The Transformation of the German Electricity Sector: Neither Abrupt Change nor Continuous Path

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1. Introduction

The question as to which possibilities exist for a low carbon energy supply is closely interconnected to the requirements to be met for sectoral change. The German electricity sector is a complex infrastructural system, which like telecommunications or public transport systems decisively shaped the sociotechnical development of industrial societies throughout the 20th century. Over a long period of time, these infrastructural systems were characterised, not only in Germany, by their stability – stability in terms of technical structures, sectoral enterprise and the cognitive and normative rules necessary to maintain the system. The starting point for such systems were innovations that brought forward something radically new, but once the system had consolidated itself and turned into an infrastructural necessity for society, it appeared to be an immobile dinosaur, incapable of undergoing *fundamental* changes on its own.

Research has shown that large technical systems such as the electricity supply normally show a tendency to stabilize through permanent growth. For technical, economic, knowledge and power-based reasons, they develop a kind of "momentum" (Hughes 2009/1994), which is self-enhancing, difficult to reverse and which forces the systems to a form of incremental change which could be called "upward transformation" (*Aufwärtsformation*). The term refers back to the German sociologists Bernward Joerges, Ingo Braun and Johannes Weyer. Their basic assumption is that forms of linear system growth (through spatial expansion of the technical infrastructure, through increase in the number of participants etc.) reach technical or economic limitations relatively soon. The system slips into a state of *internal* pressure –

further growth depends on the ability to diagnose and solve newly arising problems, for example intra-system frictions and functional flaws (Weyer 1994: 332-366).

Upward transformation aims at enabling the further growth of large technical systems through qualitative 'upgrading', thus stabilizing their key structures and securing their longer term existence through improvement innovations.[1]

Finally, the interaction with the social environment, typical for large expanding technical systems, also had a stabilizing effect: Thus, the electricity systems emerging in the 20th century had the structural property of penetrating not only the economic exchange relations but also everyday life. The pervasive supply of households with electricity has substantially changed lifestyles and structures of consumption – whereby the change in styles of consumption towards an increased use of electricity retroacted to stabilize the electricity system (Hughes 1987). In principle, this nexus still exists today: According to the German Federal Environmental Agency (*Umweltbundesamt*), the increase in technical efficiency is not sufficient to compensate for the increase in energy consumption triggered by growing demand, the general expansion of living space and the increase of electrical equipment in German households. The Agency's conclusion: The decoupling of consumption and the demand for energy still has not happened (Umweltbundesamt 2006: 9).

Joachim Radkau, an expert in the history of technology, has been tracing the development of the German electricity system, which for many decades has been characterised by its high degree of path continuity. The main features of the German electricity sector were already established in the aftermath of the First World War. Germany at first took a special path, whereas other European countries followed only later. Radkau describes the emergence in the early 1920s of a coalition comprising German politicians and representatives of the energy sector which pressed ahead with the centralisation of power generation in big block-unit power stations, and secured political backup for the regional monopolies of a few big electricity companies. Under the Nazis, this supply structure was legally secured by the Energy Industry Act (*Energiewirtschaftsgesetz*) of 1935. After the Second World War, this combination of centralised technical structures and a power market characterised by an

[1] "The switch of the electricity systems to alternating current as upward transformation case has been well documented by historians of technology" (Joerges/Braun 1994: 33). With the advance of alternating current at the beginning of the 20th century, which was better suited for the long-range transport of electricity, the remaining direct current components became problematic and a nuisance factor for the existing system. Only the complete switch to alternating current components enabled the expansion of today's electricity system.

oligopoly was retained (Radkau 2008: 308-313). Right up to today, this market-dominating position of a few big electricity companies is still very much in place.

However, since the last decades of the 20th century, the big infrastructural systems, including the German electricity sector, have been confronted with new challenges – challenges that increasingly call the system's stability into question:

Firstly, the political challenge, best described as "liberalisation": The shift of formerly monopolist companies under state control into the market and competition, e.g. by privatisation and the dissolution of enterprises or through the deregulation and new regulation of markets.

Secondly, the challenge posed by new technologies: The key technologies as driving forces for sociotechnical change here are microelectronics and the new information technologies.

Thirdly, the ecological challenge: Environmental risks caused by large technical systems have become a topic of public discussion and political intervention.

It goes without saying that these challenges are of varying relevance to the different infrastructural systems and so far have had quite different effects. The measures of liberalisation taken in Germany have to date contributed to a further strengthening of the big electricity companies. The pressures exerted on the traditional electricity system derive from the challenge posed by an ample "ecological coalition" in politics and society as well as by the dynamics of technological niches. The following chapters elaborate on the nature of these challenges, especially with an eye to the niche expansion of renewable energies (chapter 2). Afterwards we will state the reasons why from a sociological perspective this development should not (any longer) be interpreted as a confrontation between *internal* forces of continuance and *external* forces of change but rather as an interplay between the dynamics of niches and changes on the system level (chapter 3). The different strategies of change within the German electricity sector serve as an example to clarify this point (chapter 4). Finally we will discuss the question of whether the German electricity system is on its way to a new "dominant design" and try to name the issues which will have to be tackled by further research.

2. Renewable energies as a challenge to the German electricity system

At first view the electricity sector seems to have remained relatively unaffected by the phase of 'postfordist' restructuring.[2] So far, the liberalisation of the electricity market, which began in 1998, has not led to a break-up of the oligopolistic structure of the German electricity industry. Instead, favoured by mergers, the power sector consolidated itself. As a result the German electricity market is now dominated by four big companies. Nevertheless liberalisation did lead to some structural changes: *Firstly*, since 2005, when a new regulating authority was set up, the conditions for grid use by independent electricity suppliers have improved. Moreover, the start in 2009 of an incentive regulation (*Anreizregulierung*), oriented towards more efficiency, is intended to lower the costs of grid use und to intensify competition among network operators. However, a complete unbundling of electricity producers and network operators has not yet happened. *Secondly*, the big electricity producers have expanded their room for manoeuvre in order to act in a more market-oriented fashion and to follow a strategy of profit maximisation oriented towards shareholder value: Especially Eon and RWE have turned to an internationalisation of their value-added chains and are meanwhile strongly involved in the European electricity market. At the same time, a market-oriented restructuring of companies took place, e. g. by a stronger concentration on core competences in the electricity and gas business, through strategic acquisitions and interests in other companies and the establishment of affiliated firms at home and abroad. However, so far the outlined developments have had little effect on the dominant design of the German electricity system: a centralised combined system dominated by a few corporations, resting on a fossil-atomic basis.

All this seems to indicate that the traditional path of the German electricity sector shows an astonishing continuity. However, on closer examination, we see that this picture is incomplete. Over the last two decades, the German generation of current is undergoing a remarkable structural change and has initiated some basic innovations. Above all, this concerns the increasing generation of current by means of *renewable energies*: Whereas in 1990 the latter had a share of just 3.5 percent of the German electricity consumption, by 2008 this share had risen to 15.1 percent (BMU 2009: 16). According to the plans of the new conservative-liberal government, the share of renewable energies will rise to 30 percent by

[2] For the changes taking place in the German social and economical system since the 1980s cf. Streeck 2009; Berghahn/Vitols 2006.

2020 and will, in the long run, account for the lion's share of energy supply.[3] From 2003 to 2008, the renewable energies industry (including the sectors of heat supply and transportation) has had annual growth rates of more than 35 percent, and in 2008 had a total turnover of around 28.8 bn. EUR with a workforce of ca. 278.000 employees (BMU 2009: 30-31).

This sectoral change has its origins, among others, in the socio-cultural upheavals within German society, running parallel to the beginning erosion of the 'fordist' mode of production (based on industrial mass production), and in a certain sense also contributed to this erosion process. In the 1970s, following the students' movement of 1968, the rise of the "new social movements" was accompanied by the emergence of a relatively broad ecological and anti-nuclear power movement, criticising the environmental risks involved in the production and consumption patterns of industrialised society. The change towards an energy supply based on renewable energies was seen as one of the most important solutions and one began to actively work towards such a change.

Looking back to the beginnings of this process, we see that it was not triggered by new technical inventions but rather by environmental and socio-political blueprints and utopias, developed in the context of the new social movements. It was basically a matter of a reinterpretation and reactivation of already known technologies (e.g. wind turbines, biogas plants, photovoltaic cells etc.) from a new perspective and within new social contexts. To put it another way: This was the *social construction* of a radical technological innovation which – for the time being – could only be adapted and spread *outside* the traditional electricity sector. The initiators of this development, stemming from the ecological-alternative *milieu*, were not only thinking in terms of energy and environmental policies, they also had socio-political objectives: aiming at a comprehensive decentralisation and democratisation of social and economical structures (well beyond the energy supply). Technology in the sense of "alternative technology" (Dickson 1978) had explicit political connotations and was perceived as an inseparable component and integral part of a fundamental reform of society.

What emerged during this discourse about alternative energy was a fundamental counter-project concerning the energy economy, i.e. the attempt, to initiate a *paradigm shift* of the energy system. This counter-project comprised the following three dimensions (Mautz et al. 2008: 18-19):

[3] As stated in the coalition agreement between CDU/CSU and FDP.

Technical structure: The centralised system of electricity generation and distribution based on large fossil and atomic power stations was confronted with the principle of decentralised structures of generation and distribution based on renewable energies as well as on small or medium-sized production units.
Structure of participants: Instead of the oligopolistic structure of the established electricity industry for the regenerative energy sector one envisaged a pluralised structure of electricity producers, independent of the existing electricity companies.
Central theme: Whereas in the traditional electricity industry the idea of a reliable and cheap electricity supply occupied centre stage the question of energy was now seen from an ecological perspective. Now risk avoidance and preservation of nature by means of renewable energies were given priority.

What followed – from the mid-80s onwards – was a development which from the perspective of evolutionary innovation theories can be conceptualised as technological niche dynamics. Within the field of research concerned with the evolution of technology these technological niches are seen as areas of "incubation rooms" for radical innovations (Geels/Schot 2007: 400) and thus as a favourable setting for the emergence – resp. the intentional creation – of new technological paths (Garud/Karnoe 2003: 281). The fact that in the case of renewable energies the early experiments did not fizzle out, but rather led to a remarkable niche dynamic and niche expansion, was due to the interplay of several factors.

2.1. Emergence of decentralised systems of diffusion

The rediscovery 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 decentralised 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 characterised by decentralised transfers of knowledge and experience – with decentralised 'change agents' as a main driving force of the diffusion process. These networks provided opportunities of feedback between the operators and the manufacturers of power generation on the basis of renewable energies. While the operators did control the usefulness, the reliability or the safety of the newly applied technologies, the manufacturers became a main driving force of technical innovations. Under ideal circumstances such feedbacks led to an

upward spiral of “recursive innovations” (for some examples, appropriate to illustrate the recursive innovations in the biogas, the wind power and the solar energy sector, see Mautz 2007: 118-119; Mautz et al. 2008: 72-77). With the development of decentralised diffusion systems not only the learning curves accelerated, but the social basis of alternative electricity producers broadened as well. In this context, an important role was played by groups from civil society: Thus the dissemination of wind power was at first promoted by such groups before from the mid-90s onwards professional start ups (as planning, operator or investment companies) began to dominate the further developments within the German wind energy sector. Alongside numerable small and medium-sized enterprises, the activities of civil society in hundreds of projects are contributing significantly to the growth of the solar energy sector. And last but not least, the new decentralised electricity producers include a significant number of farmers. They are the most important operators of – meanwhile more than four thousand – biogas plants und one of the most important groups operating solar power plants.

2.2. A politically protected niche

Special promotional programmes as well as the statutory feed-in compensation for regenerative electricity make sure that the renewable energies are protected against market forces until they reach complete marketability. The coming about of such a subsidies policy with its incentives for alternative electricity producers was also a consequence of specific feedbacks between niche operators and politicians, in the sense of advocacy coalitions, formed by protagonists of renewable energies together with environmental politicians (Jacobsson/Lauber 2006: 266-269). In a study of our own, we have investigated the development of local governance structures that evolved as a result of successful feedbacks between protagonists (mainly from civil society) of the use of solar energy on the one hand and local politicians on the other. In the course of bottom-up processes solar technology was introduced in several municipalities and regions, especially in the South of Germany. Moreover, this approach also served to figure out – initially on a municipal level - the necessary promotional frame of a cost-covering feed-in compensation for solar power and by doing so to prepare legal regulations on a federal level (Mautz et al. 2008: 78).

2.3. A changed mode of regulation in energy politics

In Germany public regulation has always played a crucial role in the development of the electricity sector (see above). In the case of renewable energies, however, we are not talking about monopolies of production and distribution protected by the state. The issues here are primarily the promotion of technology, the goals of climate protection and structural changes of the regional economy, especially since the commencement of the Renewable Energies Act in the year 2000. Due to the liberalisation of the European electricity market at the beginning of the 1990s the actors of the power sector see themselves confronted with a new framework – well beyond specific regulations on a national level. That does not mean, however, that a liberalised electricity market *per se* offers favourable conditions for the development of technological niches. Deregulation can rather lead to a widening of strategic options on the side of the big electricity producers – as happened in Germany – so that they can even expand their market-dominating positions (see above). Even under the auspices of liberalisation alternative technologies can assert themselves more forcefully, if there is a suitable regulatory framework to enhance their market potential – e.g. through fair access regulations for decentralised power plants, through incentives for network operators to promote decentralised electricity feed-in, through long-term guaranteed feed-in compensations for renewable energies etc. (Praetorius et. al. 2009: 191-226).

2.4. Adaptability towards external developments in technology

The German renewable energies sector not only shows learning curves in its technical key sector, e.g. continual improvements of energy efficiency in wind energy, biogas and solar technology. In addition, within the last years, innovations have been promoted in this sector also based on the adaption of external technology developments in the IT sector with the aim of improving the market position of alternative electricity producers. The background to this development were technical problems regarding system integration which increase when the share of fluctuating electricity feed-in from wind and solar energy plants rises. In order to avoid this leading to a delay in the further expansion of regenerative electricity or to an impediment in certain regions quite a number of protagonists from the renewable energies sector are pushing an innovation, the combined renewable power station, partly in cooperation with scientific institutes, municipal utilities or network operators. The basic idea behind this is the connectivity and central control of many decentralised power sources from wind energy,

photovoltaic and biogas plants (into so called “virtual power plants”) in order to steady the power input and to adapt it to the consumption curve. Apart from creating an integrated grid this is also intended to advance the market integration of renewable electricity. As the electricity from combined renewable power stations can be delivered reliably and predictably it is also suitable for sale at the current exchange. The incentive for the operators of “virtual power plants” is that at the current exchange they can reckon with higher revenues for their electricity than they would get from the legal feed-in compensation. All things considered, the connectivity and market integration of renewable energies made possible by information technology creates the conditions for the integration and consumption of ever greater capacities of renewable power within the grid. Therefore, it is an important step towards the intended dominance of renewable energies within the future power supply.

3. Renewable energies and the electricity system: Integration or system change?

The relation between the renewable energies sector and the traditional German electricity system betrays a specific ambivalence. As shown above, right from the start the protagonists of renewable energies were striving for a paradigm shift in the course of which the centralised system of electricity production, relying on fossil and atomic energy sources, would be overcome. However, from the perspective of the traditional electricity supply system and its main actors the new electricity producers represented an alien force which they at first perceived as an external threat. Under the auspices of a paradigmatic competition ‘old’ and ‘new’ electricity producers faced each other as opponents, separated by a gulf - not only in terms of energy policy but also ideologically and socio-cultural. However, from an early stage there was an interface which demanded a durable linking up of the ‘renewables’ with the existing electricity grid: As far back as the 1980s the pioneers of renewable electricity production had, for reasons of practicability, decided themselves against a radical island solution of a self supply with electricity but rather for a feed-in of their self-produced power into the mains. This strategy corresponded with the layout of the emerging state funding for renewable energies which provided state subsidies for the feed-in of electricity into the general grid.

The decision for a linking up of renewable energies was one of the preconditions for the subsequent growth of the renewable energies sector and at the same time constituted the starting point of a development in the course of which the character of the originally

externally caused challenge changed substantially. The impulses emanating from the renewable energies can by now be partially *internalised* by the established electricity sector without losing their essential potential for change in the process (see below).

This development has consequences, not least for the sociologist's perspective, because it means that the changes within the German electricity sector triggered by the renewable energies can no longer sufficiently be decoded as a confrontation between *internal* forces of stabilisation and *external* forces of radical change, as was the case during the pioneering phase of renewable electricity.

Recent sociological approaches, concerned with the stabilising and destabilising factors of sociotechnical systems, have dropped the polarisation of internal forces of continuance und external causes of a (radical) change of system in favour of a stronger emphasis on the *interaction* between niche dynamics and developments on the level of sociotechnical regimes. Conceptually based on a multi-level approach of sociotechnical transitions which beside the niche and regime level, also takes into account the macro level of the social "landscape", Schot/Geels (2008: 547) draw the conclusion that "niche innovations thus need not always compete with and substitute the prevailing regime, as was assumed in earlier SNM (strategic niche management) work. They may also be incorporated and transform the regime from within". According to them, what we are dealing with here are "co-evolution patterns" for which it was typical that "the dynamic is less about substitution and more about how niches can branch, pile up, and contribute to changes in the behaviour, practices and routines of existing regime actors". In short: as a consequence of these findings, not only "a more differentiated view of niche-regime interaction" developed, but also "a fruitful terrain for further research."

An example for "a more differentiated view" is given by Geels/Schot (2007), presenting different forms of niche-regime interaction based on a variety of "sociotechnical transition pathways". Thus, the type of *incremental change* is not limited to the successful adaption of single niche innovations by a stable sociotechnical regime. In a different variant the new technological challenges trigger a gradual, but in the end far-reaching reconstruction of sociotechnical system architectures. *Radical transitions* do not necessarily occur as a result of swift substitutions, old technology being replaced by new technology. The challenges posed by niches, on the one hand, and macro-structural changes on the "landscape" level, on the

other, can also manifest itself as a gradual but far reaching process of erosion on the side of the dominant regime. In their investigation of the conditions of sectoral change, Dolata/Werle (2007: 34-35) argue in a similar fashion. According to them the use of “dichotomous typifications”, which only distinguish between long periods of stability and rare incidents of radical upheaval, triggered by “exogenous shocks”, turns out to be an inappropriate tool for analysis. Much more typical are “gradual transformations” through processes of incremental restructuring and adaption. As a consequence of accumulating effects they could well lead to “entirely new system architectures” und therefore to a similarly strong pressure for change, as it is mostly assigned to external shocks. Moreover, because of the pressure for innovation exerted by “new cross-section technologies” (e.g. microelectronics or new information technologies) a lasting closure of sectors is less likely today than in earlier phases of sociotechnical development (Dolata: 2008). Such a process of gradual transformation can hardly be attributed to forces which are unambiguously external or equally unambiguously internal to the system. It is much more plausible to assume an interplay of endogenous processes, carried out and promoted by actors from within the system as well as by new external actors, forcing their way into the system with different orientations (Dolata 2008: 56).

Such a transformation, distinguished by interaction rather than by polarity, appears to be characteristic of the present German electricity sector. Actually, several restructuring perspectives are competing with each other: In various mixtures, they contain strategic elements of system integration of renewable energies and of system change by way of renewable energies. In any case, they can only insufficiently be described by the dichotomy “incremental change versus radical transformation”.

4. Perspectives of change within the German electricity sector

4.1 The integration perspective of the electric power companies

As shown above, the German electric power companies have used the liberalisation of the German and European electricity markets for strategic reorientations and internal restructurings. Part of this new orientation is a change of strategy regarding renewable energies: After a long period of resistance, all major power companies are now participating in the expansion of the renewable power generation. They took this step not least in order to

influence the direction of development in the renewable energies sector and (by doing so) to secure the dominance of fossil and atomic energy sources in the future.[4] In case of success, this would mean that a formerly external 'disturbance' has been used as an opportunity for incremental change and a stabilising of the system. The step into renewable energies also helps the big power companies to counteract their negative image as 'climate sinners' (*Klimasünder*), ascribed to them by the public because of the high share of coal power stations in their generation of electricity. In addition, the Renewable Energies Act offers financial incentives to tap new operating areas in the sector of regenerative power generation. Thus, all big electric power companies have now set up subsidiaries in the field of renewable energies and started to invest into these technologies. It fits the traditional model of centralised energy supply that so far their investment planning centres upon huge offshore wind farms at home and abroad (Greenpeace/IÖW 2008: 117-118).

Some of the big power companies have also started to get involved in the use of biomass and of onshore wind power. They also participate in pilot schemes for the decentralised coupling of power generation, power distribution and power consumption by means of advanced information technologies and within the framework of the innovation programme 'E-Energy', which is sponsored by the Federal government. This entry into new technologies *also* means that they get involved, at least partially, into a process of decentralisation – something that within the electricity system has hitherto been perceived by them as dysfunctional. For the big electricity companies, this in effect means that they participate –if only peripherally so far - in the expansion and usage of new techno-structures, which from the perspective of protagonists of renewable energies count among the key elements of a fundamental restructuring of the system.

4.2 The decentralised expansion of the renewable energies sector

The renewable energies sector is still exerting external pressure on the existing electricity system. Thus, several of its protagonists are locating themselves firmly and explicitly outside of the established electricity sector. Moreover, in Germany the renewable energies sector

[4] Thus, the four big German electric power companies (Eon, RWE, Vattenfall, EnBW) are planning to once again extend the capacities of their coal, gas and atomic power stations (partly by projects abroad) till 2020 resp. 2030 (Greenpeace/IÖW 2008: 118-119). According to IÖW's calculations the share of electricity from renewable energies will in 2020 amount to 15 percent (Eon), 12 percent (RWE), 33 percent (Vattenfall) and (projected for 2014) 21 percent (ENBW) with 14% stemming from hydroelectric plants (Greenpeace/IÖW 2008: 115).

enjoys broad support from *civil society*, still capable of sending confrontational impulses concerning energy policy, for example with regard to a rigorous decentralisation and ecological restructuring of electricity generation or with regard to the overcoming of oligopolistic market structures within the energy sector. Meanwhile the social spectrum of civil society participants goes well beyond members of the environmental movement or the archetypical 'eco-idealist'. In addition, for several years now, regional and local initiatives have been active that aren't any longer limited to one topic only. They have taken up the demand of the pioneers back in the 1980s to not only install an ecological counter-model, but also a social alternative. Their aim is an ecologically sustainable and socially embedded self-supply (in the long term: a hundred percent supply) with renewable energies accompanied by a promotion of the regional economy.

For years there has been an expanding *medium-sized branch of industry* pressing ahead with the expansion of renewable energies in Germany (see above). The structural strong points of these enterprises concern the further development of innovative energy technologies and the implementation of decentralised projects in the renewable energies sector. However, as far as centralised large-scale projects are concerned (e.g. offshore wind farms) they often reach the limits of their own financial, technical or human resources. If they undertake such projects at all they depend on the cooperation with well-funded companies (e.g. from the energy or the financial service sector). If they do so they run the risk of losing a (large) part of their entrepreneurial freedom of action. Right here one frequently encounters a specific type of entrepreneur: As a member or sympathiser of the ecological movement he advocated alternative power engineering from an early stage, and later became one of many 'green' founders of companies in the 1980s and 1990s. He often matches the 'creative' type of entrepreneur who – e.g. as an engineer – pushes ahead with new developments of his own trying to place them in the market or actively participating in the diffusion of technical innovations adapted by him.

The economical (and ecological) perspectives of this type of enterprise and entrepreneur aim at a technological restructuring of the energy industry, heading towards a functioning, safe and – at least in the medium-term – inexpensive supply with regenerative electricity. Such a perspective of restructuring, however, stands in stark contrast to the integration strategy of the big electric power companies. The most striking example here is the solar electricity industry: It is an important force towards a decentralised electricity supply and a thorn in the flesh of

the big electric power companies. According to experts, within the next few years the costs of decentralised solar electricity production will fall below the threshold of the average household's electricity costs and thus reach so called 'grid parity'. This could immensely increase the attractiveness of solar plants and drastically diminish the electric power companies' sales volume in private households and as such is definitely be perceived as a threat alien to the existing system.

In the course of their expansion, however, renewable energies have long since become an *intra-system component* which – because of its technical features – enforces restructuring measures within the system architecture. Only the optimal integration of the regenerative electricity generation – with its partial dependency on the weather – into the power supply system guarantees an economically and ecologically reasonable use of regenerative electricity potentials. Thus, for several years now the demands facing the old *as well as* the new actors of the electricity system have been increasing. They have to actively – also in the sense of incremental steps of restructuring – contribute to the stability and safety of the grid and the power supply. These efforts are most urgent in the case of wind power, which has been the most important source of regenerative electricity in Germany for some years, utilisation being especially concentrated in some North German regions. The demand – meanwhile regulated by public law – facing the network operators (mostly subsidiaries of the big electric power companies) is to strengthen or expand the grid in order to avoid overloading of the power lines by wind farms. Today, the operators of wind energy farms too are legally obligated to provide certain technically supported ancillary services (*Systemdienstleistungen*), which for example help to avoid wind turbines from suddenly disconnecting in case of voltage fluctuations or short-circuits which endangers the reliability of the power supply. The mutual commitment to system security not just caused by economical interests, but based on the notion of supply security, shows once again the difficult process of internalisation of an originally external challenge to the system: This process of internalisation draws on the one hand on the successful cooperation between traditional actors from the electricity sector and actors from the renewable energies branch,[5] but it has on the other hand time and time again been aggravated or obstructed by conflicts between both sides, for example by judicial rows over the legality of the grid operators' interventions into the electricity generation or the urgency of certain measures concerning the expansion of the grid.

[5] For example in the case of the above mentioned combined renewable power stations. If they are to be realised normally a cooperation of the regional grid operators is needed.

4.3. The centralised expansion of renewable energies for electricity generation

The strategy of centralised expansion is being propagated on a German and European level by some actors from the renewable energies camp, a number of scientists and some politicians. The basic idea is to produce electricity from renewable energies on a large scale while exploiting comparative advantages at those locations where the efficiency of power generation is highest – e.g. in offshore wind parks in the North Sea, in concentrating solar thermal power plants in North Africa or in Eastern European biomass power plants. By means of a "supergrid", consisting of high-voltage direct-current transmissions the regenerative electricity produced in world-scale plants shall be transported to the European centres of consumption in an energy-saving fashion, i.e. with only minimal transport losses. The advocates of this concept see it as one of its important advantages that a technically efficient and, because of the economies of scale to be expected, cheaper solution can be found than by means of a decentralised expansion of renewable energies. In terms of system integration of renewable energies, they also assess the efficiency of the concept concerning positively: A geographically spread combined system, so they expect, would ease the compensation of intermittent electricity sources as for example offshore wind power, especially when solar thermal power stations are part of this combined system. Their contribution to system integration is above all seen in their ability to feed in electricity continually and reliably (by using special storage systems at night). It is expected that solar thermal power plants are capable of providing safe and stable capacities of base-load and balancing power – thereby becoming important components of a transformed (European) grid which, at least in the long run, will be predominantly based on renewable energies.

This perspective, aiming at a long-term restructuring of the European and Mediterranean power system, combines the turning away from a fossil and atomic energy base with a centralised concept of power generation well conforming to the present system. Eventually this may lead to a far-reaching conversion of existing production and producer structures. Because of the structural affinities between such a "supergrid" and the traditional centralised electricity system there also exists the possibility of a *convergent development* with a limited restructuring of the system architecture: i.e. convergence of centralising strategies in the camp of the 'renewables' on the one hand and the integration of regenerative technologies by the established electricity industry on the other. Such a development is already visible in the case of the DESERTEC consortium, founded in summer 2009, which is planning the build-up of a

large-scale solar electricity generation in the North African desert. The DESERTEC project goes back to a network of scientists and politicians, founded in 2003 by the Club of Rome, the Hamburg Climate Protection Foundation and the Jordanian National Energy Research Centre (NERC). In the following years they advocated the realisation of their project by means of scientific reports, public relations and political lobbying in Europe, North Africa and the Middle East (Knies et al. 2008). This network, at first strongly influenced by actors from civil society, formed the nucleus of the present DESERTEC consortium. It is still supported by the Club of Rome (and the newly founded DESERTEC Foundation) but in the main consists of German large-scale enterprises, the two biggest electric power companies Eon and RWE amongst them. DESERTEC aims at the creation of a solar thermal path of electricity supply. Given the present constellation, it is not yet clear whether the participants interpret this project primarily as a complementary innovation within the framework of the existing electricity system or as the core element of a fundamental change of system.

5. En route to a new "dominant design"? Reflections on additional research questions

Which developments are to be expected considering these competing models of reconstruction? Are we to expect a further heterogenisation, pluralisation and easing of formerly stable system structures? Or are we presently dealing with an intermediate state of affairs which at some stage will be superseded by a new, homogenous solution, i.e. a new "dominant design"? At present it is of course not foreseeable to which extent a new and stable configuration will develop in the medium and long term – a configuration that would encompass a specific institutional setting and a 'fitting' technical structure, a dominant strategy on the part of the actors, a predominant model of technology etc. Research into the nature of sociotechnical upheavals has shown that periods of destabilisation or even dissolution of traditional sociotechnical configurations are normally superseded by social processes of search which – at least temporarily – lead to a new, functioning, i.e. *compatible* pattern of technology, structures and institutions (Dolata/Werle 2007: 26).[6] Presently, the German electricity system finds itself in such a situation of upheaval and the perspectives of restructuring, as outlined, are already part of the search for a transformed electricity system. There is, however, no guarantee that thereby the path to a new dominant design is predestined or can even be anticipated. To be sure, the perspectives of restructuring, as outlined above, are

[6] The types of sociotechnical transition analysed by Geels/Schot (2007) also show this common feature: From periods of instability or erosion of a dominant regime emerges a more or less transformed and self-stabilizing system configuration.

partially connectable, but they have a considerable *potential for conflict.* The scope of this conflict with regard to the transformation of the German electricity system will require more detailed research in the future. For the time being some provisional considerations may suffice.

It can by no means be ruled out that the conflict provoked by the renewable energies right from the start, presently hidden by the search for integration on the part of the new as well as the old actors of the electricity sector, might burst into the open again with all its virulence if the expansion of the renewable power generation continues. Thus, the German renewable energies branch has publicly announced that it is capable and willing to push the expansion of renewable energies beyond the political targets (so that, from their point of view, by 2020 not just 30 percent but 47 percent of German electricity consumption could be covered by renewable energies). These efforts are thwarted by the fact that the electric power companies are currently planning new coal-fired power stations[7] and in addition are demanding a longer, legally guaranteed, life span for German nuclear power plants.[8] It is already foreseeable now that such a strategy is incompatible with a steadily increasing share of regenerative electricity in the grid. The planned base-load power stations with their inflexible mode of production cannot appropriately react to intermittent power generation by wind energy or solar plants, thereby threatening 'to choke up' the power supply lines. From the viewpoint of the SRU (German Council of Environmental Experts) a "system conflict" is looming which, in the long run, could jeopardize not only the path to a sustainable power supply but also the targets of the Federal government's climate change policy. According to these experts what is needed, in order to avoid this trap, is a "fundamental choice" and a complementary – in terms of energy policy – regulation, opening the way for a development path which combines the massive expansion of regenerative energy sources with sufficient capacities of flexibly deployable gas-fired power stations (SRU 2009: 10+18).

A second line of conflict is to be found within the ranks of the renewable energies sector. As shown above, amongst its protagonists are not only advocates of a decentralised restructuring of the electricity system, but also proponents of a centralised expansion of renewable energies. At first view the existence of different positions doesn't seem problematic, all the more so as the Renewable Energies Act promotes both variants of expansion (e.g. small solar

[7] In Germany new coal-fired power stations with a capacity of nearly 28000 megawatt were under construction or in the planning phase in 2009.
[8] The present conservative-liberal government is expected to implement a respective amendment.

or biogas plants and large offshore wind farms). Scenarios of things to come like the "Model Study 2008" *(Leitstudie 2008)*, published by the Federal Ministry of the Environment, are acting on the assumption that for the period up to 2050 Germany will increasingly be supplied with electricity from decentralised *and* centralised renewable energies (Nitsch 2008).[9]
On closer inspection, however, it turns out to be an open question whether the intensified expansion of a centralised-decentralised type of system can meet the compatibility requirements for a new stable system configuration:

Firstly, the debate on decentralisation vs. centralisation has already led to a split amongst the proponents of renewable energies. The arguments made it clear that two philosophies – or rather two sociotechnical visions (*Leitideen*) – are clashing here the outlines of which cannot easily be reconciled: The advocates of the "supergrid" strive for cost and energy efficiency by using world-scale plants and – with an eye towards Africa – have set themselves targets in terms of development policy. They criticise the purely decentralised path not only as inefficient but also as a risky loss of time on the way to the intended turn in energy policy. By contrast, the main concern of the advocates of decentralisation is to free themselves from the dependency on large grids and their operators. They are concerned with targets in terms of regional and agricultural policies (in Germany) and an intensified integration of decentralised power consumers (e.g. private households) as co-producers of energy and energy services.

Secondly, as far as the centralised-decentralised option is concerned, the demands on processes of governance in terms of energy policy are rising dramatically: The idea of decentralisation requires totally different targets, criteria of promotion and processes of coordination on part of the participants than the concept of a transnational centralisation and cross-linkage of the regenerative generation of power. The opposing targets would have to be reconciled not only by way of an integrating vision, but also by an integrated and – internationally coordinated – political concept. Whereas a further decentralisation of power generation would follow an already established path in Germany, building on existing potentials in terms of technologies and actors in the renewable energies sector, the concept of the "supergrid" is something altogether different. It would require an internationally coordinated build-up of infrastructure and would have to face the problem that the new construction of power supply lines is quite difficult in most European countries today. The

[9] Including, from 2020 onwards, increasing quantities of imported current from centralised renewable energies.

main reason here is the lack of acceptance on part of the population – provoking the threat of local resistance, legal rows and lengthy approval procedures.

Considering the conflict potential, the research question goes as follows: Does the process of system integration of renewable energies which began some time ago ultimately lead to a confrontation of incompatible strands of development? If one excludes the possibility of a permanent instability in terms of the sociotechnical system of power supply: Does that translate into a *setting the direction* propelled by economical and political factors – which, because of demands on compatibility, would lead either to a far reaching substitution of the centralised power plant structures by *decentralised* renewable energies or to a reformed and re-stabilised variant of the *centralised* electricity system? If this adds up to the alternative centralised-decentralised it would in *both* cases require that the noticeable structural change of the German electricity system has to be extended or modified. To be sure, the decentralised option can smoothly build on the previous niche dynamics in the renewable energies sector and its protagonists, but it would require a fundamental change of the existing stock of conventional power plants as well as a change of the business fields and intra-organisational structures of the electric power companies (radical reduction of coal-fired and nuclear power plants; switch to gas-fired power stations, accelerated entry into renewable energies). Admittedly, the centralised option is prescribed by the hitherto dominant system logic, but it would – considering targets in terms of climate change policy – require the electric power companies to quickly switch to power plant technologies with reduced carbon dioxide (gas-fired power plants; carbon capture and storage; centralised renewable energies) and on the part of the renewable energies branch a profound structural change in direction of centralised large-scale projects.

Eventually the question arises whether a type of transformation is conceivable which combines the two kinds of processing logic and defuses the conflict potential mentioned above. The assumption is that a solution relying on advanced information technologies could emerge. Thus, with the interconnectedness in terms of information technology and the central management of many decentralised electricity producers in “virtual power plants” as well as with the implementation of “smart grids” a “loose coupling” seems possible: combining a regional and strongly decentralised power supply system with a centralised power supply system for urban agglomerations and industrial centres. Apart from the “loose coupling” – designed to minimise mutual systemic dependencies – an appropriate regulatory concept will

have to be developed and implemented which firmly supports the technical variety of renewable energies and the plurality of power producers as well as the power companies' switch to fundamentally changed, i.e. renewable production structures.

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