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The Expansion of Renewable Energies in Germany between Niche Dynamics and System Integration – Opportunities and Restraints

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Abstract

The main assumption is that the expansion of the renewable energies in Germany is not only the result of technical innovations, but also the outcome of specific social and institutional innovation processes. The article first examines the reasons for the increasing diffusion of renewable energies. Some attention will be directed to the relevance of political regulation and to actor networks, which have been important for the process of innovation. Secondly, the question will be discussed if there is another side to the rapid growth of the sector for renewable energies, in the sense of specific problems and ambivalent results caused by the growth. One example could be conflicts, which emerge from divergent interests of actors involved or from the risks of technological niche promotion. The third main topic takes as its point of departure the fact that the relationship between the "renewables" and the traditional industry of power generation was marked from the outset by competing paradigms. The renewable energies could at first only be propagated in small niches, which had to be protected by political regulation. The question will be discussed whether the increasing expansion of the niches causes growing problems with integrating the renewable energies into the given centralized electricity system and what kind of different interests and ideas about system integration have to be taken into consideration.

1 Introduction

Two different characteristics are significant for the German electricity sector. On the one hand there is the *traditional path* – with technical and economic structures that emerged at the beginning of the twentieth century and remained up to date in their substantial parts; but the importance of renewable energies is increasing. Until now the dominating paradigm has been that of a *centralised* generation and distribution of electricity within an interlocking technical system (Hoppe-Kilpper 2001; Leprich 2005). Market concentration is as well characteristic for the German electricity sector; an oligopoly of a few energy suppliers traditionally dominates the production and distribution of power. In spite of several "disturbances" the continuity of the traditional energy path remained steady in Germany. Neither the oil crisis of the 1970s and the growth-critical debates which followed nor the critical debates on nuclear power and on environmental protection caused ruptures, or even withdrawal, from centralised power generation on the basis of fossil and nuclear energy resources. The liberalization of the German electricity market, which dates back to the year 1998, even stabilized the process of economical concentration. Four suppliers were to remain dominating and a "duopoly" of two main suppliers is by now responsible for about 70 percent of the entire electricity production (Leprich 2005: 15-16). Considering their economic dominance, their organisational structures and their long-term investment strategies, there is much evidence that the major companies in the electricity sector will pursue their well-tried path in the future. Recently they announced to invest in new brown coal and hard coal power plants, which will be built in Germany in the years to come.[1]

On the other hand there is structural change and innovativeness of the German electricity sector, as the main perception is guided by the success story of the renewable energy sector. Here Germany is perceived as playing an internationally acknowledged "pioneering role": as the "world market leader" in the field of wind energy and as a member of the world wide top league for other types of renewable energy technologies, for instance solar cells (Reiche 2004: 189). The business strategies, especially those of the manufacturers of wind turbines and solar cells, have an international focus today – the industrial site Germany has become "a lead market for the renewables and a leader for technology and innovation in several fields" (BMU 2005: 9). The renewable energy sector takes a share of around 12 percent in German power generation by now. It therefore can no longer be assessed as economically insignificant. Thus, it became an expansive branch of economic activity, with total turnovers of 21.6 billion Euro in 2006 (BMU 2007: 6), meanwhile securing "significantly more" jobs (214000 in 2006) than "coal and nuclear power plants in all" (BMU 2005: 4; BMU 2007: 6).

The present article is based on empirical research performed at the Sociological Research Institute Göttingen (*Soziologisches Forschungsinstitut Göttingen, SOFI*). It concentrates on the development of the renewable energies in Germany[2]. The main assumption is that the expansion of the "renewables" is not only the result of technical innovations, but also the outcome of social and institutional innovation processes. Furthermore we con-

[1] The German news magazine DER SPIEGEL reports that the energy suppliers are planning to build 26 new coal power plants, with a total capacity of 25,500 Megawatt (DER SPIEGEL 12/2007: 43).

[2] The research project was financially supported by The Deutsche Forschungsgemeinschaft (DFG). The final report was completed in May 2007 and will be published within a short time in the Universitätsverlag Göttingen (Mautz/Byzio/Rosenbaum 2007).

ceptualize renewable energies as a *radical innovation*.[3] This assumption has to be substantiated, as biomass, water power and wind energy already constituted the energy basis of the pre-modern ages, and most of the modern technologies for using renewable energy sources were invented some decades before the 1970s. Hence it would seem inadequate, from a technological point of view, to describe the renewable energies as radical innovations. The innovation process rather has to be conceptualized as the rediscovering and further development of the above-mentioned technologies, embedded in new social contexts and linked to societal and environmental objectives of a wider range. From *this* point of view, the early process of innovation and diffusion of the renewable energies was – in Germany – to a high degree connected to the rise of the new social movements in the 1970s, especially the ecological and the alternative movement. At the beginning of this process we do not find radical technological innovations, but radical - and in part even utopian – new ideas and objectives, which resulted in a *reinterpretation* of established technologies. Following this conceptual focus our research underlines the relevance of social shaping of technological innovations and the importance deliberate agencies of collective actors play in this game.[4] Today and ever since, supporters and actors directly involved in the field of renewable energies try to enforce a radical *paradigm shift* in the energy system. The fundamental principles of the new paradigm are:

- Technical and economic decentralization of the energy production.
- Extension and pluralizing of the relevant groups of actors in the energy sector.
- Protection of the environment and climate as a guiding principle of action in the energy sector.

In the following stage, the article first tries to examine some important reasons, which played a major role for the increasing significance of the new paradigm, as indicated by the progressing diffusion of renewable energies in Germany. Some attention will be directed to the relevance of political regulation and its embeddedness in wider forms of governance. The analysis will further concentrate on actor networks and their relevance for the process of innovation and for the technological "path creation" within protected niches.[5]

The second section of the analysis concentrates on the question as to whether there is another side to the rapid growth of the renewable energies sector, in the sense of specific problems and ambivalent results caused by the growth. There is some evidence that the technical growth and the economic expansion of power generation based on renewable energies can be blocked or delayed by specific barriers of diffusion or by conflicts emerging from divergent interests of actors. Both factors lead to an increased demand of political steering in the field of renewable energies.

The third main topic takes as its point of departure the following question: Can one detect any growing problems with integrating the renewable energies into the given system of power generation and distribution? Ever since the relationship between the "renewables" and the traditional industry

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[3] The concept of *radical innovation* as a specific type of technological innovation is discussed, for instance, by Werle 2003: 6-16; Braun-Thürmann 2005: 42-51; Dolata 2007: 25-46.

[4] The "social construction of technology" approach is discussed, for instance, by Pinch/Bijker 1987; Hughes 1987; Rammert 1995; Weyer et al. 1997: 23-52; Ornetzeder 2000: 29-58; Degele 2002, 98-103; Meyer/Schubert 2007: 33-36; Rammert 2007: 37-46.

[5] For the concept of "path creation" see Ortmann 1997; Schreyögg/Sydow/ Koch 2003; Windeler 2003; Garud/Karnøe 2003; Meyer/Schubert 2007.

of power generation was marked by competing socio-technical paradigms. Taking the large companies' perspective, one can say the renewable energies were merely perceived as an alien element, compared to the dominant system. At first, the renewable energies could only be established in small technological niches, which had to be protected by political regulation. Political support and regulative protection are still necessary, but with the increasing expansion of the niche the question of integration became more acute. This is caused by growing incompatibilities between the existing centralized electricity systems on the one hand and the increasing number of decentralized and renewable power sources on the other.

2 Renewable energies – reasons for success

Most research, which focuses on the development of renewable energies in Germany, emphasizes the tremendous importance of political regulation as the driving force in this field (e.g. Heymann 1997; Lucke 2002; Umbach-Daniel 2002; Durstewitz/Hoppe-Kilpper/von Schwerin 2003; Jacobsson/Andersson/Bangens 2002; Jacobsson/Lauber 2006). This fact is little surprising, as researchers agree on the high impact governmental steering and regulation normally has on the opportunities and the restraints of environmental innovations (from the viewpoint of institutionalism theory in economics: Zimmermann et al. 1998; Linscheidt 1999; Hübner/Nill 2001; in the context of sociological analyses of technological environmental innovations: Huber 2004, 2005; from the viewpoint of studies on environmental and sustainability policy: Blazejczak et al. 1999; IÖW 2001; Jaenicke 2001; Coenen 2002). Examining the present success of renewable energies, some relevant studies do not only analyse the effects of specific key measures, like the Renewable Energy Law (Erneuerbare-Energien-Gesetz), but rather put a particular emphasis on the fact that "political patterns" (Hemmelskamp 1999; Blazejczak et al. 1999) or a broad "policy mix" have been created in this field of environmental and political action. The main elements of the "policy mix" are technology-specific feed-in-tariffs for the producers of electricity generated from renewable energy sources, financial support for R&D and for private investments in renewable energies (e.g. for house owners intending to install solar panels), and the implementation of appropriate instruments in the field of planning law (Reiche 2004; Reiche/Bechberger 2006b).

In terms of evolutionary theory of innovation, the political regulation has helped to generate and stabilize a *market niche* for renewable energies (Markard/Truffer 2006; Smith/Stirling/Berkhout 2005). Geels/Schot (2007: 400) describe such niches as "incubation rooms" for radical novelties. Niches are "protected spaces" to shield radical new technologies or experimental projects "from mainstream market selection" and to enable heterogeneous actors to cooperate in a new and innovative way. If successful, niches "provide locations for learning processes, e.g. about technical specifications, user preferences, public policies, symbolic meanings". Another important quality niches can provide is the possibility to force actors "to deviate from the rules in the existing regime" (Geels 2004: 912). Garud/Karnøe (2003: 281) consider the "process of mindful deviation" as a substantial condition for the emergence – respectively for the deliberate creation – of new technological paths. In the case of renewable energies the existence of a politically protected niche was – and is – an important prerequisite for the rise of a new socio-technical paradigm in the field of power generation and supply.

A considerable part of the relevant research nevertheless considers governmental regulation and promotion of the sector for renewable energies to be a necessary, but not sufficient, condition for successful diffusion processes.

First, there is much evidence that the political regulation of the energy sector is embedded in broader institutional changes, for instance changes of political main constellations on the national level or changes on the level of international institutions regulating environmental issues (Reiche/Bechberger 2006a, 2006b). Furthermore the interactions between political regulation and other social processes – like changing technical visions in society, the emergence of public debates on specific environmental issues or the integration of new social movements into society – call for careful consideration. From this point of view the governmental support for the renewable energies is as much the result of the political, economic and societal “institutionalization of environmental protection”, as it is a driving force for this process (Byzio/Mautz 2006: 67-68).

Second, most of the studies put emphasis not only on governmental actors, but they also try to include different types of non-governmental actors, which are involved in the process of adapting, disseminating or using renewable energies, in their analysis. Such an analytical focus can be useful to illustrate the limits of governmental means to act in the field of renewable energies. This sector of politics is regarded as a good example to depict the relevance of complex forms of governance, in which governmental steering is embedded. Some studies show that the development and success of socio-technical “niche regimes” (Smith/Stirling/Berkhout 2005) does not only depend on market protection by law and on appropriate financial incentives, but also on effective collaboration or interaction of different actors such as researchers, technicians, manufacturers of technical installations (e.g. wind turbines), different types of users, or protagonists of non-governmental organisations, for instance environmentalists, conservationists or citizen groups concerned with energy policy or with the promotion of renewable energies (Geels 2004). Jacobsson/Lauber (2006) focus on specific governance structures, which have been developed at an early stage of the “renewables” and which have been stabilized by positive feedback between several social actors. In the late 1980s protagonists of non-governmental organisations, the Green Party, citizen groups etc. and early economic actors in the field of renewable energies formed an advocacy coalition to put pressure on the government. One result was an incipient relationship and collaboration with some political protagonists involved in the milieu of environmentalists, who did not only support the expansion of renewable energies but also became an integral part of the advocacy coalition themselves. Such feedback – especially under the auspices of a federal government led by the red-green coalition (1998-2005) – was able to help to strengthen actor strategies. These strategies were aimed to create better political measures on one hand and better technical possibilities and economic conditions for the expanding renewable energy sector on the other.

The interaction between political regulation and various actors involved in this industry is related to another factor of success, which is still a driving force of innovation and sectoral growth in this field. The key phrase is “decentralized systems of diffusion”.

The rediscovering and early dissemination of renewable energies within the networks of the environmental or the alternative movement of the 1970s and 1980s already showed patterns of decentralized systems of diffusion, as examined by Rogers (1983). Later on – in the 1990s – these early systems of diffusion evolved into networks of innovation, which were still characterized by decentralized transfers of knowledge and experience – with decentralized “change agents” as a main driving force of the diffusion process. The Renewable Energy Law provided favourable conditions for the further differentiation and professionalization of innovation networks. These innovation networks provide opportunities of feedback between the operators and the manufacturers of power generation on the basis of renewable energies. While the operators do control the usefulness, the reliability or the safety of the applied technologies, the manufacturers are a main driving force of technical innovations. Under ideal circumstances such feedbacks lead to an upward spiral of "recursive innovations" (Kowol/Krohn 1995; Krohn 1997; Degele 1997; Degele 2002).

Examples, appropriate to illustrate the recursive innovations, which help to stabilize a newly created technological path, are *biogas power plants*. The development of this technology was initially characterized by the commitment of many non-professional change agents (e.g. students of agricultural science or members of the environmental movement). Today this is a field of activity for a multitude of professionals: besides planning companies and several manufacturers of biogas power plants (most of the manufacturing companies have been founded since the middle of the 1990s) representatives of professional associations (e.g. *Fachverband Biogas*), of regional farmer associations or of agricultural departments of the German federal states, are involved. Up to now, the power generating biogas technology has evolved, following a process of *learning by doing*. Farmers, the main operators of biogas power plants in Germany, play an important part in this process: Initially – due to a former lack of professional manufacturers in this field – some pioneers among the farmers built the first small biogas power plants in a do-it-yourself manner. Today farmers still contribute substantially to the improvement and the technical maturing of professionally constructed biogas plants (Mautz/Byzio/Rosenbaum 2007: 73-75).

In the sector of *wind power* generation, wind farm operators promote the steady advance of innovations in the field of wind turbine technology. This process is guided by the vast interest to obtain systematic know-how about material faults, about breakdowns of wind turbines etc.. Systematic reports on damage, prepared by the Federal Association of Wind Power (*Bundesverband WindEnergie, BWE*), and information pools on cases of damage have become important tools supporting recursive innovation in the sector of wind power. According to the wind farm operators' expectations, these tools lead to an increasing transparency concerning typical technical problems they have to deal with. Additionally, an increasing ability to solve those problems in cooperation with manufacturers and service companies is expected. And last but not least a generally strengthened position in the field of communication and bargaining with manufacturers or suppliers is hoped-for (Weinhold 2006).

Compared to the above-mentioned technologies, the *solar energy sector* still shows a remarkable coexistence of professional and non-professional change agents, for instance in the context of local actor networks. Here we often find craftsmen (e.g. plumbers or electricians), energy consultants, citizen groups committed to solar energy or representatives of the local government, collaborating to support the dissemination and use of solar energy. Innovative activities in this field are typically located within the "high tech" laboratories of the manufacturers of solar cells or solar panels; for instance innovations, which are aimed at more efficient use of material (e.g. thin layered solar cells) or at an increase of the total energy efficiency of solar panels. When the solar cell and, respectively, the photovoltaic technology, was invented in the 1950s the range of application was initially rather small. Until the 1970s photovoltaic cells were only used for spacecraft and for some niche applications (e.g. toy cars, watches)

(Grober 2004). Hence the pioneers of solar energy, who emerged in the 1970s and 1980s, had to open up new possibilities for using this technology. They soon concentrated their efforts on the problem of how to disseminate solar panels as roof installations among private users – at first especially among private home owners, later on also among citizen groups who were willing and able to buy joint solar panels, which had to be installed upon larger roofs (e.g. on top of churches, municipal buildings, trade buildings or apartment houses). This quest for applicable solutions had (and still has) an influence on the manufacturers of solar panels and the suppliers of specific components. One result was the development of weather proofed and more robust solar panels; another result is evidently to be found in the increasing efforts to improve the integration of solar panels into buildings (roofs and facades), for instance by using variable coloured solar panels or thinner and more flexible photovoltaic cells (Mautz/Byzio/Rosenbaum 2007: 75-76).

The positive impact of renewable energies on regional economics and labour markets is another factor, which helps to disseminate them. For this reason, numerous promoters from outside the branches of "renewables" (e.g. representatives of regional governments or trade-unionists) became interested in increasing the diffusion of these technologies. These promoters are now an integral part of the decentralized systems of diffusion, which serve to support and improve the effectiveness of governmental measures in the field of renewable energies. In sum, the political support of the "renewables" has been highly successful. The governmental regulation in this field – especially via the Renewable Energy Law – revealed innovative potentials and supportive capacities which already existed inside the social networks promoting renewable energies. As a result the diffusion of these technologies was accelerated – especially since 2000[6] – and the social range of those who are involved in the renewable energies sector became noticeably broader.[7]

3 Restraints and obstacles

However, there is some evidence that the diffusion of renewable energies – driven by social, institutional and technical innovations – is accompanied by ambivalent outcomes, which could conceivably restrict the further growth of this economic sector to a certain degree.

3.1 Renewable energies as a matter of conflict

First, we have an *increasing number of conflicts* accompanying the accelerated dissemination of renewable energies.

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[6] From 1999 to 2006 the number of wind turbines in Germany went up from about 8000 to nearly 19000; the installed capacity of all wind turbines was about 4200 megawatt in 1999 and increased up to nearly 21000 megawatt at the end of 2006 (www.wind-energie.de/de/statistiken/?type=55). In the same period the number of German biogas power plants went up from 850 to 3500; the installed capacity of biogas power plants increased from 50 megawatt in 1999 to about 1100 megawatt in 2006 (www.fachverband-biogas.de). In the same period the installed capacity of solar panels in Germany went up from 69.5 megawatt to about 2500 megawatt (www.solarwirtschaft.de).

[7] In the field of power generation based on renewable energies, we nowadays find a multitude of small and medium-sized businesses (e.g. companies operating wind farms, biogas power plants or large solar power plants), an increasing number of utilities which operate their own biomass power plants, thousands of farmers who operate their own wind turbines, biogas power plants and/or solar panels, citizen groups operating their own wind turbines or solar panels, an increasing number of home owners with a solar panel on the roof, and meanwhile some big energy suppliers who have already invested in (offshore-) wind farms or biomass power plants.

Indirectly, this is a result of the governmental support for the "renewables". The feed-in-tariffs guaranteed by the "Renewable Energy Law" are combined with technology-specific rates of digression,[8] which can be regarded as effective incentives for producers and operators to minimize their costs and to maximize the energetic efficiency of wind turbines, biogas power plants or solar panels (Nitsch et al. 2005). In addition to several other possibilities, one way of reducing costs is to *centralize* the power generation. Here, centralization means concentrating a large number of wind turbines in huge wind farms, building up extensive solar power plants consisting of hundreds (or thousands) of solar panels, or concentrating several biogas power plants in so-called "biogas parks". But, the renunciation from small and extremely decentralized units of power generation – which were the dominating technologies in the early years of the renewable energies – can lead to increasing problems of acceptance and to specific conflicts in the field of "renewables. Recently, there is a growing number of conflicts caused by large outdoor solar power plants (Janzing 2004, 2007), and in some German coast regions conflicts emerged, when the plans for huge offshore wind farms in the North Sea and the Baltic Sea were publicly announced (Byzio/Mautz/Rosenbaum 2005).

One important type of conflict caused by renewable energies can be described as a local or regional *clash of interests*, which often occurs in the case of competing interests with regard to the utilization of specific areas (onshore and offshore; see for instance the competing interests of offshore wind farm operators and the coastal tourism industry; Byzio/Mautz/Rosenbaum 2005: 63-80). In other cases *controversial risk perceptions* play a major role. The location of wind turbines in close proximity to residential areas, for instance, is regarded as a source of serious health problem by some people – an accusation normally rejected by wind farm operators. More generally: many people who live in the neighbourhood of wind farms, biogas power plants or large solar power plants fear a negative impact on their *quality of life*. In the case of wind turbines, for instance, people are strained by noise problems or by visual disturbances (e.g. by the so called "disco-effect" caused by the rotating wings). In the case of biogas power generators, people who live nearby often feel disturbed by the offensive smell. And large-scale outdoor solar power plants provoke some critics to complain about the disfigurement of the rural landscape (Janzing 2007). If such critical perceptions go hand in hand with concerns about the loss of property value in the vicinity of wind farms, biogas parks etc. conflicts can become even more explosive.

Last but not least, the expansion of renewable energies causes *conflicts within the ranks of the ecologist movement* itself. "Ecology" is open to various interpretations and to the establishing of different priorities. Wind turbines, solar panels or biogas power plants are "technology" and not "nature". Often they intervene in nature (e.g. disturbing birds and other animals or having negative effects on land- or seascapes) and therefore cause environmental "costs", which have to be balanced with the ecological benefits renewable energies can provide (Meyerhoff/Petschow 1999; Dehnhardt /Petschow 2004). The expansion of renewable energies has led to "inner-ecological" conflicts caused by the following guiding principles, which both play an important role within the ecologist movement. One guiding principle can be described as "ecological modernisation of the energy sector for the protection of the environment and the climate". The other guiding principle is "conservation for the benefit of

[8] Digression means that year by year feed-in-tariffs for *newly* installed wind turbines, solar panels etc. decrease at a fixed rate.

biodiversity and the protection of endangered species" (with regard to inner-ecological conflicts see Byzio /Mautz/Rosenbaum 2005: 108-165; Hirschl/Hoffmann/Wetzig 2004; Krewitt/Nitsch/Reinhardt 2004; Musiol 2004).

The conflicts described narrow the range of possible locations for power plants, which generate on the basis of renewable energies, and exert pressure on planning and operating companies. But, these conflicts are also integral parts of a *societal learning process*, which helps to find out about the opportunities and limits of a socially acceptable expansion of renewable energies. Doubtless, there will be no general solution, as the constellation of the conflicting parties and the actors involved can differ in every special case. However, it can be expected that experiences and learning processes of people, concerned about negative effects of renewable energies, will help to form general opinions with respect to the following questions: Under what circumstances is living in the neighbourhood of these technical artefacts unproblematic? Under what circumstances is it unacceptable? And what kind of solution should be taken into consideration in such a case? To some degree it will depend on the viability and transferability of solutions once found (e.g. compromises which are accepted by all sides) whether the future development of renewable energies will be strongly supported by politics and society, or not.[9] With regard to inner-ecological conflicts there are good chances to find "productive" solutions, for instance as a result of increasing mediation efforts within the environmentalist organizations, or as a result of learning processes, which are based on conflicts already resolved.[10] However, the large environmentalist' organizations still have to reconcile different preferences and guiding principles within their own ranks – it depends on one's point of view whether this fact should be regarded as a necessary corrective or as a serious obstacle to the "energy turn".

3.2 Structural restraints of diffusion

Second, there are some indications for *structural restraints of diffusion*, which could impede the dissemination of solar panels and of biogas power plants. The dissemination of solar panels for the most part still follows the paths of decentralized systems of diffusion, which took shape in the late 1980s. The efficiency of that kind of diffusion is illustrated by several regions with a higher-than-average rate of solar panels on the roofs. But there are enormous differences with regard to the regional distribution of solar panels. This indicates that successful diffusion of solar power in some regional strongholds (especially in Bavaria and Baden-Württemberg) cannot be transferred easily into other regions. Even today, it is less difficult to establish such a process in the social environment of a rural village than in an urban environment. Besides the fact that the rate of home owners is normally higher in small communities, compared to the big cities, there is some evidence that promoters of the "solar scene" or local opinion leaders generally meet with more response within the dense social networks and the face-to-face-relationships inside a rural village, than within the more anonymous and heterogeneous social environment of an urban area. In correspondence to this fact, our findings show a relatively slow-moving dis-

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9 For the analysis of conflict constellations, conflict dynamics and conflict solutions, especially in case of offshore wind farms see Byzio/Mautz/Rosenbaum 2005; Byzio/Mautz 2006. Typical conflicts caused by onshore wind farms are described in Byzio/Heine/Mautz 2000: 363-372; Scheer 1998; Franken 1998.

10 For the discussion and documentation on "productive" solutions of inner-ecological conflicts see "Ökologisches Wirtschaften" 5/2004.

semination of joint solar panels owned by citizen groups in some of the big German cities (Mautz/Byzio/Rosenbaum 2007: 101-102). Furthermore – with regard to the intensity of solar radiation – there is a significant "solar divide" between the south and the north of Germany. This has inevitable consequences for the average electricity production of solar panels and thus for the average feed-in-reimbursements the operators of solar power plants can expect. If the average incomes are low, as they are in several northern regions of Germany, it is rather difficult – but not impossible – to find prospective buyers of solar panels beyond the limited circles of "eco-idealists" or technology enthusiasts. Since there are higher rates of return in southern areas of Germany, there is a larger potential of mainly economically motivated buyers of solar panels compared to the north of Germany. This target group is indispensable, if recent expansion rates on the German photovoltaic market should be stabilized for the future (Mautz/Byzio/Rosenbaum 2007: 102). On account of rising prices for solar panels such a marketing strategy has become more difficult. In 2006 solar panel sales among German farmers – one of the most important groups of purchasers in this market section – decreased, because many farmers expected diminishing rates of return and therefore looked for better chances of investment (Rentzing 2006).

Similar to solar power the sector of *biogas power plants* – for the most part operated by farmers – has been booming since 2004.[11] But, with regard to considerably high investment sums for a biogas power plant and with regard to competences and working hours necessary for operating such a plant, the expansion of the biogas sector will possibly touch limits. Considering the different sizes and financial situations of farms and considering different qualifications, motivations and mentalities of their owners, only a limited number of farmers will presumably be able or willing to go into the production of biogas (Mautz/Byzio/Rosenbaum 2007: 103-104). Bensmann (2007: 53-55), who analyses the development of the biogas sector in 2006/2007, underlines the fact that farmers certainly are the main driving force in the present expansion of this sector of energy production, but he also states that "the group of individual farms, which are possible investors", has become "calculable" in the meantime.

3.3 The opportunities and risks of technological niche promotion

Third, it must be taken into consideration that the development of renewable energies has so far been, to a great extend, a *politically driven process*. Success or failure of the political regulation in this field depends much on the quality of legislative readjustments and the fine-tuning of governmental measures and instruments. The example of large-scale *outdoor solar power plants* shows that the constructional features of the Renewable Energy Law influence the ups and downs this important market segment has to face within the solar power sector. In 2004 the first amendment to this law was enacted, which raised the feed-in-tariffs for solar power significantly and thus led to a boom for photovoltaic panels in general, and for large-scale solar power plants in particular. To stimulate the increase of energetic efficiency the amendment prescribes comparatively large steps of digression for the feed-in-tariffs paid for outdoor solar power plants.[12] Due to the mode of digression

11 In 2004 the German parliament enacted an amendment of the Renewable Energy Law with raised feed-in-tariffs for electricity generated by photovoltaic panels and by biogas power plants.

12 In 2004 the feed-in-tariff, which will be paid for 20 years for solar power plants in outdoor areas, was 45.7 Cent. On January 1st 2005 the 20-year-long feed-in-tariff

a sudden boom in this market segment was followed by a significant slump in sales, intensified by a recent rise in prices for solar cells (Rentzing 2005a). Alternative strategies pursued by the companies involved are aimed at two different directions: Some companies try to intensify their activities in the realization of major projects abroad, for instance in southern European regions with a high degree of solar radiation. Other companies are increasingly interested in building large solar power plants on suitable roofs (e.g. on top of commercial or public buildings). The obvious reason for this strategy lies in the higher feed-in-tariffs for roof-based solar panels, if compared to the tariffs paid for outdoor solar power plants. But, "going onto the roofs" does not seem to be an altogether promising alternative: Many roofs do not meet the structural requirements for large solar power plants. Other projects fail, as the interest of the owners of municipal or commercial buildings lacks in this case (Rentzing 2005b).

The planned *offshore wind farms* in the North Sea and the Baltic Sea are further examples for the difficulties, which can arise if innovative technological niches are to be supported by legislative measures and readjustments. In the late 1990s, when the German federal government decided to promote offshore wind farms, appropriate incentives had to be offered to those wind power companies, which seemed to be ready to go into offshore projects. Besides special feed-in-tariffs the government gave the companies considerable room for manoeuvre to choose appropriate offshore locations for the planned wind farms. After the Renewable Energy Law had been passed in 2000, numerous licensing procedures for offshore wind farms were initiated (more than 30 until 2002). Until now a considerable number of applications has been granted by the responsible authorities. In 2004 the amendment of the Renewable Energy Law comprised a readjustment of the feed-in-tariffs for offshore wind farms. Now the companies could expect better payments for electricity from offshore wind farms, compared to the past.

But to this day, not any of the planned offshore projects has been realized – one reason for this is the fact that the governmental promotion of offshore wind farms led to some *unintended outcomes*. First, several of the planned offshore projects caused internal ecological disputes and met with opposition from conservationists who feared the increase of environmental stress for seabirds or sea mammals and a serious threat to the ecologically unique mud flats of the North Sea coast. Second, a multitude of people living on the North Sea islands or in the coastal area remained sceptical about the expected economic results an "offshore boom" might bring, especially with regard to the regional tourism and the regional fishing industries. Representatives of the tourist industry argued that offshore wind farms would chase away many guests and therefore cause serious problems for a region, whose economy is to a great extend dependent on an expanding tourist industry. Additionally, the fishermen expected a decrease of their own economic chances, if important fishing areas were to be occupied by large offshore wind farms. Thus, the situation in the coastal area was soon marked by conflicts between the promoters of offshore wind power on the one side, and the opponents of these projects (e.g. environmentalists, representatives of seaside resorts, fishermen) on the other side (Byzio/Mautz/Rosenbaum 2005: 91-107). A further need for legislative readjustments was determined: Due to the above-mentioned conflicts there were no realistic chances of building wind farms on less cost-intensive near-shore locations, at

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for newly built solar power plants in outdoor areas decreased by 5 percent; on January 1st 2006 it further decreased by 6.5 percent.

a maximum distance of 12 to 15 kilometres from the coastal line, as practised in Denmark and Sweden. Thus, most of the German offshore wind farms will be located far out in the open sea. Besides the fact that an appropriate and economical location for the projects was hard to find, the wind power companies also had to deal with rising prices for steel (which is needed in large quantities to build wind turbines). Only one year after the amendment of the Renewable Energy Law was enforced, representatives of the wind power industry called for further legislative readjustments. They argued, that the planned projects "could hardly be financed" on the basis of the present feed-in-tariffs (9.1 Cent/kWh) for offshore wind farms (Lönker 2005: 12). A further legislative readjustment followed in autumn 2006: The German net operators were bound by law to assume the costs for the main connection of offshore wind farms. Consequently there are increasing expectations within the ranks of the wind power industry that the profitability of offshore projects could now be achieved (Bauchmüller 2006).

The above-mentioned cases of outdoor solar power plants and offshore wind farms underline the fact that governmental promotion of innovative niches opens up new possibilities for environmental technologies, but also entails some risks – especially the risk to fail in pushing forward a new technology, which could achieve a real deduction and full marketability. To minimize this risk appropriate readjustments of the political measures and instruments are necessary – as exemplified by the gradual improvements of financial conditions for offshore wind farm operators. Nevertheless, political protagonists are caught in a *dilemma*: The strategy of continuous improvement in favour of a specific technology (e.g. by measures of financial or legal support), which up to now has been very successful in the case of the "renewables", can mutate into false political steering, if the "endogenous potential" of a new technology turns out to be overestimated.[13] Hence, one cannot exclude that the political promotion of certain technologies in the field of renewable energies – contrary to the intentions of the Renewable Energy Law – could end up in an enduring "subsidies trap".

4 The integration of renewable energies into the electricity system

As long as renewable energies only contributed a rather marginal part to the power generation as a whole, the question of how to integrate small, decentralized and (in the case of wind turbines and solar panels) intermittent[14] power sources into the given electricity system was considered of secondary importance. With the accelerated expansion of the renewable energies this question has become more urgent recently. Incompatibilities between this new sector of power generation and the established system of power supply will probably increase and become a serious obstacle for the further dissemination of the "renewables". Meanwhile several authors who contribute to the debate on climate change and the "energy turn" under-

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13 This problem is discussed by Huber focusing on concepts of political support for technological environmental innovations: "With new technological regimes it is in principle much the same as with newly industrialising nations. If there is not enough endogenous potential, an artificially levelled playing field can even be counter-productive in that it pushes or conserves inefficient and unconnective structures" (Huber 2004: 237).

14 "Intermittent" means that wind turbines or solar panels are technologies of variable output: The changing wind forces or calms are not exactly foreseeable and have a direct impact on the generation of wind power. Solar panels generate electricity only by day; in the course of the year solar power production is at maximum during the summer and at minimum in wintertime.

line the importance of optimizing the integration of decentralized power sources (on the basis of renewable energies or high-efficiency combined combustion of heat and power) into the electricity system (Jochum/Pfaffenberger 2006: 24; Bauknecht et al. 2006: 260; Hennicke/Müller 2006: 144). On the one hand this discussion has a far-reaching "visionary" aspect, aimed at a completely decentralized system of power generation and distribution. From this point of view, according to the new socio-technical paradigm for the energy system, only a relatively small market niche for centralized power plants, which operate on the basis of fossil energy, will finally be left (Leprich 2005: 16).

On the other hand the present debate on system integration has a pragmatic aspect, as the expansion of renewable energies actually puts pressure on a multitude of actors – in the fields of the "renewables" and of the conventional electricity system – prompting them to enforce the integration of decentralized power sources into the system of electricity supply. The principle of "priority-dispatch" made the process of power balancing in the electricity system even more difficult.[15] "Priority-dispatch" is regulated by the Renewable Energy Law and normally opens up possibilities for wind farm operators, owners of biogas or solar power plants etc. to generate and feed in electricity, irrespective of the present demand for power or of changing grid situations. But, with regard to state-of-the-art technologies in the field of renewable energies, an increasing number of currently active operators (especially operators of large wind farms) could contribute to power balancing, for instance by selling electricity on the balance market, where short-term power reserves are traded at relatively high prices. This requires the foregoing priority dispatch as a general principle for renewable power sources, because "upwards control" of power balancing – in the case of wind power – can only "be provided by partly curtailed wind farm generation, kept within a predefined capacity band and made available within seconds" (EWEA 2005: 101). Under ideal conditions, solutions which help to improve the system integration of renewable energies could become attractive to the actors involved – on the part of grid operators *and* on the part of power plant operators in the field of renewable energies (Leprich et al. 2005; Bauknecht et al. 2006). But currently, the possible solutions are controversial: Appropriate solutions have to be adjusted to two competing socio-technological systems, which coexisted fairly peacefully as long as power from renewable energies was produced in a small niche. The expansion of the "renewables" certainly requires new ways to achieve better system integration, but the corresponding technical or organisational solutions can cause specific transaction costs and economic risks, especially for operators of small and decentralized power plants (Bauknecht et al. 2006).

A present-day example to illustrate this would be the active wind farm power control (*Erzeugungsmanagement*), which is practised by grid operators in some North German regions to prevent temporary overloading of lines and to better adjust the regional wind power generation to the actual demand. But, wind farm power control has often become a matter of conflict: On the one hand grid operators are interested in the most effective use, technically and economically, of the power grid; on the other hand wind farm operators are interested in keeping losses of feed-in payments as low as possible. The

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15 "In power systems, the power balance between generation and consumption must be continuously maintained. The essential parameter in controlling the energy balance in the system is the system frequency. If generation exceeds consumption, the frequency rises; if consumption exceeds generation, the frequency falls. Ultimately, it is the responsibility of the system operator to ensure that the power balance is maintained at all times" (EWEA 2005: 71).

German wind energy branch has repeatedly complained about reduced incomes of millions of Euros, as grid operators occasionally scaled down the output of wind farms or temporarily disconnected a considerable number of wind turbines from the power grid (Schäfermeier 2006; Pries 2006). Several of these conflicts have ended up in court by now, for instance in the case of controversies about the legality of scaling down wind farm outputs, or in the case of disputes about financial compensations for reduced feed-in payments. Using legal pressure as an instrument, the wind energy branch wants to force the large energy suppliers to optimize or extend their power grids. This is for the sake of expanding amounts of wind power to be transmitted in the future.

The increasing controversies about wind farm power control led to the result that some protagonists in the wind energy sector try to push forward an alternative solution (of which a pioneering project has already been realized in the north east of Brandenburg): the linkage of several wind farms by means of appropriate power lines, which are property of the wind farm operators themselves. The declared objectives pursued by promoters of such "networked power plants" (*vernetzte Kraftwerke*) are independence from the established grid operators, and provision of a steadier and more reliable supply of wind power (Lönker 2006). If such pioneering projects set a precedent and can help to further stabilize the wind energy path in Germany will depend on gaining political support for this kind of innovation, for instance via financial incentives for networking activities of wind farm operators or wind power companies.

From a more principle-rooted perspective, political regulation which aims at a better system integration has to deal with different challenges, compared to those of governmental support for niche technologies in the field of renewable energies. To support system integration governmental regulation will be dependent on governance structures, which also have to embrace relevant protagonists of the dominating electricity system, for instance the large energy supply companies and grid operators – along with their economic interests and their instruments of economic power. Political support could certainly serve to reduce structural divisions between the conventional and the renewable electricity sector and could help to open up new ways of diffusion for the "renewables". But, the question is if this will lead to sufficient willingness or ability to cooperate, on the part of both the established and the new actors in the electricity system. The chances of efficient cooperation must not be considered as being all that favourable if one follows Reiche (2004: 139-144) and the advocacy-coalition approach he applies. Besides economically caused conflicts of interest, Reiche also describes a socio-cultural divide between the oligopoly of the large power suppliers (who are the main owners of the power grid) and the promoters of renewable energies. He underlines a far-reaching controversy between two "belief systems", which has characterized the German energy policy and energy industry since the 1990s. One belief system – socially and politically connected to an "ecological coalition" – is based on the premise that for the benefit of environmental and climate protection all renewable energy sources available have to be promoted by the government. The other belief system – supported by an "economic coalition" – is based on the premise that ecological modernization of the energy system primarily has to correspond with economic efficiency and competitiveness. Therefore only technologies with a high potential of efficiency and marketability should be promoted in the field of renewable energies (Reiche 2004: 140).

The ideas about system integration might correspond with quite different strategies and political measures, as they depend on the different premises.

From the standpoint of the "ecological" belief system an appropriate integration of renewable energies will require a far-reaching conversion of the existing power supply system and power grid, aimed to better technically fit in decentralized and partly intermittent power sources, which in the end will increasingly replace centralized power plants. From the point of view of the "economic" belief system renewable power sources are useful as long as they fit into the centralized system of the conventional power sector and as long as they are able to compete on the general electricity market, at least in the medium term.

The controversial debate about the integration of renewable energies into the electricity system reproduces the rivalry of paradigms, which already left its mark on the German electricity sector since the early confrontations between the pioneers of renewable energies and the large energy companies. If the German government sticks to the broad promotion and the financial support of renewable energies in the future, the pressing issue of *system integration* will sooner or later – after an essential phase of technological *niche promotion* – require a further landmark decision in energy and environmental policy.

5 Conclusion

Since the (re-)discovering of renewable energies in the 1970s, the German electricity system has passed through a transformation process, which is described here as a confrontation of two competing socio-technical paradigms. In the course of this confrontation the "renewables" have become a serious challenge for the traditional German electricity sector. Its protagonists formed the fundamental principles of the new paradigm – decentralization of energy production, pluralizing of the relevant groups of actors, environmental and climate protection – taking a way of deliberate dissociation from the given energy system; thus they became the main attributes of a radical innovation in the electricity sector. The development of decentralized governance structures, including a wide range of non-governmental organisations and citizen groups, enduring governmental promotion, a supporting legal framework, and a partly close feedback between the operators of renewable power generation and the manufacturers, were important reasons for accelerated niche dynamics and the dissemination of renewable energies.

Despite the remarkable expansion of the renewable energy branch in recent years, the traditional electricity sector still remains the dominant economical and technological force in the field of power generation and distribution, showing strategies which aim at a (re-)stabilization and long term maintenance of the traditional energy path – on the predominate basis of fossil and nuclear energy resources. Moreover, the protagonists of renewable energies are confronted with some *new challenges*, as the former clear-cut profile of the new socio-technical paradigm meanwhile has become more or less diffuse. *First*, there is a tendency in the renewable energy sector towards larger technical units and towards centralization of power generation. *Second*, the expansion and centralization of renewable power generation causes increasing environmental costs. This often leads to opposition by people living in close proximity to wind farms, outdoor solar energy plants etc. and furthermore gives rise to conflicts within the ranks of the ecological movement itself. *Third*, with the increasing amount of electricity produced by the "renewables" it has become more and more clear that the legally guaranteed "priority-dispatch" – and so climate protection as a fundamental principle of alternative power generation – can only be maintained as far as the protagonists of the renewable energy sector themselves will serve to achieve a better system integration of renewable power sources, and do not leave this task to the large electricity suppliers.

The transformation of the German electricity sector is not completed. In the course of this process the principles of the alternative paradigm have been modified significantly. As a result there is more than one option for the further development of renewable energies. On the one hand the *new openness*, regarding fundamental principles, could give a fresh impetus to the further expansion of renewable energies by attracting a wider range of actors (for instance investors, innovative companies, municipalities) to join this ecological *and* economical relevant industrial sector. On the other hand this openness could reinforce an already perceptible tendency of splitting up relevant actor strategies, regarding the problem of optimal system integration of renewable power sources or regarding the question if a more centralized or a consequently decentralized way of diffusion of the "renewables" should be preferred.

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