas drillings considerably curbed the exploration and development of geothermal technologies, since international drilling companies were operating at full capacity as a result of the increasing demand for oil and gas wells, and because the amount of drilling equipment available was limited and therefore expensive.

The domain of wind power benefited from developments in aircraft construction (aerodynamics) and in composite material development. These were combined with existing technologies from mechanical and electrical engineering. The success factor therefore resulted from merging a number of modified elements from these technologies. The interest in this innovation was initially fueled by the desire to prove the technology's competitiveness (representative for the entire sector of renewable energy). What was important was to demonstrate its "feasibility". In the expansion phase, the focus shifted toward operating optimization, increased capacity and system integration.

Biogas generation in the agricultural sector was initially a "by-product" of the interest in turning liquid manure into recyclable fertilizer. Technologies for manure fermentation and biogas generation drew on components from agricultural technology, such as silo and container construction and stirring equipment. Integration into the existing network was possible insofar as many farmers were quite familiar with this simple and rugged equipment. As power generation became increasingly important, engine technology and energy conversion technologies gained in significance as well. The gas processing technologies required for power generation were already being used in the processing of industrial and noxious gasses. These processes were harnessed by modifying them to meet the specific requirements of biogas processing.

This suggests that one of the key success factors in the development and expansion of an innovation is to tie in the new technologies with the existing know-how of a sector. If a technology cannot be integrated into existing structures, its development will require greater efforts.

9.2 Inhibitory Influences in the Innovation Biographies

9.2.1 Investment Costs and Limited Resources

Investment costs as well as access to resources for power generation are factors that limit the scope of potential users and investors. The higher the costs and risks, the more limited the users. However, a large range of users – as shown in the example of wind power – is an important factor when it comes to embedding a technology in society or initializing the expansion of a certain technology.

In the case of deep geothermal systems, the majority of actors interested in renewable energy is excluded as a result of the technologies' dimension and costs as well as the high investment risk involved. Photovoltaics, by contrast, is a "technology for anyone" in terms of its potential range of operators. It can be installed in small units and can be operated with little specific knowledge ("plug and play"). What may be limited though is the scope of installation due to restricted availability of space on roofs or other sites.

Operating biogas plants, however, requires numerous prerequisites to be met. Along with site and substrate availability, the control of the fermentation process involves considerable time, attention, and laboratory skills. These properties limit the potential operators to professional actors, preferably from or under participation of the agricultural sector.

The range of small hydropower operators is essentially restricted to actors who have water usage rights for existing sites. Plant operation and control require certain technical know-how, but this can also be outsourced to external operators (service contracts), as in the case of wind power.

In the field of wind power the increase in capacity was also accompanied by an increase in the size of the wind power stations and by higher investment costs. While privately owned wind farms could be financed and operated by small groups of investors, private investments in larger wind farms can only be made by joining an investment company.

9.2.2 Inhibitory Advocacy Coalitions

The continued prevalence of fossil and nuclear energy in the German energy industry is indicative of its high economic significance. The four major power companies that dominate the power generating market and control key sections of the power grid have excellent possibilities of influencing politics and controlling the competition. They form a coalition of extensively overlapping interests with the Federal Ministry of Economics, and also with the energy-intensive industrial sectors.

This coalition, which initially underestimated the potential of wind power, became aware of it with the introduction of compensation for alternative electricity fed into the grid, and then fought the StrEG fiercely (see Sect. 3.7.1). Ultimately though, the coalition had to put up with the expansion of wind power.

For many years during the 1980s the power supply companies managed to prevent amendments to the German Energy Industry Act (Energiewirtschaftsgesetz – EnWG) and hence kept it from opening up to competition (see Sect. 3.9.3). The power utilities were in a better position to participate in and influence the EnWG's policy formulating process to their own benefit since they clearly had greater capacities and the relevant expertise, and excellent connections with the Federal Ministry of Economics as well.

Under the red-green coalition, the alliance of those opposing a large share of renewable energy was faced with a loss of responsibility, when in 2002 the domain of renewable energy was transferred from the Ministry of Economics to the Ministry for the Environment (see Sect. 3.4.3). In the current phase, the further expansion of renewable energy depends on the power grids. Grid extension, however, has been blocked by the grid operators, who continue to have close ties with the major power generating companies (see Sects. 3.9.3.3 and 9.2.3).

There was a large overlap of interests between representatives of the utility lobby, the energy-intensive industry and the Federal Ministry of Economics. Since the 1930s the close agreement of government and industrial interests on energy has led to closed political arenas, consolidated structures and personnel overlap that give this coalition of actors extensive influence. This power has not only been used in legal proceedings against the Electricity Feed-in Act, but also in many other legislative and regulatory projects designed to counteract the diffusion of renewable energy. Another example of continued antagonistic action is the repeated challenging of supply reliability in the case of an increasing share of renewable energy (see electricity gap discussion, Sect. 3.1.4), which is used to fuel uncertainty.

9.2.3 Insufficient and Incompatible Infrastructure

As soon as the electricity generated ceased to be used to only supply isolated grids, the renewable energy innovation process became closely connected with the capacity of already existing power generation (see Sect. 9.2.2) and transmission line infrastructures. The lack of capacities in regional distribution grids and the low capacity to absorb fluctuating feed-in quantities form a central technical barrier to expansion. This applies in particular to the development of wind power. In the early 1990s it became apparent that grid access and the grid's capacitance crucially limited expansion.[10] The reason for this was that, despite the right to feed in electricity granted in 1991 by the StrEG, grid operators were in a position to temporarily take

[10]Prior to 1991 grid operators were in a position to deny access to the grid, stating possible overloads or limited capacity of regional grids. In 1991 the StrEG legislated the right to feed electricity into the grid.

wind turbines off line, if there was an excess supply of power. These incalculable downtimes implied considerable profitability risks for wind turbine operators. They were not eliminated before the EEG gave priority explicitly to renewable energy in 2000. The integration of wind turbines, for instance, into the existing power generating and distributing system required the development of specific electronics which permitted dynamic adaptation to the voltage levels required by the power grid. Although the legal position of renewable energy suppliers has improved, the problem of the grid's regionally insufficient technical capacity remains.

The issue of lacking grid capacities increased remarkably in the face of the volume of electricity and the transfer requirements expected from offshore wind parks. Their connection to the grid requires eliminating numerous obstacles, which in turn demanded taking a number of corrective measures. As a result, additional regulations governing the connection of offshore wind parks and the expansion of the power grid were formulated. Yet due to the high investment costs involved, the power utilities' interest in expanding the grid infrastructure remains low.

Feeding biogas into the supply network, on the other hand, is subject to less restrictions. All technical feed-in problems were rapidly solved. Operators of pipeline networks and major power supply companies were cooperative due to a convergence of interests.[11]

9.2.4 Loss of Acceptance

Loss of acceptance occurs if the expansion of the technology is accompanied by noticeable environmental impacts and landscape changes or from incalculable risks. These are perceived by the population to have negative impacts on their own individual environment. In view of the growing spatial requirements and the dimensions of the constructions, fears concerning the extent of these impacts have been increasing. Boom phases were particularly detrimental to acceptance because they reveal a large number of additional impacts within a short period of time. If the local population feels excluded from the development and overrun by undesirable effects, and if they feel they are being forced to subordinate their interests to the particular interests of the operators, they will reject or even oppose the technology. This may occur if only a minority of the local population benefits or if – as is the case with many wind farm projects – those profiting are investors who are not local.

The biogas sector is affected by similar phenomena. Loss of acceptance looms when agricultural production, i.e. corn cultivation for non-food uses, grows disproportionally. Large biogas plants and biogas parks are perceived as oversized, with related congestions not being accepted by the population. In these cases, an

[11]Pipeline operators and major power utilities also operate biogas plants and semi-central block heating and generating plants.

open-minded attitude toward new power generation technologies may turn into rejection.

Climate protection targets as pursued by wind power use and biogas conversion compete with nature conservation goals most of all when the unspoilt landscape is at stake. Photovoltaics by contrast have relatively low potential for conflict because these systems are usually installed on buildings in Germany, where at the most there may be conflicts arising in the context of heritage conservation.

Deep geothermal systems have so far hardly been noticed by the population, one reason for this being the small number of existing pilot systems. However, the 2006 earthquake in Basel, Switzerland, revealed that this technology may be faced with acceptance problems as well. The lack of knowledge concerning possible seismological effects and risks involved in the exploration and use of deep geothermal heat causes people to assign a higher risk to the technology rather than a lower one.

9.3 Comparison of Innovation Processes: Characteristic Phases and Different Processes

Figure 9.1 shows an overview of the innovation pathways of renewable energy in Germany. It compares the sequence of the phases within the innovation process.

The figure shows that each innovation pathway is individual, but that certain phase types occur in all of the innovation processes examined:

The innovation biographies of electricity generation from wind power, biogas and solar energy feature a *pioneering or pilot phase*, varyingly intense *dynamic* (inception, breakthrough, expansion or boom) phases, phases of *instability* (crises, setbacks, stagnation) and *stabilization* (or consolidation). So far all of the renewable energy sectors have managed to overcome even multiple phases of instability and to stabilize their development, hence preventing dropout.

The innovation biographies begin in the 1970s, when the two oil price crises and the awareness of "limits to growth" formed significant context factors. Germany banked in particular on the expansion of nuclear power; investment in alternative technologies was comparatively low.

The vertical, shaded strip in Fig. 9.1 marks a period during which each of the sectors experienced a transition from the pilot phase to a clearly dynamic innovation process or at least a significant change. The Chernobyl reactor accident (see Sect. 9.1.3) brought about societal and political processes of reorientation and strategy formation (see Sect. 9.1.4). Alternative concepts of energy supply enjoyed increasing attention. The passing of the Electricity Feed-in Act (see Sect. 9.1.5) falls in this period as well. It proved to be a strong stimulus and marked the beginning of a new phase for all renewable energy sectors, except for deep geothermal energy.

The phase types identified in the five innovation pathways can be characterized as outlined in Ch. 9.3.1–9.3.6 (Fig. 9.1).

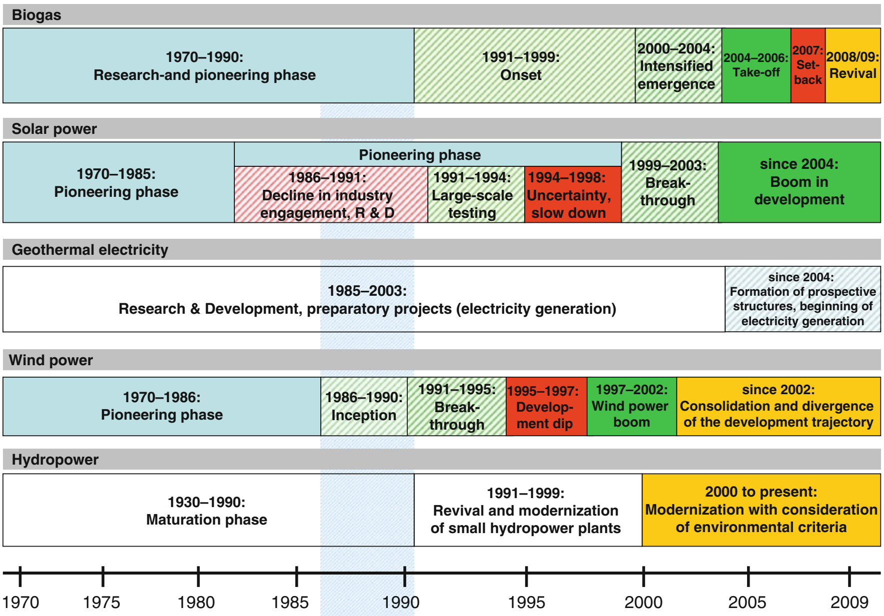

Fig. 9.1 Phases in the innovation process of renewable energies

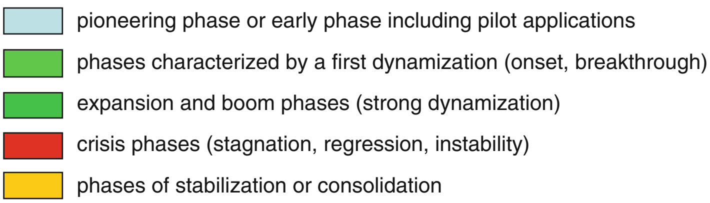

Fig. 9.2 Key to phase types

9.3.1 Pioneering Phase or Early Phase Including Pilot Applications

One issue all the renewable energy sectors examined here (except hydropower) have in common is that they underwent a pioneering phase, or an early phase including pilot applications, when the new technology was introduced or – as in the case of wind power – when an existing technology was rediscovered or placed in a new application context. In the case of hydropower, this early phase dates back as far as the last century. During this early development period, the actors involved invested a lot of time and money in a technology that was still unprofitable. This phase is characterized by improvisation, creativity and a keenness to experiment.

However, the triggering stimuli and key actors who spurred the early phase of the development differed from sector to sector. The pioneering phases of wind power and power generation from biogas were accompanied by a broad involvement of private actors and operators of low-capacity plants. Changes of mindset in the population (brought on by the oil price crisis in the 1970s, the anti-nuclear power and environmental movement, the desire for self-sufficiency and autonomy) encouraged active involvement in alternative technologies. As a result of research subsidies granted in the 1970s, the pioneering phase of solar power generation began earlier than that of the other sectors – yet it also lasted considerably longer.

Interestingly enough, farmers accounted for a large share of the operators in several sectors. One reason was that they had the necessary resources: access to sites suitable for the hydropower plants and wind turbines, the latter in conjunction with privileges concerning approval regulations (in connection with outdoor agricultural buildings), as well as substrates such as liquid manure for biogas generation. Furthermore, as business people they were also interested in additional options of generating income.

Innovation in the wind and biogas sector emerged primarily as a result of amateurs, hobbyists and innovative idealists applying principles from other domains to the new field of power generation from renewable energy sources.

Power generation from deep geothermal sources is currently undergoing a pilot phase which can not, however, be defined as a pioneering phase. Unlike for wind power or photovoltaics, the actors involved at this early stage are not pioneers in the sense of non-professional actors, but are predominately professional actors from a variety of industries.

9.3.2 *Inception*

Another similarity is that the early or pioneering phase of their innovation development passed into a first inception phase, which saw a rise in the demand for the technologies and a larger number of plants being built. This inception phase was characterized by a first commercialization and professionalization in the field of plant construction and marketing, as well as design and maintenance services that accompany the operation of power stations.

In the case of wind energy and biogas, the launching phase was sparked off by the StrEG. This Act also affected low-capacity hydropower stations (below 1 MW), which experienced a revival thanks to this government incentive. Solar power generation initially did not benefit from the feed-in compensation to the same extent, even though it was accounted for in the StrEG. The inception and breakthrough of solar power occurred only after several insecure phases of stagnation and further government stimuli.

9.3.3 *Breakthrough*

A breakthrough phase is marked by the fact that the technology has made its first development steps and has already been able to prove its potential. The innovation's progress reflects in a dynamic increase in its capacity and efficiency and in its expansion. However, the process still requires a supportive framework in the form of public interventions. In this phase new actors enter the constellation whose interests and motivations expedite the development.

The inception phase of wind power was followed by a phase in the early 1990s that can be defined as a breakthrough due to the fact a clear increase in the output of individual systems was achieved. As the technology of wind power became better and, more importantly, more reliable, the demand for turbines increased.

However, inception phases were not always followed on smoothly by breakthrough phases. In the field of biogas generation and conversion into electricity, for example, it had not been possible to achieve a rate of expansion comparable to that of the wind power sector within such a short time because these technologies were tied to small and medium-sized agricultural business structures. Yet the trend to expand continued under the influence of the EEG (2000–2004), and the inception phase developed into a boom in the biogas sector (breakthrough) in 2004.

Solar power generation was initially faced with sluggish take-up by major companies, so the technology was subjected to large-scale testing in the form of the 1,000-Roofs Program. Yet this stimulus, too, failed to bring about a dynamic phase. Rather, it resulted in a further stagnation phase, during which a larger number of municipalities kept the development from coming to an end. The breakthrough finally occurred in 1999, sparked off by higher feed-in compensation as specified in the so-called Interim Photovoltaic Act (Photovoltaik-Vorschaltgesetz), which was passed as a result of the EEG revision.

9.3.4 Expansion and Boom Phases

Boom phases, i.e. phases during which the respective sector expanded dynamically, occurred first in the wind power sector, later in the field of power generation from biogas and most recently in photovoltaics. Typical of this phase is the technology's dynamic development: the relevant engineering know-how becomes more sophisticated and the power plants' technical capacity increases. Along with this, boom phases saw the emergence of new forms of operation like operating companies and associations that constituted a way of jointly running renewable energy facilities. Advocacy groups consolidated their influence, and the sectors expanded as a result of new business formations. Due to the economic success, investors and investment companies began to take an interest in these sectors. A certain degree of security for investment and legal certainty are important prerequisites and a key feature of boom phases. With the technologies' growing success, their politically intended contribution to power generation increased as well.

9.3.5 Phases of Instability and Crisis

The innovation of wind power, photovoltaics and power generation from biogas all took a discontinuous course and included unstable phases, times of stagnation or setbacks. These critical phases were characterized by strain, conflict or resistance, which arrested the dynamic development of the innovation; typical of these phases was an unstable constellation of the influencing factors. If resistances were overcome rapidly, these critical phases remained short. Yet critical phases can also reverse a development or bring it to a halt, presenting the actors involved with an uncertain and worrying state of limbo. Such phases jeopardize the political will to support the innovation and its path.

The occurrence of crises or setbacks in innovation processes may have various causes. They may be triggered by the resistance of opposing actors or interest groups, by a state of legal uncertainty, a change of conditions in the context of the constellation, a loss of image and acceptance concerning the increasingly diffusing technology, cost pressure or insufficient or cancelled economic incentives. Conflicts arise in particular if innovation expands (too) swiftly, if other sensitive usages like recreation or housing are affected and if public goods such as biodiversity or resources such as land, landscape and water, are at stake. Loss in acceptance may thwart project implementation, especially at local and regional levels, and thus considerably impede the overall process.

For wind energy, the slump occurred in the mid-1990s, when the new sector tried to make inroads into the electricity market, while the established actors were anxious to prevent this. Their agitations caused a number of legal uncertainties shortly after the breakthrough. In addition, the failure to adjust the relevant planning and approval conditions, rejection of wind power by local and regional interest groups, and negative media reports contributed to the critical situation.

Biogas generation did not experience this kind of slump until after the first boom. This slump was the result of a strong dynamization in connection with a big increase in substrate demand. At the same time substrate prices rose due to the developments on the world market. In view of these uncertain and hard to control situation, the new compensation regulations were not so much intended to promote strong growth, but rather to stabilize biogas generation and its conversion into power.

With regard to photovoltaics, the market launch program that should have followed the promising early 1990s initially failed, because no portfolio felt responsible for or pursued the systematic expansion of PV. This resulted in a decline in growth and great uncertainty in the part of both small and large companies, who considerably limited or even gave up their involvement. However, local initiatives and initiatives at the state level in conjunction with private investors backed up the constellation during this phase, and thus bridged the critical phase.

9.3.6 Phases of Stabilization and Consolidation

After the crisis, the innovation biography of power generation from biogas and wind energy blended into stabilization and consolidation. In this phase the development is back on safe ground. The dynamic of the preceding boom (as with biogas and wind) is over, the peaks of additional plant construction have passed, and any high-flying expectations are adjusted to reality. Consolidation sets in when the demand has reached a certain degree of satiation (as with wind), when natural resources and resistances within society set limits to the expansion of the technology (as with biogas and water), or when the established system is anxious not to lose any further market shares and tries to prevent further dynamic expansion to the new technologies (as with offshore wind power).

This phase benefits the technology in that it allows it to become established, to spread slowly but continually, which creates stable framework conditions. A complex structure of actors, norms, procedures, decision-making structures and infrastructures develop at various administrative and organizational levels. However, the development relies less and less on governmental intervention, but increasingly pays for itself. We assume that this development phase can lead to system changes if the technologies in question gradually permeate the market, and if they are accepted as a new technical and economic paradigm.

Chapter 10
Insights into the Drivers of Innovation

Abstract The innovation biographies show that public policy making cannot "create" innovations – they do, however, play an important role in shaping the overall conditions for innovation. The course for the development of renewable energies was set at the international, European, and national levels, as well as at regional and local levels. In order to meet the objectives, policies and measures have to be geared toward different tasks and problems in each individual phase of the innovation process.

When the process was faced with strong resistance from lobby organizations or the political opposition, it was frequently possible to intervene at other political and administrative action levels. In many cases, actions coming from different levels took effect at staggered intervals, which intensified their impact, provided they were heading in the same direction. The task of harmonizing and coordinating the timing of policies and actions demanded a reflexive design that is both relevant to a number of different administrative and political levels, yet tailored to the process in question.

Keywords Renewable energy sources • Innovation • Policy measures • Multi-level governance • Reflexive governance

This book is based on the premise that political mechanisms that aim to initiate and disseminate innovation are dependent on the constellation of stakeholders and influencing factors involved. As a matter of course, the diverse range of changes these factors undergo over time represents a central challenge when driving innovation.

Constellation analysis is used as a diagnostic tool to analyze complex situations. It creates views on factors that depict the complexities of real processes in a simplified manner. The constellations must be easily manageable on the one hand, yet still capture the complexities of reality on the other. This makes it possible to focus on key starting points for intervention aimed at driving innovation in a complex environment. By analyzing the interests and motivations of the various actors, the type and mode of action of the policies implemented and the diverse interplay of factors,

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it is possible to anticipate the interrelationships and impact of an expanding technology and it helps to identify the scope for intervention.

The aim of the following is to isolate factors key to successful governance that emerged while analyzing the renewable energy innovation biographies. The hypotheses concerning policy making were derived from the prototype project Innovationsbiographie der Windenergie (2007) and further scrutinized and amended for the German version of this book called Innovationsbiographie der Erneuerbaren Energien (2009).

No claim is made, however, that these hypotheses can lead to the formulation of generally valid rules concerning the governance of innovation processes along the lines that a certain action will produce a certain outcome. Innovation biographies are more typically characterized by individual, unique attributes. Actors driving innovation will always be faced with the challenge of developing a set of tools tailored to the context of the individual innovation process. Complex policies and actions are required to promote the various technologies and ensure integration into their respective environments. Approaches that differentiate between sectors, in particular with regard to economic incentives and the respective support schemes, have proven successful in the past. Policies have succeeded when they have accounted for the specific features of the relevant field of innovation.

While a cross-sector, generalized statement concerning possible regulatory options is of limited value, the study of innovation biographies demonstrated that it is possible to identify basic principles that may play a decisive role in whether and how an innovation process can be set in motion and sustained.

10.1 Phase-Specific Adjustment of Policies

An innovation process comprises various types of phases, each with different functions. Each phase presents different opportunities for intervention aimed at driving innovation.

10.1.1 Identifying and Strengthening Innovation Processes in the Early Phase

In the early phase of development, the principal concern is to protect the technological innovation's fragile constellation to ensure it has the capacity to survive. Political decision-makers can create and safeguard the protective environment necessary by structuring and using this environment in a comprehensive manner. Systematically supporting and stabilizing fledgling innovation niches can help strengthen favorable framework conditions. The context, i.e. reference framework, of the constellation can play a pivotal role during the phases in which innovation still falls within the definition of "niche". However, it is generally difficult or time-consuming to actively exert an influence on the context. Accompanying measures are required to protect the niche until it is able to survive independently.

A nascent innovation can stabilize itself and become established if it receives support from as many influencing factors as possible at different levels. During this process, the new technology and its field of application undergo changes. Technological innovation develops in close relation to the actors supporting it, as well as economic, regulatory and institutional factors. For their part, the actors also undertake any necessary adjustments and can themselves provide impetus for the implementation of innovative action strategies.

Policy cannot "breed" innovation, but it can shape the framework conditions for innovation. Actors involved in driving innovation can create the protective environment required for niches to develop by taking into consideration not only the technological innovation but also the socioeconomic and infrastructural framework conditions. The key constellations of actors, and the systematic shaping of them also plays a decisive role. Promoting niches is not only a matter of creating incentives for research and development, or safeguarding the emerging market by establishing a legal and economic framework. Supporting the formation of coalitions of interested parties and networking relevant actors (researchers, engineers, craftsmen, fitters, systems users and representatives of citizens' and non-governmental groups) can also promote development of the technologies in question. Examples of such activities in the case of renewable energy include the formation of industry and research clusters, the organization of trade fairs, congresses or regional development forums, and the implementation of public participation and monitoring processes. In Germany expert forums[1] have enabled decision-makers and experts to exchange opinions on future directions of research and development.

Furthermore, it is essential to adapt the institutional environment to the requirements of technological development. The systematic and differentiated adjustment of feed-in tariffs for renewable energy is one example; the creation and continual adjustment of regulatory approval requirements is another. Policy-makers are faced with the task of connecting stabilizing factors and actors to a network that offers as little resistance as possible and thus provides the innovation process with a favorable framework.

The innovation process is supported if supplementary developments are initiated alongside the technological innovation on a variety of levels. Social and institutional innovations should occur in an interplay with the technological innovation.

[1] These include the "Glottertalgespräche" in the field of photovoltaics and periodic professional discussion groups such as the "Gülzower Fachgespräche" in the field of biogas.

10.1.2 On the Path to a Breakthrough – Stimulating the Process in its Inception Phase

In order to boost the level of engagement on the part of private, business and political actors and thereby stimulate the innovation process, clear policy-making and leadership is required to overcome initial uncertainties. Analysis of the innovation biographies revealed that the stronger and more closely aligned the supporting drivers were, the more dynamic technical and economic innovation processes became. Following an initial drive to stimulate innovation, it became apparent that the reliability and foresightedness of policies in the long term were essential to successfully enter the market. Niche technologies were able to stabilize and gain economic and political relevance. Sizeable expectations of economic profits for investors – the option to combine numerous support programs, for example – stimulated supply and spurred on demand and thus boosted technological development. Public governance has little or limited access to contextual events and impulses from civil society, whose impact is so great as to trigger changes of mindset or paradigm shifts. Contextual events can be utilized, however, to promote the breakthrough of a fledgling niche technology. It is thus of key importance to identify such windows of opportunity which cannot be generated at will, and to make use of them for the process at hand. A time-specific strategy that systematically utilizes these windows of opportunity can expedite the development and dissemination of new technologies.

Wind energy is a striking example of how it is possible to induce dynamic change in the early phases: the shock of the reactor disaster in Chernobyl shook the foundations of the established technological paradigm. The risks involved in nuclear power had become tangible. As a consequence, the prevailing energy supply regime at the time encountered considerable legitimization problems. Ideas put forward by pioneers such as Denmark and the state of California, combined with an increased level of awareness in society, acted as a catalyst in the search for new solutions. The niche of wind energy technology was in its inception phase at this time. The increase in government support at the beginning of the 1990s and society's growing openness toward alternative concepts stimulated the development process, and the niche technology was able to gain a foothold.

The upheaval in the energy sector is a current example of the process of generating dynamic change and, where necessary, boosting public awareness and understanding. The need to modernize large numbers of power plants presents an opportunity to transform the energy supply system and thus induce exceptional dynamic changes in the field of renewable energy.

10.1.3 In the Expansion Phase: Easing Integration into the System and Avoiding Acceptance Problems

In the expansion phase, resistance from the established system increases as it takes a stand to prevent the new innovation from expanding into the market. In order to sustain the process it is necessary to safeguard the technological innovation and dissemination process from opposition from the established system. At this stage, government action and intervention must also be geared toward tackling the hegemony of the dominant constellation. Expansion of new energy supply technologies is possible if the existing forces in the constellation can be influenced effectively. This can be achieved using a variety of means, such as new transmission infrastructure legislation (disclosure of information regarding grid operation), regulations, decartelization and changes to competition rules. Only when new competitors can enter the market and join in "the game" has the market influencing incentive been successful.

As the share of energy generated from renewable energy sources grows, renewables are increasingly faced with technical issues relating to system integration. Due to their decentralized and fluctuating availability, wind and solar energy are particularly non-compliant with the established, centralized system, whose storage and buffering capacity is not yet compatible enough with intermittent power generation. On the operators' side the Ordinance on System Services[2] aims at reducing obstacles to integration by providing system services to stabilize the electricity grid in Germany.

However, an integration strategy has its limitations, particularly if the rules stipulating how the expansion should proceed are set by groups of actors who dominate the market. At this stage, it is thus the responsibility of policy-makers to promote market liberalization, to open up as many segments of grid-bound energy supply as possible to free competition and to lower the entry barriers for renewable energy as far as possible.

The expansion phase brings with it an increase in the number of undesired side effects: the negative environmental impacts, siting requirements and conflicts that arise from the utilization claims of other parties come to light. Policies must aim to guide the expansion process in a manner that enables the balancing of conflicting interests. Refraining from achieving the maximum rate of expansion can prove a more enduring strategy from a long-term perspective. In order to gain acceptance, it is necessary to provide the public with comprehensive, and above all, credible information at an early stage, ensure transparency concerning the anticipated risks and impact, and find sites which provoke as little conflict as possible.

Legal regulations, such as clearance decrees implemented in the case of wind energy, can help reduce the impact on the local population.

Searching for low-conflict locations for power generation facilities and creating opportunities for the local population to benefit from the new technologies (by participating as investors or through the creation of jobs), can be viewed as components of a socially integrative strategy that promotes acceptance of the technology. In Germany, for example, much effort has been made to boost local acceptance by organizing intensive information campaigns about wind farm projects or by involving the population in the project planning and operation of the facilities.

Opportunities to get involved through formal and informal public participation in activities such as planning and approval procedures, the development of operator models which give the resident population a financial stake in the project (win-win

[2] SDLWindV; cf. Index of Legal Sources.

solutions), or the creation of jobs in the region have proved successful strategies for gaining acceptance. The impact of political measures is dependent on their ability to respond to acceptance problems. When conflicts arise they can only be successfully dealt with if the entire conflict spectrum is visible. It is important to keep in mind that the combination of different conflicts can have a cumulative or exacerbating impact. It is therefore necessary to analyze and tackle each individual conflict, bearing in mind the potential interplay of factors. There can be no justification for simply limiting attention to the most conspicuous conflicts.

Conflicts with interest groups are part of reciprocal social learning processes that do not necessarily block the innovation process, but can also serve to enhance it.

10.1.4 Sustaining Innovation Processes by Corrective Controls

Sustaining the innovation process requires fine-tuning measures that must be aimed at eliminating the obstacles that stand in the way of implementation. It is necessary in most cases, for example, to make adjustments in several fields of law linked to the implementation of the technology. Should the technology's implementation compete with other public or private interest groups or parties with a claim for recreation and tourism, to conserve the landscape and nature, or to preserve sites of historic interest, it is important to introduce accompanying measures to reduce conflict. These include formal and informal tools that help to integrate the new applications in an environmentally and socially sustainable manner in the established paradigms. A possible solution here is land-use planning which helps reduce conflict by concentrating sites and negotiate competing land use claims. Additionally, informal activities such as regional forums and initiatives can help the renewable energy source in question to retain acceptance. Creating or maintaining acceptance is an issue that particularly arises during the expansion phase, as this is the point where the manner and extent of the demands on the environment and resources, as well as the concrete impact on the local residents become apparent.

10.1.5 Driving Innovation During Unstable Phases

Unstable phases are of crucial importance as they lead to changes that are fundamental to the implementation of the innovation. Overcoming the crisis generally requires measures at various levels to steer the deployment back onto a more stable path. These modifications allow the development to stabilize in the subsequent phase and become more established. Unstable phases such as crises or setbacks can help bring about successful developments of an instructive nature. The shift between stable and unstable phases is thus a characteristic feature. Speed is not the only deciding factor when reacting to crisis situations. Reacting too hastily can be counter-productive. It is far more important to carefully analyze the nature of the crisis. The reaction and corrective measures taken during and after a crisis should be aimed at ensuring continuity with regard to political goals and schemes and accompanying support strategies. It is important to give new players to the game an indication of reliability and calculability. Only when these conditions are fulfilled do swift reactions make a positive impression.

Nevertheless, political stalemates or volatile power relations obstruct the adoption of solutions required to tackle crises in a timely and synchronized manner (see Sect. 10.4). In this situation, if it proves impossible to overcome uncertainties and opposition, new technological developments may not be used to their full potential.

10.1.5.1 Exploiting the Crisis

In a crisis phase it becomes clear that the established structures and framework conditions no longer support the development. It is then necessary to examine and strengthen the framework conditions. Remedial measures must be taken where necessary to re-stabilize the critical situation. Institutions must make adjustments to accommodate the new development, undesirable structural developments must be corrected and standards must be redefined. It may be necessary to organize promotional campaigns to improve acceptance and to go to great lengths to transform existing conditions. Pressure to act during a crisis phase may also legitimize the use of unusual policies. The challenge here is to transform the unstable constellation into a new and stable constellation to enable the technology to continue to develop and expand.

10.1.5.2 Recognizing and Eliminating Barriers

Insufficient acceptance, insufficient political endorsement, lack of motivation on the part of key actors, changed economic framework conditions and insufficient adjustments in related technological fields can result in barriers.

Impasses are often recognized at an early stage, like the issue of network capacity, for example. However, diverse forms of opposition may make it impossible to solve these gridlocks in a timely manner. Despite adoption of legislation supporting the necessary grid expansion,[3] it still comes up against resistance from municipalities, citizens and environmental groups. Energy suppliers anticipate a time frame for the completion of transmission lines of up to 10 years. There is thus reason to fear that the capacity necessary to transmit offshore wind energy, for example, will not be completed in time.

Barriers can become exacerbated if conflict-laden infrastructural expansion measures are used to provoke opposition toward modernization processes in the energy sector. In the case of grid expansion, it has become clear that it is absolutely imperative to accompany these kinds of infrastructural measures with campaigns designed to inform and boost acceptance such as those flanking the approval process.

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[3] Cf. Section 3.7.6 on the Energy Line Extension Act.

A failure to drive the innovation process forward at all levels of the value chain can also lead to barriers. From a medium-term perspective, policies that are limited to the promotion of power generation are not sufficient. The innovation process must therefore incorporate various aspects in order to increase the share of electricity generated by renewable energy. These range from the development of new electricity plants and transmission infrastructure, to energy storage and the amalgamation of facilities to form groupings similar to power stations. Insufficient policy action in any of these areas will impede future development. This example demonstrates that, in order to successfully eliminate impending barriers, they must be tackled, where necessary, on a range of political and administrative levels and in a variety of different sectors.

10.2 Recognizing and Limiting Unintended Outcomes in a Timely Manner

Successfully driving innovation demands the ability to recognize and limit unintended outcomes ensuing from particular actions, in a timely manner. This requires a flexible set of policies and tools. The greater the ability to adjust and the quicker this adjustment can happen, the greater the chance of achieving the goals.

Analysis of the renewable energy innovation biographies revealed that phases in which the diffusion of new technologies increased dramatically were generally afflicted by unwanted effects and conflicts. Strong government actions aimed at promoting market entry must be flanked from the outset by approaches which restrict the overexploitation of natural resources and enable a balance between the interests of affected parties and beneficiaries.

The capacity of policies to generate the desired effect depends on a number of factors, such as the extent to which they are able to react to unexpected developments in a flexible and prompt manner. Regulation of monitoring systems and amendments to the Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz – EEG) every 4 years have proved successful strategies in Germany to date. The establishment of an EEG clearing house, which deals with questions that arise when interpreting legislation and develops proposals to overcome disputed matters, enables the innovation system to react more efficiently. Policy approaches vary in their capacity to reduce undesirable side effects. As in the case of biogas plants, specific environmental recommendations have been developed that are to be considered when it comes to siting and approval procedures (see Sect. 4.3.5.6). However, the reach of such informal approaches is rather limited compared to economic incentives.

The current scope for pursuing energy crop cultivation in an environmentally sound way is equally limited to informal efforts, such as restricting energy crop cultivation to particular areas. In view of the provisions already in place, such as the regulations concerning “good agricultural practices” and cross-compliance, the agricultural sector sees currently no reason to implement further policies.

Regional planning authorities are helping to reduce the impacts of ground-mounted photovoltaic systems or wind farms on the landscape. The aim is to reduce the scope for conflict in approval procedures by integrating environmental planning into overall regional planning and by adopting a strategic land use policy.

Estimating the scale of the dynamic triggered by a policy in advance is a particular challenge. Policy measures can initiate an unexpectedly strong dynamic if, for example, influences from other fields are geared in the same direction and thus combine and intensify the dynamic (see Sect. 10.3.2), which can require corrective action.

10.3 Integrating Levels of Action and Actors

10.3.1 Coordination and Integration of Policy Levels

Establishing renewable energies within the energy industry is both a cross-sectoral and interdepartmental task, and a multi-level challenge. Policies have often stemmed from many different political and administrative levels, and subsequently impacted many different political and administrative levels – local, state or national level, for example. The interplay of the various decision-making and implementation levels within Germany's governing system has given rise to a complex network of (intended and unintended) effects and subsequent consequences. In many cases, policies coming from different levels take effect at staggered intervals, which can either intensify or weaken their impact.

Drivers from the federal level are generally closely interconnected with drivers at state, regional or local levels. These subordinate levels implement national standards on the one hand, while pursuing their own goals and action strategies on the other.

Levels superordinate to national states – policies at EU level, for example – also have a decisive impact on the relevant constellation. The interplay between a number of different initiatives at superordinate level[4] has proved particularly effective, insofar as it drives and strengthens actions with converging goals for the deployment of renewable energy at subordinate level.

When policy measures have the same goal, this strengthens the approach. Gearing them toward different goals, however, will create obstacles to achieving these goals. The task of harmonizing and coordinating the timing of policies demands a flexible design that is both relevant to a number of different public policy levels, yet tailored to the process in question.

[4] For example, the international climate protection policy and the EU Directive on the Promotion of Renewable Energy.

10.3.2 Integrating the Goals of Government Portfolios

Due to variously allocated responsibilities, among other factors, it is sometimes the case that different portfolios simultaneously launch measures and thus create momentum. For instance, in 1996 the amendment of the building law granted privileges to wind farms in undeveloped, non-urbanized areas (the ministry responsible was the Federal Ministry of Regional Planning, Building and Urban Development). Shortly afterward, in 2000, the EEG introduced fixed compensation rates, thereby establishing planning security from a cost-accounting perspective (the ministry responsible was the Federal Ministry of Economics). The incentive and expert support for both of these actions came from the Federal Ministry for the Environment, which was not yet responsible for renewable energies at the time.

In order to ensure the success of policies, the various portfolios must pursue strategies with clear and consistent goals. However, this necessitates more than a mere accumulation of non-conflicting measures; it requires an integrative strategy. Policies prove particularly effective when the portfolios involved succeed in coordinating their goals in a sustainable manner from a content, spatial and time perspective.

10.3.3 Integrating Sub-Constellations

The increased diffusion of renewable energies resulted in increased resistance from the traditional energy industry, particularly as they were initially unable to benefit from the feed-in payments. For a long time, the potential yields were too low to encourage involvement of the industry in the renewable energies sector. This situation has only changed in the last few years.

The proliferation of renewable energies increases the need for measures that facilitate greater integration of the respective fledgling niche into the dominant system, i.e. the traditional energy industry. The moment representatives of the dominant sub-constellation see potential to make a profit they will be more likely to accept the new technology. This is most apparent in the cases of geothermal and offshore wind energy.

10.3.4 Planning Policies

In the case of technologies that require large areas of land and might have a tangible impact on the environment, it is necessary to develop an approach that accounts for overall planning strategies. Using both the formal and informal instruments of spatial planning can help ensure that generating renewable energy in specific scenarios is environmentally and socially compatible with other land-use claims. The renewable energies vary in their attitude toward planning policies and measures.

The case of wind energy is a good example of how planning approaches, such as the designation of suitable sites at the regional planning level and the zoning at the municipal level, have been used to intervene in the development (see Sect. 10.1.3). Zoning was instrumental in ensuring well-balanced development during wind energy's second "boom" phase.

There are currently no new policies in the area of hydropower. Some states, such as Baden-Württemberg, assist in the application process for new plants with informal mapping of appropriate sites from an environmental viewpoint.

Other renewable energies are not always subject to the same degree of planning approaches. Decisions determining the location of biogas plants, for example, do not (as of yet) fall within the remit of regional planning, primarily due to the lack of mandatory zoning regulations. Energy crop cultivation can only be influenced by informal approaches where necessary, such as restricting energy crop cultivation to specific areas. Some German states are also taking steps at the regional planning level to establish sites for ground-mounted photovoltaic systems that require large areas of land. The selection of sites for deep geothermal energy plants is primarily determined by the on-site conditions (accessibility of heat-conducting layers below the earth) and is not (yet) subject to planning-related policies.

10.4 Synchronization-Based Policy

10.4.1 Temporal Synchronization

Each new phase of the renewable energy innovation biographies brings with it substantial changes to the constellation, which then place new demands on policy interventions. However, it is generally not possible to forecast developments and the impact of previous policy action. Measures are, therefore, often of a reactive nature and subject to a time delay. Political governance has been successful in cases where it correctly assessed the constellation's phase-specific level of development and implemented the necessary policies in a timely manner. Developing the policy instruments is part of the innovation process; they should be continually adapted to the innovation process. In order to ensure a successful and adaptable approach, support schemes designed to run over long periods should comprise flexible modules which are only valid for a limited time and whose revision is mandatory by law.

10.4.2 Accumulation of Policy Action

In order to set the innovation process in motion, it is necessary to overcome the initial moment of inertia. One method of achieving this is to manage the timing of policies geared toward common goals in such a way that they overlap and thus have a combined impact (see Sects 9.1.4 and 9.1.6).

Wind energy, for example, received support from a number of parallel measures at the beginning of the 1990s (the Electricity Feed-in Act, feed-in remuneration, the 250-MW program, funding from states), which gave it a massive boost and helped create huge demand in the sector in a short period of time. In 1999 the photovoltaic industry experienced a similar boost when research funding – which had traditionally been generous and technologically oriented – was coupled with a far-reaching market introduction program which led to an increase in demand that initially exceeded the production capacity of companies in Germany.

10.4.3 Synchronizing Heterogeneous Innovation Processes

By synchronizing innovation processes at various levels, public policies have helped promote the diffusion of renewable energy technologies. Support programs only had their full impact when backed by a suitable legal framework (energy, building or planning law). In order to successfully control heterogeneous constellations, it is thus necessary to synchronize the timing of various policy actions that foster one another. Failure to implement accompanying measures in a timely manner can halt or disrupt the innovation process. A striking example of this was the granting of privileges in building law to wind energy plants in 1996. Had this action not been taken at the right time, the expansion process – which had a stabilizing effect on the sector – would have slowed down dramatically.

10.5 Coherent Policies in Complex Constellations

In the case of public policy, one must take into account the interplay of heterogeneous driving forces; the measures' impact is closely linked to socio-technological change and economic processes. When addressing the course of innovation biographies, it is essential to ensure harmonization of the heterogeneous elements involved and their various interrelationships with policy approaches. In this process, such actions should not be viewed as actions "from outside". Actors involved in politics are part of the system (the constellation) themselves.

A policy approach must be free of contradiction in several respects in order to be labeled coherent.[5] It must firstly follow a clear goal. The constellation's structure and level of development must then be taken into consideration, and thirdly, the necessary policies must be selected.

When overviewing the innovation biographies, it becomes clear that the increasing complexity of the constellations limits the possibility of taking an overarching approach to promote renewable energies. As the complexity of the technology involved increases, so does the challenge of managing the technological innovation

[5] Often it is only possible to say whether a regulatory impulse was consistent in retrospect.

process. As the actors involved become more diverse and the market economy ties more complex, so does the process of policy making. All these factors make it even more important to define, develop and fine-tune comprehensive goals that are adapted to the particular situation and promote consensus between the parties involved.

10.6 Future Challenges Facing Governance

10.6.1 From Integration to Transformation in the Electricity Sector – a Complex Policy Task

In the past, policies in the renewable energies sector essentially focused on boosting the share of these forms of energy, producing results that even exceeded the targets set on numerous occasions. The sector has since developed to the point where the diverse implications for the entire energy supply system are now apparent. Increasing the amount of electricity generated by intermittent renewable energy sources prompts the following question: will the strategy of integrating these technologies into the existing system and ensuring their compatibility produce the desired results from a medium to long-term perspective – or does the goal of increasing the share of power supplied by renewable energies instead require a fundamental transformation of the energy supply system? In order to achieve Germany's long-term goal of generating between 80% and 100% of power from renewable energy sources, it will be necessary to create entirely new grid and regulatory conditions. Policy makers must adapt the institutional framework step-by-step to account for the diffusion of renewable energies in order to bolster the technological innovation and diffusion processes even in the face of adverse established systems.

10.6.2 Compatibility of Power Generation Systems

The electricity supply system that has evolved over decades and is divided into a few large-scale generating units must be reconfigured to account for the requirements arising from the increased share of renewable energies. The ability to regulate both conventional power plants and renewable energy facilities, the temporary storage of energy, and an active demand-side policy approach (load management) are all crucial to achieving a higher share of renewables in the energy mix.

In technical and economic terms, nuclear and coal-fired power stations are designed to generate an almost constant amount of electricity to cover the base load. Renewable energies, whose input fluctuates, and power plants designed to cover base loads are not yet compatible, since electricity generation in large plants varies very little, making them only minimally capable of adapting to changing levels of power generation and demand.

In order to further increase the share of renewable energies, it will be necessary in future to make transitional use of "flexible" gas and hard coal-fired power plants, which only require a limited number of full load hours to be economically viable. By evenly distributing and limiting the size of these power plants[6] it would also be possible to counteract grid bottlenecks, as smaller power stations working in conjunction with renewable energy plants enable a more needs-based and even utilization of the network. This type of venture already exists in the shape of the pilot "combined power plants" or "virtual power plants", which involve different energy providers joining forces to achieve the aim of producing electricity levels adapted to actual needs.

In addition to a more flexible overall system, it is essential to increase energy saving and energy efficiency in order to achieve a high share of renewable energies. Highly efficient plants and cogeneration power plants are particularly economical in their use of raw materials. It is also possible to efficiently utilize regulating and compensation energy, which will be required more frequently as the share of intermittent renewable energies rises. Merging the existing control zones of the German transmission service operators could significantly boost efficiency. The problem of intermittency could also be offset by combining different renewable power generation facilities with load management measures and energy storage.

A major factor determining the extent of the transformation of the power generation system will be whether generation and supply concepts based on a number of different decentralized technologies are strong enough to hold their own from a political and economic perspective. The oligarchy of major power utilities continues to wield a phenomenal influence over the market and has incredibly resilient structures as a result of the traditional energy supply system that has emerged over many decades in Germany.

10.6.3 Optimizing the Power Line Infrastructure

Problems relating to limited transmission capacity and network compatibility were faced initially by wind energy and were primarily contained at the regional level. As a result of the overall significant increase in the share of energy generated from renewable sources these challenges have since escalated and become a "system-wide" issue. The resulting necessary restructuring and expansion of the grid infrastructure is viewed as a major obstacle. It is essential here to develop cost distribution models for financing this crucial infrastructural task together with energy providers. The development of a coherent policy approach

[6] The size of the power plants and their location could be influenced by the approval procedures or a law specifying that plants may only be built based on demand.

requires continued debate on the issue of whether the goal of optimizing the grid infrastructure can be better achieved by opening up further segments of the grid-bound energy supply system to the free market – and which incentive systems are necessary to this end – or whether public policy should play a fundamental role in the optimization of the grid. Analyzing the existing obstacles to grid expansion can help indicate which promising approaches could successfully motivate actors.

The question of which technological solutions are required to achieve a significant improvement in the transmission grid also remains open. Power generation management, intelligently designed routes and effective load management (demand-side management) facilitate forecasting of network load and allow adjustment of the network output in accordance with demand. Experts have varying opinions on the level of improvement all this would have on the performance of the existing electricity network.

Looking beyond national borders, the creation of a European "super grid" based on high voltage direct current transmission (HVDC) would not only balance out the intermittent power input from renewable energies, but would also make it possible to handle regional peaks in demand or offset possible power plant failures. This would both enhance security of energy supplies and reduce the costs of providing electricity. A "super grid" which enabled power transmission over long distances with minimal losses would be essential to integrate electricity from solar-thermal power plants in the Mediterranean region and from Norwegian hydropower plants. Within the super grid, hydropower plants would be able to assume an important role with regard to storage.

A further approach that could be pursued in the short term is the expansion of interconnectors to neighboring European electricity networks whose transmission capacity is currently such that it causes grid congestion. Expanding these interconnectors is imperative to connecting previously separate electricity markets and enabling an exchange of electricity from renewable sources.

10.6.4 Prospects for System Transformation in the Electricity Sector

The alliance of powerful players in the prevailing system of fossil fuels and nuclear energy might strive to maintain the status quo. Transforming the existing system is an incredibly challenging task. It requires fundamental economic, social and structural change and the dismantling of traditional paradigms and conventions. Transformation of the system not only entails disseminating and implementing the new technologies, but also creating regulations, standards, institutions, organizations and networks with the aim of developing a new and stable regime. This multi-actor and multi-level process is characterized by uncertainty and risk as it involves many actors at different levels and in different locations. Far-reaching change takes time, demands large amounts of investment and is the combined product of different approaches at different levels.

Nevertheless, the process to date has at least sparked initial changes to the framework of the energy supply system: society's awareness is growing with regard to the dangers of nuclear and climatically harmful energy generation technologies and the limited nature of resources. The share of power generated from renewable energy sources is increasing and energy providers are challenged to account for this rising share as they are obliged to connect these plants to the grid. The hope remains that the renewable energy innovation process thus far represents the start of a sustainable system transformation.

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Annex

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