Wind Power Generation in Germany
– a transdisciplinary view on the innovation biography

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Abstract: *This article is based on two interdisciplinary research projects that examined the innovation pathways of wind energy in Germany within the last 30 years. The research team used constellation analysis, a methodology that has been developed for the ever-growing field of interdisciplinary research and policy advice. It facilitates the whole-systems approach, drawing on engineering, economics and the environmental and social sciences. The term 'innovation biography' expresses that the reconstruction of the development path pays much attention to its specific characteristics and to the ruptures of the process. Focus of the research project was to analyze the driving forces and facilitating impulses that allowed wind energy to develop from a niche technology to an internationally successful industry.*

The analysis shows that governance on different levels was decisive. Granting the right of access to the grid, precedence for feeding in electricity from renewable and cost covering feed in tariffs were key policy factors, implemented via the feed-in law (StrEG and EEG). But a comprehensive explanation of the wind energy development acknowledges that the regulation was embedded in an interplay of various supportive factors.

The process of innovation, taking place in the niche, was backed by the anti-nuclear movement and upcoming environmental groups. The process of entering the market, stabilizing after a short setback which was followed by a boom appears to be multi-layered with a high interdependence between different driving factors. The successful innovation pathway has arisen from dynamic interactions between governmental and non-governmental actors within a framework of complex conditions. Although the government changed, proponents succeeded in keeping the supportive framework stable and reliable over a long time.

Wind power gave rise to public debate as the acceptance of wind turbines decreased during the expansion phase. These challenges were countered by policies enacted by state actors at the regional and local levels. Decisive factors were the amount, duration and reliability of the feed-in compensation, funding policy and the zoning and building laws. The successful establishment of wind power has been possible in spite the fact that it has been difficult to integrate wind power into the energy supply system due to wind power's intermittent nature, and despite resistance from actors of the fossil-nuclear energy supply system. This has been possible as a result of continually adjusting the policy approaches at various governance levels and reflecting various requirements in the different phases of the innovation process. The analysis reveals that 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. Different phases of innovation processes bring with them substantial framing changes, which then place new demands on policy interventions.*

Keywords: *wind energy, innovation process, niche, constellation analysis, energy policy, multi-level governance*

1. Introduction

Germany has become one of the world's leading wind energy producers over the past twenty years. By the end of 2009, a wind energy capacity of 25,730 MW (BMU 2010) had been installed (see Figure 1).

This fact leads us to the following intriguing questions:

- How could this technology successfully[1] develop within the framework of the existing energy system?
- What were the driving forces and how were impediments overcome?

These questions were the focus of two interdisciplinary research projects dealing with the analysis of the 'innovation process'[2]. Both research projects understand the dynamic process of German wind energy development from the 1970s to the present day as an 'innovation biography' of that specific technology. The term 'biography' expresses that the approach to reconstructing the development path pays much attention to its specific characteristics and to the ruptures of the process, which could either become a starting point for new developments or turn the development in a different direction (Rammert 2000). In addition to the key questions mentioned

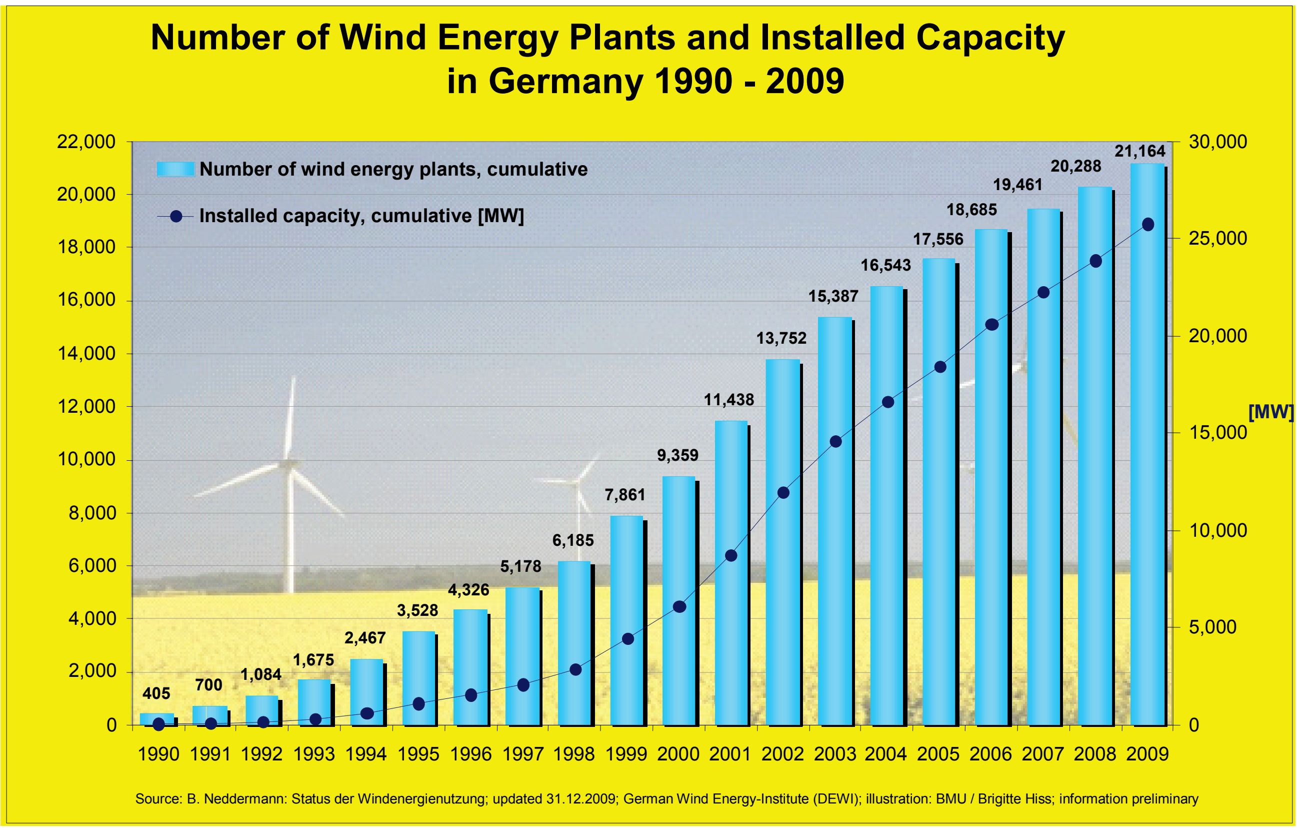


Figure 1: *Development of wind power plants and installed capacity from 1990 to 2009 (BMU 2010)*

above, the following questions have been of central interest in our projects:

- How could the outstanding expansion of wind energy production in Germany take place?
- To what extent was the process guided by policies and political actors?
- Who were the core change agents and the pivotal forces behind the development?
- What was the role of larger-scale political and social contexts?

Most technological innovation occurs without government support. However, this paper focuses on a case of government-facilitated innovation process aiming to reveal the intents and the actual effects of a variety of regulating impulses and their relevance for the innovation process. The innovation biography of wind energy shows that political and administrative steering mechanisms cannot "create" the innovation – they do, however, play an important part in shaping the facilitating conditions for innovation in the case of wind energy.

2. Methodological Approach

The study applies constellation analysis (Schön et al. 2007) 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 one to correlate the various disciplines' views, bodies of knowledge and approaches to solutions. The key elements of the respective development phase are identified, taking into account their interlinkages, and assessed after their relevance for driving or hindering the innovation process. The resulting constellation diagrams aim at simplifying the complex field of actors and interactions. They graphically depict the results of the analysis – both the role of constellation elements and their interrelations (Sections 2.1 and 2.2). Preceding the detailed textual analysis of the respective phase, they enable an elaboration of 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.

2.1 Elements

The study focuses on four equally important types of elements (cf. Figure 2) that make up the constellations: social and institutional actors, natural elements, technical elements, and 'systems of signs/symbols´ (Schön et al. 2007, 18). Different elements are marked by different colors and graphical representations.

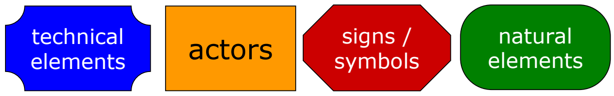


Figure 2: *Categories of elements*

The category of technical elements covers the whole range of artefacts, both existing and under development. The category of `actors´ includes individuals or groups, private persons or public representatives as well as institutionalized actors (such as associations, agencies, authorities or enterprises). The category `signs / symbols´ summarizes a variety of impulses including concepts, strategic goals, legislation, communication and prices. They are expressed both by words and numbers etc. Natural elements represent the natural resources like biotic and non biotic components of the environment (plants, animals, water, soil, and air), landscape and natural phenomena (climate). They allow the depiction of potential impacts on the environment exerted by the application of the technology.

Using these four categories leads to a substantial reduction of complexity. Furthermore, the broad frame of the categories enables us to integrate each discipline's specific perspective on the topic into the constellation

2.2 Relations

The interaction between the elements is expressed by a variety of defined types of relations (cf. Figure 3). Understanding these relations is important in order to understand the structure and the functional principles of the constellation. They reveal the character of interrelation between the elements.

There are the following different types of relations:

- Simple relations: elements are more or less closely connected.

- Directed 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.
- Resistive relations: one element offers passive, non-explicit resistance to an expectation or ascription from other elements
- Conflicting relations: there is conflict between two or more elements, which reflects in one element expressly and intentionally acting against one or several other elements.

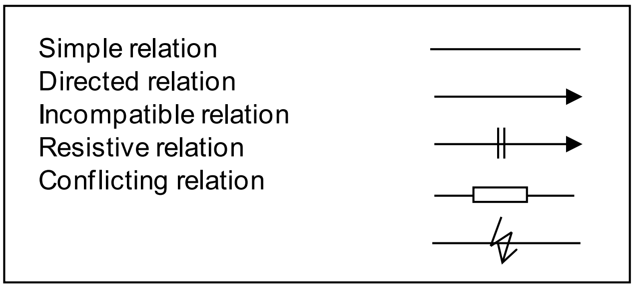


Figure 3: *Categories of relations / interactions*

2.3 The Context

Each constellation is embedded in a context. Context conditions are 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, unforeseen phenomena, variations in the availability of resources, political changes of power, cultural beliefs, academic paradigms, or important events that affect public awareness. Conditions that are classified as context elements form the backdrop to fuel certain developments. Context in this sense favors the development and introduction of certain innovations while impeding that of others.

2.4 Development Phases

The division of the innovation process into phases forms the basic heuristic for the constellation analysis, creating chronological reference points that are used to map the constellations at hand. To gain an overview of the chronological process of wind energy development in Germany, important determinants such as legislation, administrative regulations, sociological responses, as well as unforeseen events were arranged on a timeline.

A selection was made by evaluating their relevance for the process, with a focus on those factors that were considered to be most influential on the development, such as strong steering impulses, incidents, and turnarounds. Subsequently, the chronological process was divided into subsequent phases (cf. Figure 4), which form the basis for further analysis.

In the next step, the relevant actors and elements characterizing each individual phase were identified. The aim was to develop several comparable constellations for the entire innovation process, which would allow us to depict the changes that occurred from one phase to another. The depiction of constellations was a result of regular interdisciplinary colloquia. The arrangement of elements and relations was determined by these key questions:

- What are the key elements of the constellation in the respective phase?
- Which elements are of ‘central’, which ones are of `peripheral´ meaning?
- What elements form, respectively are linked to, the core of the constellation?
- Are there partial or sub-constellations having their own dynamics?
- Which contextual elements are particularly important?

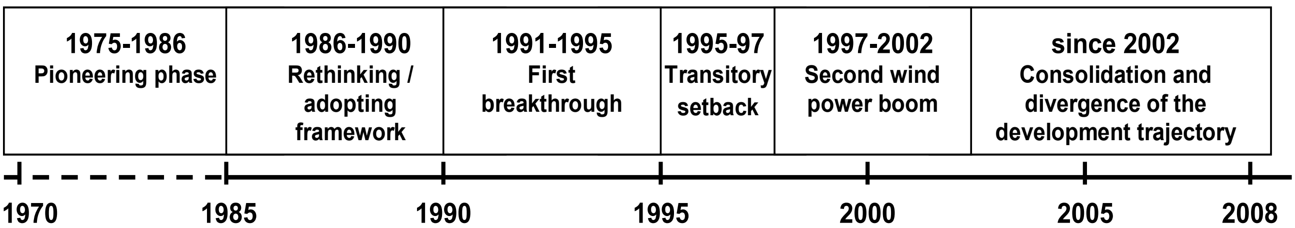


Figure 4: *Phases of the development process in Germany from an interdisciplinary and integrated view*

The constellation diagrams are used as a means to structure the presentation and contextualize the complex activities of the actors, lines of motivation and influencing factors. They serve as a visual summary of what is described in the text.

3. The Innovation Biography of Wind Power Generation

Figures 5 to 10 show the simplified graphic representations of the constellation analysis in the six phases we identified within the innovation process. The visualization of elements and relations leading to a constellation graphic is a result of an iterative interdisciplinary discussion process which was continued, until all members of the interdisciplinary team agreed on the result.

The elements at the upper rim of the graphic represent the contextual elements. They comprise factors or occurrences which influence the entire constellation, e.g. by causing a crisis, by raising the awareness on societal problems, or by drawing attention to radical changes in the developments (see figures below).

The core element of the constellation is represented by a circle in the centre. It consists of elements that predominantly characterize the constellation. Technical elements and their progressive development play, in our case, a key role and thus belong to the core.

The constellation graphics neither claim to be complete, nor are they self-explanatory – the graphics need an elaborate description, explanation, and interpretation. In this article, the written description is shortened to a passage explaining the functional principles and the core agents of each phase (see Bruns et al. 2008 for more details).

3.1 Pioneering Phase (1975 to 1986)

This scheme represents the constellation of influencing factors and elements in the first phase of the process from 1975 to 1986. The oil price crisis in

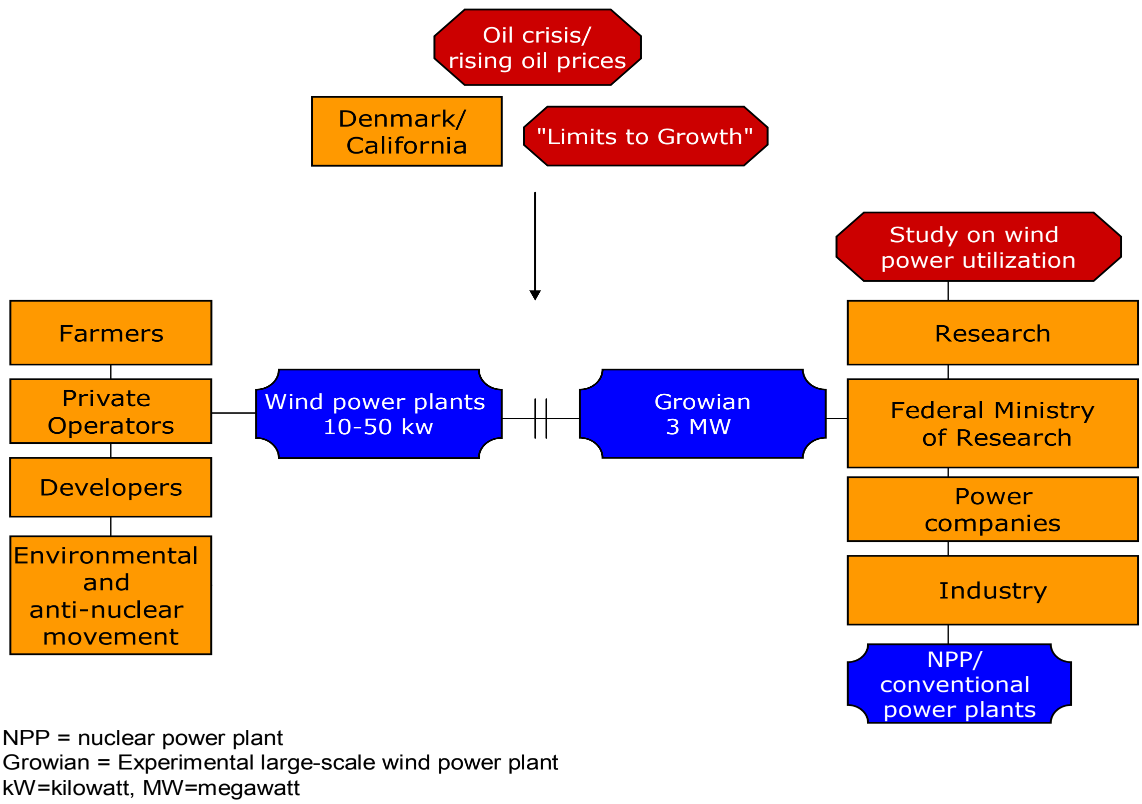


Figure 5: *Pioneering phase from 1975 to 1986*

the 1970s as well as increasing consciousness about the “Limits to Growth” (Meadows et al. 1972) had put the prevailing energy policy strategies into question. The energy sector was dominated by centralized structures of energy production such as nuclear energy. The necessity to become more independent from oil imports enhanced public perception of ‘alternative techniques’ like wind power. A discussion about the need for decentralized structures in German power supply emerged. As more and more people joined the anti-nuclear power movement, it spread all over Germany, gaining influence on the established institutions, political parties, and associations (Saretzki 2001, 206). Gradually, the concerning prevailing paradigm concerning how to ensure safe and reliable energy supply changed and ‘alternative’ approaches advanced in research and energy policy. Furthermore, successful wind power development in Denmark as well as the thriving export of Danish wind power plants to the United States motivated the German government to pursue further technical development of wind power generation (Heymann 1995).

The constellation, as mapped in Figure 5, is characterized by the coexistence of two technological concepts, splitting the constellation into two parts: The niche constellation on the left side is technologically characterized mainly by small wind turbines up to 50 kW, which were installed by private and idealistic operators and small cooperatives. It represents an innovation strategy based on an iterative step-by-step approach. Improvements were made on the basis of practical experience, supporting the development of small and reliable techniques. Power was generated mainly for private and local needs. In this constellation, wind energy is a niche technology, developed by pioneers seeking an alternative, decentralized power supply.

In contrast, the right side of the constellation represents the incumbent system. With *Growian*[3], it underlines the governmental focus on large systems of energy production. In light of rising oil prices and widespread critique of nuclear energy, the Federal Research Ministry had been funding development projects to adapt wind energy technology to the setting of the dominant constellation.[4] This initiative was based on the results of a study (Armbrust et al. 1976) that for the first time assigned a significant potential to wind energy use. The *Growian* exemplifies the failure of the attempt to develop a turbine in the megawatt range not in a step-by-step approach, but in a “quantum leap”. *Growian* had to be dismantled after seven years of unsteady operation. It can be assumed that the failure corresponded to the interests of the power supply industry: *Growian* proved that wind energy technology was not an efficient and sufficiently reliable power source.

The actors - private, mainly idealistic persons in the niche, and institutionalized actors in the prevalent constellation - were driven by different motivations in this phase. Aims and actors form a rather heterogeneous conglomerate. Their concepts for the development of wind power were not compatible. Governmental regulative impulses of research and development were not in line with the technical know-how available at that time. The niche constellation with its actors, motivations, and framework conditions was disregarded; initial potentials were not yet employed efficiently.

3.2 Reconsideration and Changing Framework Conditions (1986 to 1990)

Between 1986 and 1990, the overall framework conditions in the field of energy policy began to change for three main reasons. Firstly, confidence in nuclear power was severely shaken by the Chernobyl reactor catastrophe. This catastrophe marked a turning point in the energy supply paradigms and led to a broad anti-nuclear debate in Germany.

Secondly, at the same time, the ‘Brundtland Report’ (Hauff 1987), which was published in 1987 by the United Nation World Commission for Environment and Development, was widely recognized by experts, politicians, and the public media alike. In consequence of the Club of Rome’s report “Limits to growth” (Meadows et al. 1972) and the Brundtland Report, the idea of finite earth resources limiting steady economic growth became an issue on the political agenda and raised attention towards a more sustainable development, including the beginning awareness of climate change as a global challenge.

Thirdly, the successful development of wind energy, in Denmark in particular, was regarded as a role model. Small scale wind power plants proved reliable – a fact that was welcomed by the still small group of German manufacturers and operators. The interplay of the contextual factors mentioned above exerted a driving force on the innovation process. In the niche constellation, the wind power plant producers were complemented by idealistic individuals who wanted to be part of the development as operators. Operator communities were founded to raise and bundle private investment capital. Gaining independence ('autarchy') from the incumbent system by producing one's *own* electricity was a strong motivation.

Besides single wind power plants, the very first wind farms comprising five or more wind power plants with a capacity of 200 to 400 kW were realized. However, clear approval regulations[5] for this type of facility were missing. Given broad discretionary power, the attitude of the communal administration was decisive for getting building permission or not. Their cautiousness and reluctance led, in this phase, to a restrictive rather than a supportive handling.

An increasing number of governmental activities were established, focusing rather on the niche than on the established energy sector. Substantial support schemes such as the 100-MW Programme, established in 1989 by the Federal Ministry of Research[6], and governmental subsidies fostered the technical progress. Regulating impulses concentrated on strengthening the performance of the technology and on the market launch of wind power plants. Due to a strong competition among wind power plant producers, a vital interest arose to technically improve their wind turbines. The innovation process was driven on the basis of operators' feedback on the usefulness, reliability, and safety of the plants. In this phase, the niche was not yet powerful enough to destabilize the prevalent system. It served a demand for an alternative energy production, which was still limited to an idealistic part of the population.

The steering impulses undertaken to improve the technology were not yet successful, but shed a light on the still hidden potentials of technical improvement. Engineers in the wind business trusted the traditional German know-how in mechanical engineering, construction of turbines, and usage of light material techniques.

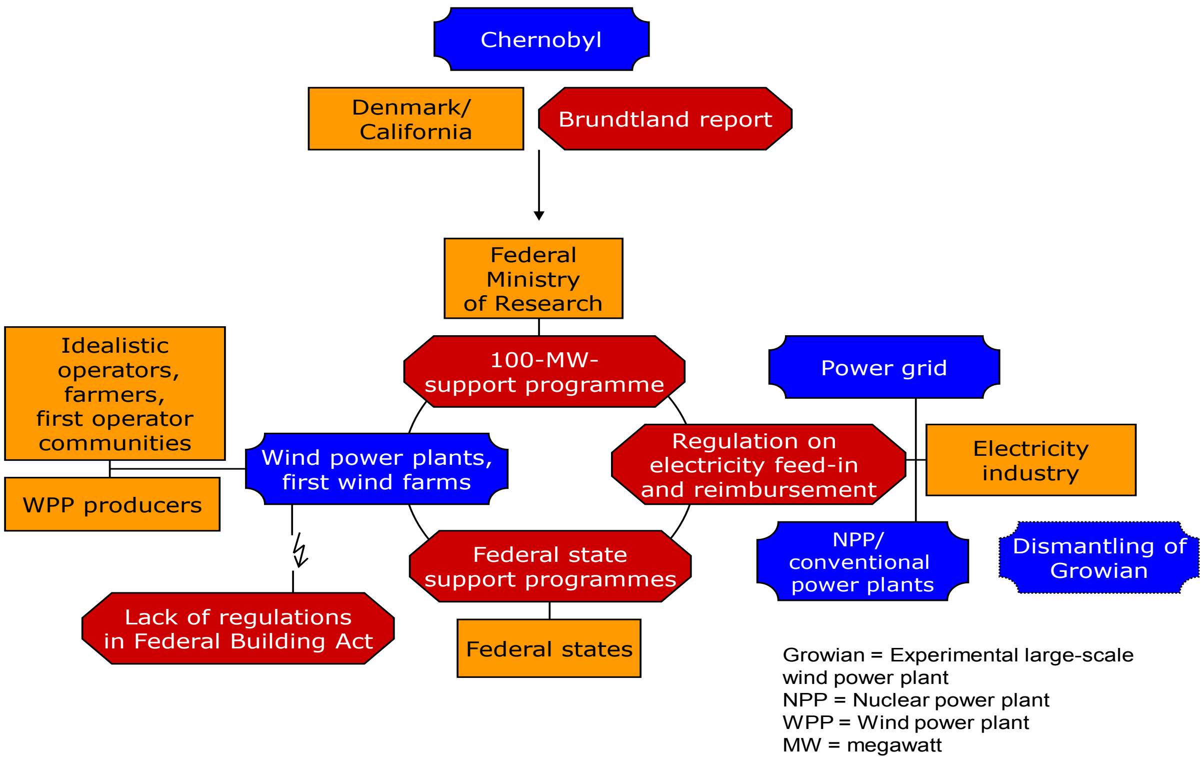


Figure 6: *Reconsideration and Changing Framework Conditions from 1986 to 1990*

3.3 First Breakthrough and Concentration Processes (1991 to 1995)

In the early 1990s, Germany was at the beginning of a national process to implement a climate protection policy. Two reports led to rising political awareness for the necessity of climate protection: The first report of Intergovernmental Panel on Climate Change (IPCC 1990) with climate protection aims regarding the reduction of CO_2-emissions and the report of the German national Enquête Commision on the consequences of climate change, published in 1990 (Enquête-Kommission 1990). The promotion of renewable energies such as wind energy was from this time on more closely connected to climate protection and carbon dioxide reduction strategies. The German Federal Parliament became a driving force supporting these strategies.

Governmental interventions to promote wind energy as a contribution to climate protection were henceforth embedded into a more consistent framework: In 1991, the Federal government established ecological and climate protection aims in a strategy paper (Die Bundesregierung 1991), which underpinned the support.

In the same year, the 100-MW Programme was modified, and the capacity of supported turbines was raised to 250 MW (Hemmelskamp 1998, 37). The 250-MW Programme, acting both as a market introduction and research programme, had stabilizing impact on the wind business.[7] Consequently, innovation took place in small and medium-sized businesses during this phase.

Also in 1991, the first 'Electricity Feed-In Act' (StrEG 1991) entered the core of the constellation. Initiated by members of the German parliament[8] its enactment entitled plant operators to feed into the power grid electricity from selected renewable energy sources[9] at a fixed price. The 'Electricity Feed-In Act' introduced a new era for bringing renewable energies into the market. It set the course for a refunding system that proved to be very successful, especially for wind energy production, in the years to come. The rising interest in erecting wind power plants strengthened the small scale wind energy enterprises and enhanced their capacities.

The governmental impulses were supported by a broad alliance of actors including politicians and lobbyists. Still, the pursuit of a common idealistic goal[10], which played a substantial role for the diffusion of the technology (Byzio et al. 2002), was mainly led by the motivation of civil society actors. At this time, professionalized operators emerged as a new type of

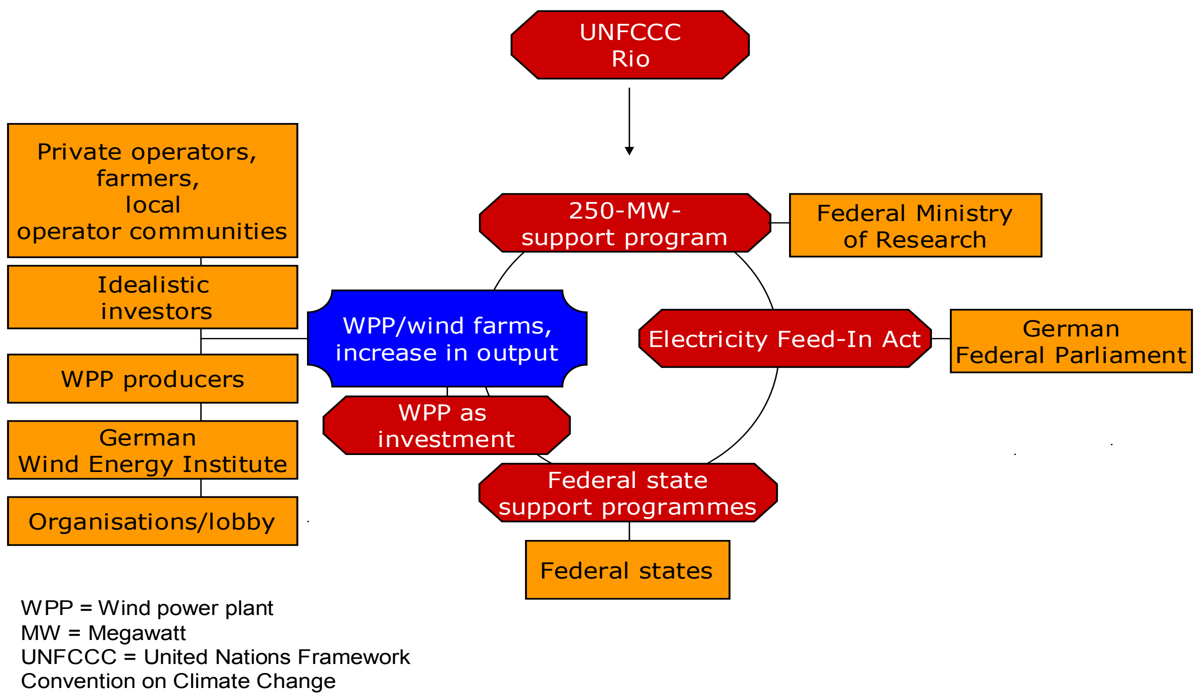


Figure 7: *First breakthrough and concentration processes from 1991 to 1995*

actor. As the capitalization and commercialization of the industry pushed the development, the wind business itself became a driving force of the wind energy boom of the early 1990s.

The former niche – represented by the elements on the left side – grew, protected by governmental subsidies. After the enactment of the StrEG, the deployment of wind turbines 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 (Molly 2009). The opponents of increased wind energy development, such as electricity utilities, do not appear in this constellation. At this time, they underrated the potential of wind energy and refrained from interventions against the rising wind energy business. This underestimation had a highly beneficial effect on the further development of wind energy (Ohlhorst 2009).

To sum up, it can be stated that the 'Electricity Feed-in Act' supplementing the governmental support programmes was the main driving force for the initial wind energy boom of the early 1990s. Due to high feed-in remuneration, wind energy production became appealing for capital investments. Operators as well as manufacturers, retaining local or regional relations, used their expertise to expand and started to professionalize their businesses gradually. This governmental regulating impulse was successful, because it adjusted to the aims and the motivation of the niche actors (Ohlhorst 2009). Those had meanwhile turned into important forerunners of the boom that unfolded in the upcoming phase.

3.4 Transitory Setback (1995 to 1997)

In 1995, the installed total wind power capacity reached approximately 1,500 MW in Germany (Molly 2009). During the previous phase, the technical development had made substantial progress: wind turbine capacities had risen from 120 to 600 kW on the average. So did the average height of the turbines, reaching approximately 70 meters by then. Facing the problems of a rapid up-scaling, some of the wind businesses got under pressure while having difficulties to keep the pace with fast increasing technical standards. Besides, new steering impulses affecting the wind industry were simultaneously gaining importance in the core of the constellation.

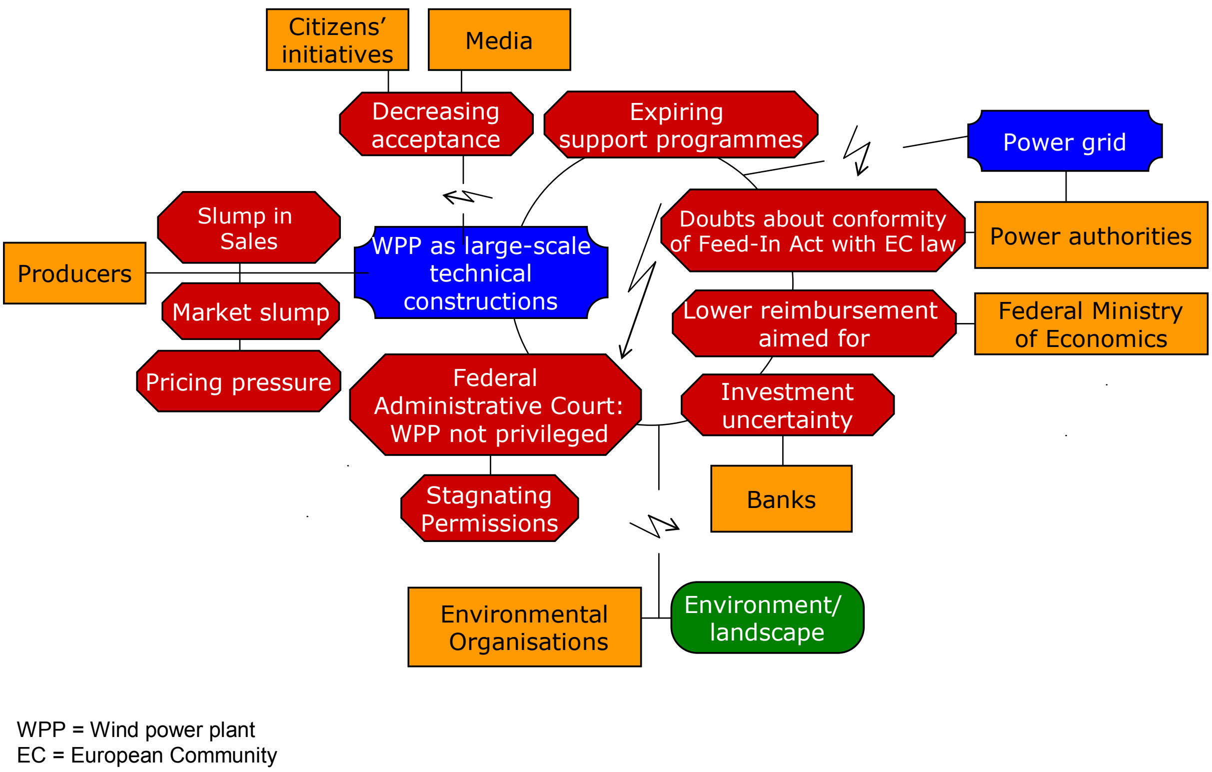


Figure 8: *Transitory setback from 1995 to 1997*

They exerted pressure on the market launch that was under way.

In the face of the wind sector's successes, established power supply companies and their associations felt the effects of inhibitory impacts. The electricity market, which had so far been dominated by the transmission and supply monopoly of the electricity market's companies, was forced to open up to private renewable electricity generators as a result of the 'Electricity Feed-In Act'. The electricity industry became aware of the Act's effects and began to oppose it with great determination. The core of resistance came from the power utilities united in the Association of German Electric Power Utilities (VDEW – now BDEW). Following a recommendation of the VDEW, some individual power companies cut the legally required financial compensation of one of their customers who was feeding power into the grid. This course of action met with massive public criticism. Members of all parties in the German parliament expressed their disapproval of the misdemeanours of the power companies and demanded the 'Electricity Feed-In Act' to be respected in the form in which the Bundestag had decided upon. Two power companies appealed the 'Electricity Feed-in Act', as to their view it did not comply with European state aid regulations. A successful lawsuit would have led to a breakdown of the young wind energy sector. The appeal caused uncertainty among investors, eventually resulting in a drop of demand for wind turbines. The drop snowballed and took in banks, authorities and manufacturers. Thus, in the middle of the 1990s the growth of installed wind energy capacity suddenly slumped.

Wind businesses suffered from the market slump and the decrease of sales rates. High development expenses, competition between manufacturers, and the pricing pressure led to a first shakeout of the wind energy industry.[11] Expiring wind support programmes – until then granted supplementary to the remuneration based on the feed-in tariff put additional strain on the young and struggling wind business. For about two years, the market was very erratic, causing two German manufactures to declare bankruptcy.

Beyond that, the element 'environment/landscape' in the constellation indicates a new field of conflicts. The risk of bird collisions and visual intrusion was gaining more and more importance. Also, noise emissions became an issue. The increasingly large turbines fuelled local resistance. More and more citizens expressed resentment against an 'asparaguising' of the scenery and organised themselves into citizen groups. Critics of wind power got broad public attention by using the media to spread their voice.

The backlog in permissions intensified the uncertainty of the market to an extent where even banks hesitated when it came to financing new turbines. Legal adjustments that could have eased the obtainment of a building permission for wind farms were overdue. In a first attempt, the Federal Parliament failed to introduce a 'priority regulation'[12] for wind turbines in the Federal Building Act.[13] As the authorities were unprepared for the multitude of applications, the investment and permit backlog persisted and ultimately resulted in a slump in the market. The request by the Federal Ministry of Economics to reduce the feed-in tariff in the upcoming amendment to the StrEG had additional retarding effects. Governmental regulative interventions appeared not clear-cut but rather contradictory.

In short, the constellation appears inconsistent concerning its motivations and aims. This occurrence and coincidence of disadvantageous factors caused a transitory setback. The means to overcome this setback will be described in the upcoming phase.

3.5 Second Wind Power Boom (1997 to 2002)

During the second wind power boom, the context was set by climate protection goals (CO_2-reduction), energy policy goals such as liberalization of the energy market on the European level, and the first EU Directive on the promotion of renewable energies.[14] On the national level, these international goals served to legitimate the national wind power policy. Driven by EU legislation for liberalization[15] the overdue amendment of the Energy Industry Act (EnWG)[16] was finally achieved in 1998. It prepared the electricity sectors' transformation to an oligopolistic structure of the energy supply market, dominated by four main energy suppliers.

In view of the pressure exerted on the struggling wind sector, a broad alliance of wind energy proponents, the 'Aktion Rückenwind' ['concerted tailwind action'] formed to defy the lowering of feed-in tariffs intended by the Federal Ministry of

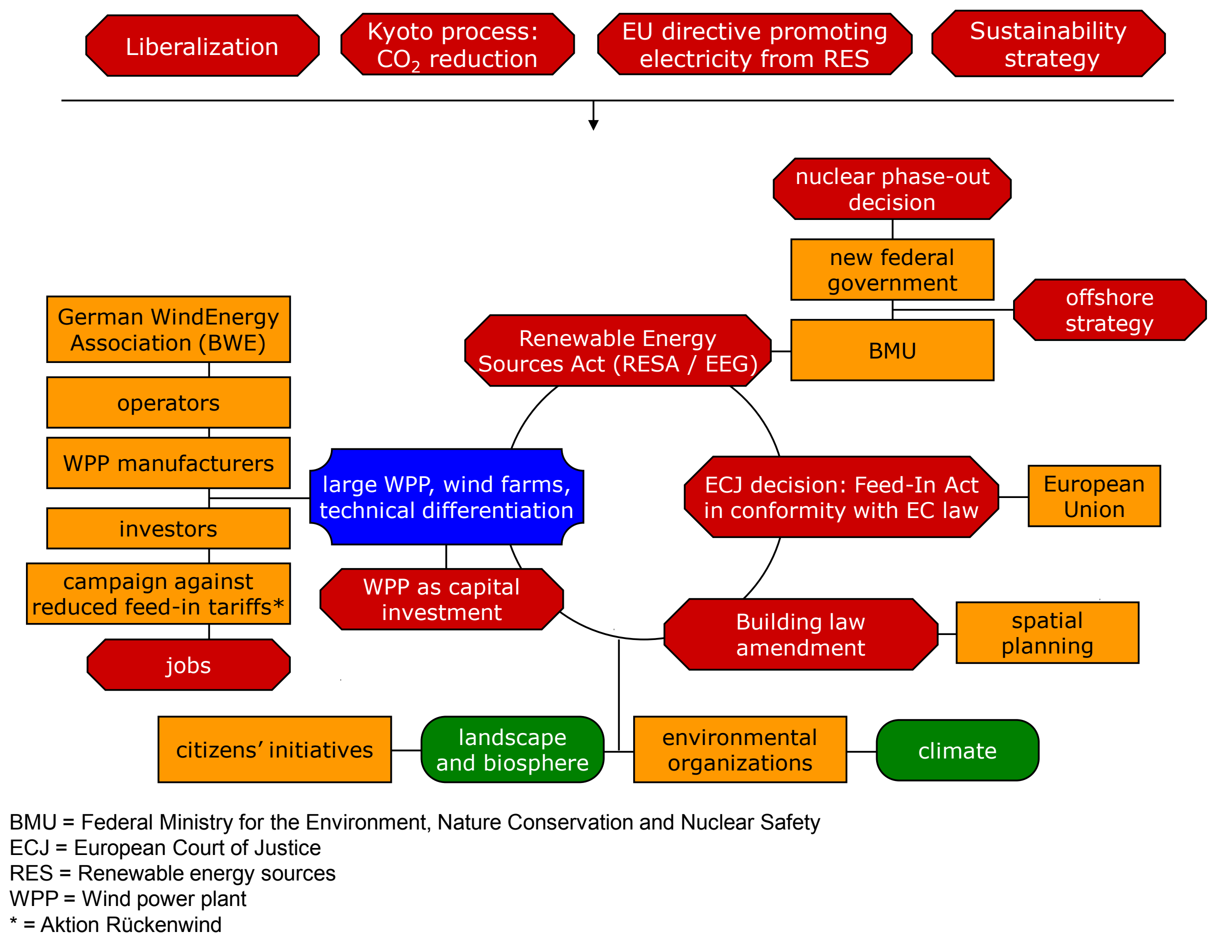


Figure 9: *Second wind power boom from 1997-2002*

Economics (Bruns et al 2008). Members of all parties in the German Federal Parliament supported the 'tailwind-concern' to keep up a stable framework of remuneration. This concerted action finally averted a cut in feed-in tariffs and re-stabilized the niche constellation.

Two legislative impulses put an end to the crisis described in the previous section and initiated a second boost: the European Court of Justice ruled that the German feed-in tariffs comply with European state aid regulations.[17] Thereupon, wind farms became attractive once again for capital investment and the demand for wind power facilities was stimulated. Moreover, the pending priority regulation[18] for the admission of wind farms was finally amended in the Federal Building Act, coming into force in 1998.

Within the context of the climate protection aim to double the quota of renewable energy in power supply, the Federal Parliament began to push for another bundle of governmental initiatives. The 'Renewable Energy Sources Act'[19] was finally passed in 2000 after strong discussions in the German Federal Parliament. The obligation of the grid operator to connect the facility to the grid, the feed-in priority for renewables, and the remuneration at a cost-covering price fixed over a time period of 20 years were (and still are) clearly decisive for the expansion of wind energy (Bruns et al. 2010). From 2000 onwards, stable investment conditions and planning reliability for investors, manufacturers, and operators fuelled the development and thus facilitated a broad market launch of wind energy. The far-reaching and constant positive effects for the wind sector can also be traced back to the fact that the Renewable Energy Sources Act was designed as a dynamic (not static), learning and self-improving law, amending to the recent state of development every four years.[20]

The feed-in conditions of the 'Renewable Energy Sources Act' even incited the established energy utilities, which still dominated the market of conventional energy, to explore the wind energy market. Yet the conventional utilities did not join on a large scale. The small-business wind industry gained increasing economic weight. In 1998, approximately 15,600 persons were employed in the wind industry. By 2002, this number had increased to 53,200 (Edler et al. 2004). The installed capacity in 1998 was around 2,850 MW, while four years later it had increased to almost 12,000 MW (Molly 2009, 9). Strong competition among the manufacturers ('grow or go´) led to a market concentration and an economic shakeout. At the end of the 1990s, the five companies Enercon, Micon, Vestas, Tacke, and AN Windenergie dominated the German market.

After the adoption of licensing regulations in 1996, some regions experienced a strong growth of wind farms. Conflicts caused by noise emissions, visual impairment, and disturbance emerged, entailing a decline in local acceptance where growth exceeded tolerable thresholds. On a strategic level, aims of climate protection, noise protection, landscape protection and protection of biodiversity (protection of avifauna) could co-exist. Still, in specific planning cases, conflicts of interest between climate protection and nature conservation became obvious. The wind energy business felt hampered by authorities that applied a restrictive interpretation of nature conservation regulations in the consenting procedure. To relieve the local authorities from increasing pressure, the German planning law was amended. Wind energy became an issue of regional and municipal master plans. The regulations aimed at spatial concentration of wind turbines in designated zones of high wind yield and low impact on landscape and human health. Separating these wind farm zones – so called suitable wind areas - from residential areas contributed to mitigate the conflicts and led to increased social acceptability.

The number of actors involved in the implementation process increased. However, the constellation of actors shows more clarity and consistency; the governmental steering responded adequately to the obstacles of the preceding phase.

3.6 Divergence of The Development Trajectory

In 2001, the Federal Government (BMU 2001) issued the national offshore strategy. This was taken as the starting point for this phase, during which the constellation is dividing into two sub-constellations, the onshore constellation on the left side and the offshore constellation on the right side. Both sub-constellations are characterized by a specific combination of actors, elements, and aims, following their specific development paths.

3.6.1 Onshore Constellation

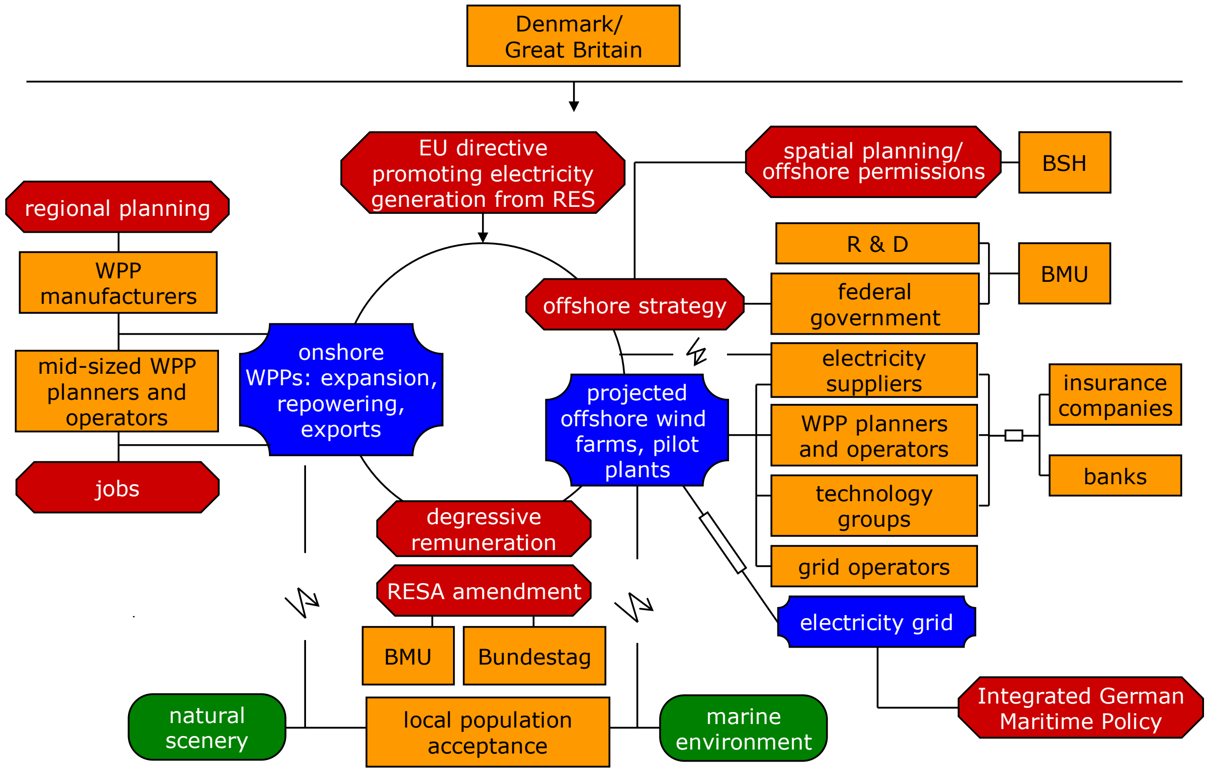
The annual onshore installation rates were high until 2004. The designation of appropriate sites for wind farms on regional planning level facilitated the planning process and the approval of wind farms. The limited abundance of suitable sites turned the pushing effect of designated wind zones rather into a limiting effect. A decline of installation rates followed.

In regions where large numbers of wind turbines were erected within a short time period, the resistance from local inhabitants rose. They felt overrun by the development, especially if the region could not benefit economically from the wind power production. This feeling was even stronger if a lack of transparency in the planning and licensing procedures occurred and gave reason to a growing distrust against the operators' intentions.

As a response to local resistance against wind farm projects, regional planning authorities and municipalities handled the designation and enlargement of appropriate sites in land-use master plans rather restrictively.

In view of the installed capacities already achieved, some federal states tightened their 'clearance decrees' for wind farms. Due to increasing noise emissions and rising height of the turbines, the distance to sensitive areas such as housing areas, nature protection areas, or protected landscape elements of outstanding beauty had to be enlarged (BUND 2004). The limited availability of designated areas for wind energy production was a clear restraint to continue the increase of capacities as in the previous phase.

From 2003 onwards, the attention shifted to the potentials of repowering. The replacement of old and inefficient turbines by new ones of far higher capacity seemed to be promising. The wind business hoped to keep up the demand for their state of the art wind turbines. As agreeable sites were getting scarce, repowering was pivotal to maintain the annual



BMU = Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BSH = Federal Maritime and Hydrographic Agency
EU = European Union
RES = Renewable Energy Sources
RESA = Renewable Energy Sources Act (EEG)
WPP = Wind power plant

Figure 10: *Divergent constellations: Consolidation onshore and pursuing the implementation of the offshore strategy from 2002 to present*

growth rates of installed capacity.[21] But the launch of the repowering strategy was and still is not optimally implemented.[22] One reason for this is that in the 1990s, many municipalities had limited the permitted height of wind power plants to about 100 meters.[23] This restriction impedes the admission of large capacity turbines (Deutsche Wind Guard 2005). Although the municipalities acknowledge their responsibilities (Deutscher Städte- und Gemeindebund 2009) to set the framework for the expansion of wind power, they were and still are not able to synchronize admission regulations to the speed of technological development. Failing to keep up with the pace of technical development prevented a smooth change from old to new and more effective technology.

Since the onshore expansion was hampered by a foreseeable decrease in demand and by the regulations, the wind business began to focus on foreign markets by the turn of the millennium. As German manufacturers held the market leadership, an increase in export rates of German wind power plants was achieved (BWE 2008). Accounting for 28 % of the globally installed wind capacity, Germany was ahead of Spain, the USA, India, Denmark and China in 2007. Moreover, Germany provided the largest industry for wind farms producing 37 % of all systems and components (Deutsche Bank Research 2007).

The average production capacity of a turbine was now about 2 MW (compared to 0.16 kW in 1990; see Ender 2010). Although the number of installed plants declined, until 2009 the installation rates kept rather stable due to the achieved production efficiency.

At present, towards the end of this development phase, the dynamics of innovation in onshore development are slowing down. Technological improvements concentrate on refined technologies to optimize and stabilize energy output and grid feed-in. Still, developing adequate offshore technologies is a challenge for innovation.

3.6.2 Offshore Constellation

A strategy paper on offshore wind energy, published by the German government (Die Bundesregierung 2002), was the starting point of the innovation process in the offshore sector, constituting a new era of large scale wind energy deployment. Its intention to establish large-scale wind power capacities offshore will notably increase the share of renewable electricity and, at the same time, minimize the inevitable conflicts of large-scale deployment onshore. The goals for offshore wind deployment raised high expectations: 500 MW were to be realized by 2006; 3,000 MW by 2010 and up to 25,000 MW by 2025/2030 (BMU 2001). It was the goal of this step-by-step approach to ensure that potential limits or unwanted side-effects could be corrected in the ongoing process and correspond to the enhancing state of knowledge about effects on marine ecosystems (SRU 2002).

On the international level, the German offshore policy was supported by the renewable electricity targets of the EU directive for renewable electricity. The offshore strategy, pointing out that its realization was indispensable to reach the climate protection targets, gained significant importance for all activities advancing the offshore wind development. However, until offshore wind power deployment took off, quite a number of challenges had to be met. In contrast to other European countries[24] Germany limited its offshore development to the "Exclusively Economic Zone" (EEZ), so offshore sites were situated at least 12 nautical miles from the coast.[25] In consequence, developers had to cope with water depths of about 40 meters, a rough sea, and high expenditures for building and maintenance of the turbines. German wind businesses started to develop new types of turbines that were expected to resist the strenuous conditions.

To enable planning and licensing procedures of offshore wind farms in the EEZ, a wide range of legal and administrative regulations and procedures were adopted (Kruppa 2007). For instance, a new scheme for the licensing procedure for offshore wind farms (Zeiler et al. 2005) was established in 2003 with the aim to simplify the procedure.

Additionally, the rising conflicts with regard to potential impacts on seabirds, migratory birds, and sea mammals made it evident that the aims of landscape (respectively seascape) and nature protection on the one hand, and climate protection on the other hand are not easy to reconcile (SRU 2002; Zucco et al. 2006). To limit these conflicts, the German offshore strategy was accompanied by a research programme investigating the ecological impacts on marine ecosystems (PTJ 2002; Fachinformationszentrum 2004). This programme is currently being continued to investigate the effects at the "alpha ventus" test wind farm in the North Sea, close to the island of Borkum.[26] The amendment of the planning law in 2004 (BauGB 2004) installed a legal framework for spatial planning in the EEZ. Regulatory onshore approaches such as the designation of appropriate areas were thus shifted to marine areas, aiming to achieve compatibility between the requirements of offshore wind farms and the aims of other marine uses.

Considering the high amounts of electricity produced offshore in the future, the connection of offshore wind parks to the grid was regarded as the essential bottleneck for further development (COD 2005). Grid operators claimed that neither capacities nor transmission management could cope with the future requirements. Conflicts about who had to bear the costs of reinforcement of the grid - grid operators or offshore wind farm developers - were obstructing the development. Thus, missing cable connections and the suboptimal grid capacity onshore are classified to have a resistant effect on the development.

Due to the high risks of offshore wind energy (e.g. reliability of operation), banks and insurance companies remained cautious, as revenues from these investments were considered insecure. The high technical challenges as well as investment challenges of the offshore wind turbines had an obstructive impact. As financial risks remained high, the amended Renewable Energy Sources Act (EEG 2004) allowed for raised feed-in tariffs and for a broad extension of the period for maximum reimbursement. The remuneration conditions were once more improved in the EEG 2009.

A number of technical problems of seagoing turbines, notably problems of construction in water depths of 40 m, problems of durability due to corrosion, plus the lack of construction and maintenance techniques, made it impossible to keep up with the original schedule (BMU 2007). Furthermore, the unsolved financial risks hampered a speedy development. The constraints clearly dominated the favourable factors at that time. On the national level, the commitment of the Ministry of the Environment – based on the governments' offshore strategy paper – kept the momentum towards offshore wind deployment going. Meanwhile, the ambitious aims for the offshore wind energy deployment have been rescheduled.

To foster the commercial production of offshore wind energy, an offshore foundation was launched in 2005. It consists of the main players in the business: Representatives of institutions such as the Federal Ministry of Environment and members of the federal state governments, representatives of German manufacturers, wind energy interest groups, environmental associations, and large energy suppliers. The foundation supports the offshore wind farm 'alpha ventus', which was the first German offshore wind project, officially commissioned in April 2010. 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 planned. For several projects, the start of construction was delayed by the reticence of banks and investors. Exploding steel prices significantly increased the financial requirements for the 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.

3.6.3 Future Prospects

Offshore wind power is still regarded as a future mainstay of German energy security (see e.g. Nitsch 2008). The government has confirmed its will to promote the offshore strategy. Further supportive steering impulses will be implemented to accelerate the realization.

Besides the mentioned challenges, current findings point out that the future deployment of wind power will very much depend on whether the grid connection and transformation of the power generation system as a whole are going to be successful. In some regions, the amount of intermitting wind energy has already reached the capacity limits of the grid, making an upgrade indispensible.

Apart from realizing cable connections at sea, the integration of offshore electricity poses an even higher challenge on the land: The integration faces a highly controversial discussion on the construction of new high-voltage power lines to enhance transport capacities for offshore electricity to the south of Germany.[27] In consequence, the focus of governmental steering must now shift from mere renewable energy generation to the challenges of transformation of the energy supply system.[28] Lacking feed-in capacities and transportation capacities would otherwise constitute a bottleneck which will significantly slow down further deployment.

4. Insights and Principal Findings

Section 3 described the main actors and influencing factors, their roles, and the interplay among the actors and influencing factors in the German wind energy innovation process. The analysis of the innovation biography of wind energy shows partly specific, partly generalisable characteristics regarding the development of the respective constellations.

4.1 Insights about Principles of the Constellation Development

Seen from the constellation analysis perspective, the wind power developments illustrate the structural process of constellation change over time. At the beginning of the investigated period, the constellation representing the incumbent energy system clearly dominated the niche. Both constellations were distinctly contrasting. The establishment of the niche constellation was possible as the established energy sector underestimated its potential for renewable energy production. Taking profit from the absence of massive interventions the niche was able to establish and develop market power – and thus destabilize the incumbent energy system. Over time, the boundaries between the competing constellations first obliterated (Fig. 6 and 7) and finally disappeared altogether (Figures 8 and 9). Towards the end of the last period under consideration (Figure 10), the constellation split up into new sub-constellations: Offshore and onshore wind energy. Hence, since the 1990s the niche has emancipated itself, but it has – in its development towards large-scale energy production – also adapted characteristics of the dominant constellation (Ohlhorst 2009) or, as the offshore initiatives show, even started to merge.

4.2 Driving Forces and Core Agents

The driving forces of the development changed from phase to phase. Thus, each state of innovation had a specific set of supporting and supplementing key factors. The following paragraphs will highlight a selection of pivotal driving forces.

The steering impulses to come in(to play) in the phases from 1990 onwards unfolded their driving force in the respective constellation, provided they were embedded in and accompanied by a variety of aligned impulses.

Besides the early support programmes, like the 250-MW Programme (see Section 3.2. and 3.3), which were essential for the kick-off, it was the amendment of the 'Electricity Feed-in Act' (StrEG 1991) and its follow up, the 'Renewable Energy Sources Act' (EEG 2000 ff.), which are considered the pivotal driving forces during the past two decades. With the 'Renewable Energy Sources Act' a specific and dynamic steering tool has been implemented: After a mandatory evaluation of the development progress every four years, tariffs are adjusted to stabilize the development on the one hand and stimulate further technical improvement and cost degression on the other (see Section 3.5). The gradual degression of feed-in tariffs still stimulates the wind business to higher performance.

The rapid progress in technical innovation was the merit of the idealistic *small-scale manufacturers*. They represent the core agents for technological innovation during the first two initial phases. Up to now, the competitive wind industry coped successfully with the challenges of incrementally upgrading the wind turbines.

The wind industry has also undergone an institution building process: the *Federal Wind Association*[29] as the main representative of the wind industry enhanced its influence on political level considerably over the past 15 years.

Under a conservative government, a majority in the *German Federal Parliament* sympathized with the ideas of renewable energy production and its contribution to CO_2-reduction. The red-green government gave the *Federal Ministry of Environment* the competences for renewable energy research. Gradually, it conquered the leadership in strengthening the role of renewable energies. Being the forerunner among the other renewable technologies in the electricity sector (Bruns et al. 2011), a close interplay was established between the Federal Ministry of Environment and the wind industry and its stakeholders. Since 2002, the deployment of offshore wind in particular was subject to special attention and ongoing political and financial support.

4.3 Overcoming the Impediments

For successfully overcoming impediments, it is indispensable to be aware of potentially arising conflicts, to analyse them seriously and – finally – to react appropriately and in time. Adjusting the impeding regulations to the needs of further deployment appears to be the greatest challenge in that context.

During the innovation process, several impediments had to be overcome. In the first two phases, until the beginning of the 1990s, the wind power technology was not welcomed by all but had to overcome concerns both from parts of the local population and from members of municipal administration, some of them tending to rather retain building admissions. It was the *convincing performance* of the technology itself, supplemented by a *gradual habituation* to the appearance of the facilities that helped to overcome these reservations. But most notably, in the early phases the insight that small-scale wind power was profitable and could significantly contribute to the income of rural population played a central role. Thus, *offering an economic benefit* to those willing to take the risk (for idealistic reasons) was an important means to overcome initial impediments.

As described in Section 3.3, the deployment suffered from a setback which turned out to be transitory in the end. This setback was - among other factors - overcome by the support of a broad alliance of wind energy proponents (Section 3.4), the concerted '*tailwind action*'. This example shows how vital mobilizing a broad alliance of supportive actors was for keeping up the *political will* to continue the innovation process. The market entry and expansion of a new technology is strongly reliant on a broad *societal acceptance*.

The first wind energy boom (phase 2) was hampered by inadequate planning and licensing regulations. However, the *amendment of planning and building regulations* on all administrative levels involved took its time. The amendment of the Federal Building Act in 1997 was a tedious process, but crucial for further deployment – so were ordinances and clearance decrees on state level, necessary to apply the regulations to the single case. Making wind power an explicit planning issue on regional and municipal level required to reconcile diverging interests. Nevertheless, since the second boom phase, the designation of *appropriate areas and concentration zones* has facilitated the deployment of wind power use to a certain extent. Thus, comprehensive spatial planning has played an important role for reducing impediments caused by land use conflicts and undesired environmental impacts at the implementation level. To foster the repowering process, planning and licensing criteria now have to be adapted to the progressive dimensions of wind turbines.

Although having provided continuous support for offshore deployment (see Section 3.6), the impediments to realizing offshore wind farms have not yet been overcome.

4.4 The Influence of Governmental Impulses - Political Actors and Policies

As shown in Section 4.2, the regulative impulses initiated by the respective *Federal Ministries*[30] had decisive effects on the outstanding expansion of wind energy in Germany.

The innovation biography of wind energy points to the role of key cross-sectoral influencing factors, as well as that of policies designed to encourage industries and initiatives. In general, it can be said that *policies and regulative impulses* influenced the innovation process of wind energy significantly and effectively.

Retrospectively, the *Federal Feed-In Act* of 1991 successfully set the agenda with respect to the provision of effective electricity feed-in tariffs. The second boom phase in particular was triggered by the dominating policy effect of the guaranteed feed-in-tariffs, combined, inter alia, with subsequent society-centered innovations in the German spatial and environmental planning system and by court decisions at the European and the sub-national level. In force since the turn of the millennium, the *Renewable Energy Sources Act* has replaced its predecessor and from then on played a key role, having again improved the reliability of economic incentives it creates. In addition, the *German Offshore Wind Strategy* of 2002 and the *German Climate Protection Programme* of 2005 represent important policy interventions the innovation phase developed last. Political decisions and regulating impulses interacted with other elements such as technology, economy and societal impulses. Wind energy was supported and legitimized by political action, and at the same time the technological and economic development decisively influenced the political decision-making process. The course of the development of wind energy was set at the international, European, and national level, as well as at regional and municipal levels. The long-term stable and ongoing implementation and diffusion of wind energy in Germany can be seen as the consequence of iterative, step-by-step and phase-specific adjustment management.

As a result of the constellation analysis of wind energy innovation process, we think that the following general assumptions about the successful effects of governmental steering impulses on the innovation process can be framed:

Regulative impulses to promote innovation have proven effective

- if the complex and comprehensive character of the innovation task is sufficiently taken into account.
- if the respective measures are streamlined with and embedded in a complex structure of additional factors that affect the development process, e.g. the state of technology, the economic conditions, the social context, or innovative operator models.
- if they interact with or correspond to the context of the constellations. The context of a constellation may not have a beneficial effect – it may also exert pressure on the constellation to change, become active, and introduce innovation, thus pushing the search for alternative solutions.
- if they take up the ideas and interests of inspiring forerunners, who support the activities of governance.
- if they interact with economic elements. Readiness for marketing, market access, lowering entry barriers, investment security, competitiveness and profitability are key prerequisites for the diffusion

of a technical innovation. The economic motivation of the players, the successful establishment of a market, and eventual market leadership act as driving forces in the biography of innovation.
- if there is a close correlation between the controlling players of the political system and the technical and economic elements.
- if they protect the niche constellation from resistant actions of the incumbent energy sector until it gains significant momentum.

The examination of the innovation process of wind energy showed that various policies had intervened and successfully influenced the process. We observed a close interplay between the actors within the political system, the technical and economic development as well as social factors. In other words, governmental control of innovation processes does have an effect, provided it interacts with a number of heterogeneous influencing factors. Governmental control is all the more successful the more accurately the phase specific development of the constellation is assessed and control instruments are applied accordingly. Adapting the set of control instruments to the respective constellation is challenging. Therefore, one of the conditions for the success of governance is the synchronization of different impulses that promote each other.

The more clearly and consistently the respective departmental government portfolios act, the more likely the success of policies becomes. This requires an integrative strategy. Regulation measures have an effect especially if they are coordinated at the different levels of action in terms of contents, space and time. In order to ensure the success of policies, the various government 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.

4.5 Role of Larger-Scale Political and Social Contexts

In the initial phase, the Chernobyl accident and the oil crises created policy windows for promoting the wind power generation as an alternative to the incumbent system. These occurrences shaped the public perception and raised awareness to a more sustainable energy supply.

Once set on the political agenda, wind power profited from the awareness of climate change and strategies to abate CO2-emissions. The promotion of wind energy now had an additional legitimization. In order to meet the objectives, policy measures have to be geared towards different tasks and problems in each individual phase of the innovation process. When the process was facing 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, regulating mechanisms coming from different levels took effect at staggered intervals, which intensified their impact, provided they were going in the same direction. The task of harmonizing and coordinating the timing of policy demanded a reflexive design that is both relevant to a number of different administrative and political levels, yet tailored to the process in question.

5. Outlook

One of the crucial factors in the future development of wind energy is the question of whether the wind energy sector and the political proponents will be able to ensure ongoing acceptance for wind energy. On the one hand, a certain habituation has taken place over time which might diminish resistance against further deployment. On the other hand, it is obviously not easy to integrate wind energy into the power system without causing further conflicts, generating the need to expand the overhead transmission network and to build additional storage capacities (e.g. pump storage). The costs and effects of wind energy generation will not any longer be discussed without considering the costs and effects of its integration into the supply system. As additional conflicts due to infrastructural measures are foreseeable, governmental steering impulses should focus on ensuring a high level of social acceptance not only towards generation technologies but also towards the technical requirements of transport and distribution.

There are various concepts under discussion concerning how this can be achieved: offering possibilities for participation in strategic decision making as well as in planning and licensing procedures on project level can be a cornerstone to maintain public acceptance.

To date it is one of the main future challenges to achieve and keep up societal acceptance towards wind power generation and its consequences over a long time period.

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Notes

1 Success in this case may be defined as the increase in the share of wind energy in relation to the total power consumption.

2 See Bruns et al. (2008) *Die Innovationsbiographie der Windenergie*, funded by the Volkswagen Foundation, and Bruns et al. (2011) *Renewable Energies in Germany's Electricity Market*, funded by the Federal Ministry of Environment.

3 Abbreviation of the German word "**Gr**oss**wi**nd**an**lage" = large-scale wind turbine. The *Growian* had an electrical capacity of about 3 MW and a rotor diameter of 100.4 meters. Commissioned in 1980 with a height of 150 meters *Growian* was for a long time the largest wind power installation in the world.

4 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).

5 Regulations after to the Federal Building Code (Bundesbaugesetz) of 1987 and corresponding land use ordinances.

6 This programme was enlarged and continued as the 250-MW Programme in the following phase (see Section 3.3).

7 The programme assured a certain demand for wind turbines. Raising manufacturers' certainty about the demand had a significant positive effect for the upcoming wind business (Hoppe-Kilpper 2003, 86). The programme was connected to a 'Scientific Measuring and Evaluation Programme (Wissenschaftliches Mess- und Evaluierungsprogramm -WMEP) which contributed to raising confidence of investors in the technology.

8 The initiative originally aimed at improving the compensation for small hydropower energy. For more details on intentions and coming about of the StrEG see Bruns et al. (2011).

9 Such as Combined heat and power, hydro power, wind power, power from biogas and gas derived from other organic residues.

10 After Byzio et al. (2002) joining forces in operator communities in order to realize renewable energy projects represent the beginning of a socio-ecologic innovation.

11 The number of wind business employees decreased from about 1,400 in 1995 to 1,200 in 1996 (Tacke 2004; Allnoch 1998). The sales volume in 1996 was about 25 % less compared to the year before (Tacke 2004).

12 § 35 para. 3 Federal Building Act contains a list of projects which are bound to be erected in non-urban areas (outside build-up areas). They receive permits as a matter of principle and therefore have a privileged status compared to other projects. For wind turbines in non-urban areas without zoning there was now a right to permits as a matter of principle, unless such permission stood against important public interests such as conservation, species preservation, recreation, or if the overall appearance of a landscape or townscape was at stake.

13 A change to the building legislation (§ 35 para. 3 Federal Building Act) containing the new regulations concerning the priority regulation for wind turbines did not come into force before 1 January 1997; see the following section.

14 Directive 2001/77/EC of the European Parliament and of the Council of 27 October 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market.

15 Directive 96/92/EC of the European Parliament and of the Council of 19 December 1996 concerning common rules for the internal market in electricity.

16 The EnWG, enacted in 1935, had preserved the monopolistic structure of the energy supply market until the late 1990ies.

17 Ruling of the European Court of Justice of 13 March 2001, case C-379/98, dispute between the utilities Preussenelectra AG and Schleswag AG.

18 See Section 3.4, footnote 14.

19 Also referred to as EEG 2000: Act granting priority to renewable energy sources (Erneuerbare-Energien-Gesetz - EEG), version of 29 April 2000, Federal Law Gazette I, p. 305.

20 The effects of the 'Renewable Energy Sources Act' are evaluated every 4 years. The results are reported in the 'EEG-Erfahrungsbericht'. This document is an important backbone for adapting the feed-in tariffs.

21 Repowering would also have a positive effect on land use, as the number of turbines would decrease (see Albers 2009). For a description of the potentials see Neddermann/ Schorer (2009).

22 For the reasons see Grunwald et al. (2005); (Deutsche Wind Guard 2005).

23 This regulation corresponded to the state of the technical development at that time; only five years later wind power plants reached heights up to 140 m.

24 Denmark, Netherlands, United Kingdom, Ireland; see COD (2005).

25 This decision was made due to the fact that large parts of the German coast of the North Sea and the Baltic Sea are under strong protection (e.g. the Wadden sea National Park) according to the national Federal Law on Nature Conservation (BNatSchG 2005; last amended in 2010).

26 For a description of the ecological research and monitoring programme at alpha ventus see http://www.alpha-ventus.de/index.php?id=56. The findings were and will successively be integrated into a concept for investigation standards (BSH 2002, 2007) issued by the Bundesamt für Seeschifffahrt und Hydrographie (BSH) which is the competent authority both for spatial planning and licensing of offshore wind farms.

27 However, social acceptance for offshore windfarms in the EEZ far from the coast can be presumed (See unpublished results from the ongoing project 'Acceptance of Offshore wind power', http://www.umweltpruefung.tu-berlin.de/v-menue/research/completed_projects/akzeptanz_der_off-shore-windenergienutzung/parameter/de/).

28 This is also the topic of the present research project "Impediments to increasing the share of renewable energies in the grid-connected energy supply in Germany" (http://www.umweltpruefung.tu-berlin.de/v-menue/research/current_projects/renet/parameter/en/) which discusses (among others) different options to enhance overlay grids, grid integration, energy storage and the establishment of smart grids).

29 BWE (Bundesverband WindEnergie)

30 The Ministry of Research and, from 2002 onwards, also the Ministry of Environment. The Ministry of Economics, originally being the competent ministry, played an antagonistic role by protecting the interests of the incumbent system. At present, the attitude towards the renewable energy sector changes gradually in view of the growing economic significance. Still, some criticism focuses on the rise of energy prices caused by the costs for the feed-in of renewable energies.

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