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Abstract

Based on an analysis of dominant approaches for the analysis of socio-technical transitions, a new perspective will be developed based on the theory of strategic actions fields as formulated by Neil Fligstein and Doug McAdam (2011, 2012). The paper will outline the main features of the theory and will further elaborate this perspective and include thoughts on the importance of technological characteristics for successful processes of transition. Empirical cases from the field of energy infrastructures will be used for purposes of illustrating the approach.

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Moving from Institutions and Systems to Strategic Action Fields: The Governance of Innovations

EARLY FIRST DRAFT!

1. Governance of Innovations: Structural Stability and Change

Over the last couple of years research on governance has made much progress (cp. for German research efforts Benz et al. 2007; Benz/Dose 2010). We are now better able to understand how markets are working, the functioning of industrial sectors and technological developments. In all these areas coordination problems have to be solved in order to allow for a smooth operation (Hall/Soskice 2001, Beckert 2007). Coordination problems are "solved" by a varying mix of private and public actors in a more or less organized manner. Governance in this context can be defined as all forms and mechanisms used for the coordination of actors, whose actions are interdependent, i.e. they can support each other in achieving specific aims or prevent them from happening (Benz et al. 2007: 9). The reflections on the importance of governance structures are theoretically informed by institutionalist thinking (Werle 2012) and analyze predominantly specific regulatory structures (Mayntz 2004). Research has thus been concentrated on the more static-structural aspects of governance. Most of the relevant governance literature is focusing on the internal operation of governance structures and presupposes that they are working in a more or less self-sufficient manner. At least as important, however, is the challenge to analyze the *change* of existing governance structures. It has been sufficiently discussed that structures, institutions as well as organizations have a specific inertia (Scott 2001). Path dependence - among other factors - plays a significant role in making more radical change difficult (see Fuchs 2012; Fuchs/Shapira 2005). Verbong/Loorbach (2012) have recently established that especially in the field of energy infrastructures "transition" to a new state is hard to come by. This might be the effect of the inertia inherent in established governance structures. If we assume that to fight climate change significant changes in the way our established system of electricity generation works, have to be made, it is paramount to ask, whether the existing governance structures are fit for that task or whether we need to look for new forms or structures of governance to ensure a transition towards a more sustainable infrastructure. Studies employing an institutionalist framework or are being informed by one or the other strand of evolution theory have repeatedly and successfully attempted to show that changes especially of a fundamental nature will be the result of "external" demands (Meyer/Rowan 1977) or major crisis and shocks emanating from the environment (Gould 2002). Fundamental changes are not driven forward by the incumbent actors in a specific field, sector, organization or policy domain, but by challenger groups. The transformation of a field is linked to the successful realization of radical innovations as opposed to incremental innovations. Incremental innovations improve on existing ways, activities, conceptions, and purposes of doing things, while radical innovations change the ways things are done. Under this definition, the key to classifying something as a radical innovation is the degree to which it reverberates out to alter the interacting system of which it is a part (cp. Padgett/MacLean 2006).

2. The System of Electricity Supply

The development of the energy sector, which will be the empirical example to be used in the following, had in the past been determined by a small group of industrial actors along with political and regulatory decision makers (Viktor 2002). The system of electricity generation is a prime example of a large technical system (Mayntz/Hughes 1988, Mayntz 2009) characterized by a substantial degree of institutional inertia. To adapt to new demands from public authorities and consumers, the sector needs to show a significant degree of flexibility. The more intensive the organizational needs, and the more complex and empowered a socio-technical system's structures are, the more demanding and protracted a substantial transformation will be. This is especially true for the tightly knit networks and the capital-intensive organization that exist in the electricity supply system.

In many countries decisions on the use of specific technologies (e.g. nuclear energy, renewable energies) have not been the result of the activities of profit maximizing economic actors. The essential incentives for changes in the energy sector have come from the so called oil-price shocks in the mid ninety-seventies of the last century, the Chernobyl accident and the resulting critical attitude towards nuclear energy in many countries, the liberalization of markets driven forward by the European Commission and finally the Fukushima catastrophe.

Such external events can - under specific conditions, which need further analytical specification and empirical research -, lead to changes in governance structures. The standard operating procedure surely is to have the incumbent actors deal with external challenges in the established way of doing things (structures and actors). We assume that changes in the governance structure are not an immediate reaction to external shocks, but rather these external shocks have to be interpreted, mediated by new, skilled actors and seen as an opportunity to see things differently and organize and build coalitions around these new ideas of how things could be done differently. In order to be successful, a change in the relevant power constellations which supports the governance structure is required. Processes of change deal with the question, who gets what under what conditions, i.e. they transform power structures, create new practices and new rules.

An explanatory perspective, which would allow us to better understand such processes, is the evolving Theory of Strategic Action Fields by Neil Fligstein and Doug McAdam (Fligstein/McAdam 2011, 2012), which we use in the following as a basis for our discussion of changing and/or stable governance structures in the energy sector and its consequences for the successful implementation of new technologies.

Exkurs: Some Very Stylized Words on Analytical Approaches

Research so far has developed different analytical approaches to study sectoral transformation. Some of these will be briefly discussed here to help better understand the theoretical option we have chosen.

One important line of reasoning can be associated with the so called "transition"-literature. It claims to have an analytical apparatus that would help us both understand as well support infrastructure transitions towards a more sustainable state. Research done in this tradition meanwhile shows an amazing breadth (see Truffer 2012). Nevertheless, it faces some shortcomings. It has an implicit normative character, arguing that transition processes will and should develop in a direction towards more sustainability. We actually see transition processes as being open ended. The outcomes of these processes are the product of a struggle between actors who define sustainability in different ways, and favor different strategies and methods. A cornerstone of the transition approach is its emphasis on niches. Niches are important since they contain the seeds for transition processes. Niches therefore have to be protected, and new technologies have to be experimented within these niches until they are ready to help transform the system. We share the view that transformation or radical change from within a system or sector is unlikely. We doubt, however, whether the niche concept provides the best analytical concept for understanding transition processes. Niches by themselves do not necessarily transform a sector. Niches are to be found everywhere. There are niche markets which thrive on the simple fact that they concentrate on niches, e.g. by offering very high quality or specialized products or services which are relevant only for a tiny minority. However, radical change in sectors such as telecommunications, was not driven forward by niche actors but by political decisions and powerful actors from outside the field. The niche argument ultimately tends to underrate actors' aspirations and strategies which may or may not aim at sectoral transformation.

Another line of reasoning is represented by the Technological Innovation System approach. Again, this approach has produced an impressive number of valuable studies over recent years and we can benefit from their results (Coenen/Lopez 2010). Pioneering work on TIS was carried out by Bo Carlsson and Rikard Stankiewicz (1991). They define it as: "network(s) of agents interacting in a specific economic/industrial area under a particular institutional infrastructure or set of infrastructures and involved in the generation, diffusion, and utilization of technology. Technological systems are defined in terms of knowledge or competence flows rather than flows of ordinary goods and services. They consist of dynamic knowledge and competence networks." (Carlsson/Stankiewicz 1991: 111). Given that technology is the common denominator in TIS, a framework can be used that is geared to studying how the configuration of actors, networks, and institutions changes over time as the technology develops (Carlsson 1997). Recently, the emphasis on a dynamic analysis of TIS has received considerable impetus by explicitly focusing on the functions, activities, or processes taking place within the system of innovation (Hekkert et al. 2007, Bergek et al., 2008). It remains somewhat ambiguous, however, how exactly the boundaries of a technological domain are set in relation to its geographical and sectoral embeddedness. Markard/Truffer(2008) remain critical of the inconsistent way that empirical studies of TI-systems have delineated the system, using it either in a rather descriptive way as a synonym for sector or just as a catchword. From a sociological point of view the use of the systems metaphor and its more or less arbitrary listing of functions and treatment of institutions has been criticized.

Recent theorizing in the social sciences in general has stressed the importance of the meso-level and especially of meso-level social orders where actors (who can be individual or collective) interact with knowledge of one another under a set of common understandings about the purposes of (in our case) a specific sector, a field, the relationships there (including who has power and why), and the sectors' rules (cp. Martin 2011). Observing actions in meso-level social orders has already been implied in the various versions of institutionalist thinking. Meso-level orders have been variously called sectors, organizational fields, games, fields or networks. Most of this theorizing, however, is very static. It is difficult to use the insights produced by these studies to investigate change. Concepts like, for example, "institutional" or "organizational logic" are well suited for analyzing periods of stability, but not for the study of processes of (potential) transformation.

Interdisciplinary innovation research, finally, has also stressed the importance of the meso-level for understanding respective processes. For example, a whole series of research has been done under the label of "Sectoral Systems of Innovation" (Malerba 2004). This research, however, also suffers from an under-conceptualization of the processes of change and transformation. In the institutional tradition, processes of transformation are described as "periods of mismatch" (Dosi et al. 1988: 11) or as "periods of considerable confusion" (Henderson/Clark 1990:12). Thus a more thoroughgoing analysis is necessary that highlights the interplay between incumbent, stabilizing, and changing forces.

In our view, the theory of strategic action fields provides an analytical framework that enables the analysis of dynamic developments, is not normatively based, and is also not technology centered. We conjecture that a strategic action field is dominated by a set of incumbent actors who share a common belief about what the field is all about, how specific positions are attributed to actors, what the aims of the field are, and the legitimate ways to pursue these aims. From a plentiful supply of empirical evidence and theoretical considerations, we can safely assume that incumbent actors will try to oppose demands for change that will destabilize their position in the field and dominant ways of doing things. Change will therefore be driven forward mostly by challenger actors, less powerful actors within the strategic action field under analysis, or from outside actors "invading" the field. External developments that have relevance to internal field processes can include the following: political decisions such as the *Energiewende* or the liberalization of energy markets; changes in macro-cultural discourse such as the growing awareness of the dangers of climate change; or widespread external opposition against specific technological options such as nuclear energy. For significant change to take place, these external developments have to pose significant threats, or provide opportunities for the realization of collective interests. Those delivering the threats or opportunities must have command over sufficient significant resources in order to be able to generate and sustain action. Significant changes to a field will also require the use of innovative and new – possibly previously prohibited – forms of collective action. The role of individual or corporate skilled actors is paramount. They need not only to fight for a new interpretation of what the field is all about, but they will also have to forge new coalitions and compromises reaching beyond the initial set of challenger actors. Analyses of processes of sectoral transition have shown that such processes as well as their outcomes are difficult to predict and might take different forms such as: (a) a re-imposition of the old regime with some adjustments; (b) the break down into unorganized social space; (c) the partitioning into several spaces (e.g. renewable vs. traditional energy generation); (d) the development of a wholly new regime (Cp. Mahoney/Thelen 2010, Fligstein/McAdam 2011). We reserve the term "transformation" for the last option.

3. New Technologies, Governance and the Energy Sector

The energy system globally faces a variety of challenges which require adaptation. Large energy infrastructures are the precondition for economic development. But the dominant ways of generating electricity extracting them from fossil fuels (coal, oil, gas) have been made responsible for the human induced part of climate change. The technological part of a solution to the challenges of climate change is twofold: a) Alternative ways of generating energy can be developed and implemented; b) the use of fossil fuels can be made more climate friendly.

These are then the two options: either develop and use new technologies for energy generation or make existing procedures and facilities work in a more socially desirable way. In the following I will analyze the so called Carbon Dioxide Capture and Storage (CCS)- technology as an example for the latter option, which is aiming at making conventional power plants work more climate friendly, issue less emissions. The CCS technology is considered by the International Energy Agency as the only viable and available technological option if you want to continue to use and build conventional power plants and reduce CO2 emissions at the same time. A more decisive challenge for the existing governance structure is coming in the past and future from the area of renewable energies. The traditional way of generating electricity has as its backbone a centralized structure with big electricity generating units, which are run by a small group of potent firms. Renewable energies on the other hand are not only vying for attention with the claim to develop a new, climate friendly, secure way of electricity generation, but also favor a decentralized design, demanding and offering new roles for entrepreneurs as well as consumers. A totally new form of governance seems possible.[1]

3.1 The Development of CCS in Germany and Norway

Using the example of CCS we will analyze, how the governance of technology-oriented incremental innovations in the energy sector looks like and how different actor constellations and structures in a similar sector can lead to a big difference in outcome and performance: a stalling development in Germany on the one hand and a successful implementation based on a broad social consensus in Norway.

3.1.1 CCS in Norway

For generating electricity Norway uses nearly exclusively and traditionally water power. The significant domestic oil and gas reserves are nearly exclusively used for export purposes. Owing

[1] The present paper draws on the results of four research projects dealing with the development and prospects of CCS and PV. The projects used document analysis, expert interviews and discussions, scenario analysis and agent based modeling as methods. The projects were supported by the Volkswagen Foundation, the German Federal Ministry for Environmental Affairs, the University of Stuttgart and the Helmholtz Association,

to this, the discussion on CCS in Norway was advanced by actors, which did not have a significant role in the domestic electricity providing system as such. Leading actors for development of the technology and a suitable governance structure had been the oil company STATOIL and research institutes like SINTEF and the Technical University of Trondheim (NTNU). Already in the 1980s the idea of capturing and storing CO2 had been fancied. At the same time Norway's minister president Gro Harlem Brundtland chaired the *World Commission on Environment and Development* of the United Nations. Under her chairmanship a comprehensive report on sustainable development was published. In 1991 Brundtland introduced for Norway a CO2 tax for fossil fuels and fossil fuel using sectors. This tax helped increase efforts over the 1990s, to push forward plans for the capturing and injection of CO2 into oil and gas fields. Initially this happened as pure research efforts but gradually also in the form of projects testing whether the procedure was commercially viable. The interest of the oil- and gas industry is derived from two activities linked with the CCS technology: the so called EOR (Enhanced Oil Recovery) and the EGR (Enhanced Gas Recovery). By both methods CO2 is injected into off shore oil and gas fields in order to improve the efficiency of exploitation. This framing of the technology quickly brought other actors onto the playing field and the developing actor network. Norway's biggest industrial plant constructing company Kvaerner and international oil companies contributed to the research efforts. The driving force in Norway thus has been the oil- and gas industry which started R&D activities as well as partnerships with scientific institutes. Its prime interest was the injection and storage of CO2 in the nearly empty oil and gas fields.

Starting in 1996 Statoil began with the first commercial use in the gas field Sleipner West in the North Sea. From 1997 onward research activities for CCS also did get public support money from the KLIMATEK program sponsored by the Norwegian government. After Kvaerner had been successful with starting its first pilot installation of a CO2 capturer, Norway's second biggest technology company, Aker, also invested in R&D for CO2 capturing.

Only later on became CCS of great significance and interest to the Norwegian system of electricity generation. Growing electricity demand could not any longer be matched by domestic water power alone. Environmental concerns were discouraging the building of new water dams. At this moment the Norwegian energy provider Naturkraft did get a license to construct two new gas fired power plants. A lively debate on the construction of these new power plants emitting CO2 ensued. Influential environmental organizations were favoring the implementation of the CCS technology for the new power plants. It seemed to be the only option, if attempts to decrease energy consumption were not successful and if on the other hand the government wanted to stick to the political aim (in the meantime also laid down in the Kyoto Protocol) to reduce CO_2 emissions.

Since the private R&D activities, the Norwegian policies as well as the geological storage potentials made ever bigger research efforts possible, which were now also supported by the European Union (in spite of the fact that Norway is not a member of the EU), CCS gained solid support among the Norwegian public and most of the active NGOs. The initial debate on whether to build new gas fired power plants turned into a debate about the pro and cons of the CCS-technology (cp. van Alphen et al. 2009: 49), which was easily won by the supporters of CCS coming from different camps. Since 2011 the official Norwegian policy is guided by the idea that no new concessions for gas fired power plants will be granted if the CCS technology is not used.

Concluding it can be said that CCS in Norway was driven forward by a growing and broad coalition of actors coming from politics, industry and civil society. The development of the technology did not lead to a disruptive change, but was inclusive, oriented towards existing actor coalitions and broadening them in a largely consensual manner. In the Norwegian CCS case the field structures were not fundamentally transformed, but due to external pressures new types of actors were co-opted into the field. The government succeeded in framing the problem as one of caring for sustainable development. It built a broad coalition of industrial and civil society actors supporting the CCS technology. Overall the field showed a high degree of adaptive capacity and was able to push technology development forward.

3.1.2 CCS in Germany

An analysis of the governance of innovation for CCS in Germany gives a strikingly different impression. First of all coal (absent in Norway) still plays an important role for electricity generation in Germany. 24% of the energy generated in Germany has brown coal as its source; an additional 18% are derived from hard coal (UBA 2011). The brown coal used is nearly exclusively coming from domestic sources and is at the same time the only competitive domestic fossil material used for energy generation. After a period of stagnation, coal fired power plants are again dominating the German market, i.e. most running or planned construction projects are coal fired power plants (cp. Pahle 2010). In its role as buyer of power plant technologies the German energy providers have a substantial interest in technological innovation that would allow them to continue running the coal fired plants and build new ones. This refers to a further improvement of technology already in use to increase efficiency, but also to an interest in CCS, which would lower CO_2 emissions significantly. Since Germany has committed itself to an ambitious climate policy (40 %- CO_2 reduction target planned by the Federal Government), the energy providers and operators of the coal fired power plants feel a considerable pressure to reduce emissions.

The major importance of coal for the German electricity provision system is also highlighted by the fact that Germany is considered to be a worldwide leader in the development of technologies relevant for the running of coal fired power plants (Weimer- Jehle/Wassermann/Fuchs 2010). Innovation activities in the area of coal fired power plants and CCS in Germany are executed by a limited number of predominantly big actors. These are multinational companies like Siemens, Alstom and Hitachi Power Europe, which as dominant constructors of power plants build technically highly developed components like turbines, boilers and generators, producing them in a more or less identical manner for the German as well as the world market. Innovations are driven forward in clusters of research networks in which extra-university research institutions (e.g. Research Center Jülich), big university institutes, the R&D departments of the producer companies and the R&D departments of the customers, usually the four big energy providers RWE, E.ON, Vattenfall and EnBW are represented (cp. Rogge/Hoffmann 2009: 7) – sometimes all of them at the same time. Driving actors in the development of CCS and the spread of its idea in Germany therefore are the firms constructing power plants, the domestic brown coal industry, the big energy providers, which operate the majority of the German coal fired power plants and which are worried about the emission trade schemes and increased costs.

Given the importance of the constructing firms from an industrial policy point of view, early R&D activities were supported by the Federal Government. The leading actor in this respect was and still is the Ministry of Economic Affairs (BMWi). Within the so called COORETEC- Initiative for the promotion of research and development of future oriented power plants with fossil fuels, research projects and pilot installations for the capturing of CO_2 were supported. At the site *Schwarze Pumpe* in Brandenburg, a big and traditional brown coal extracting area, the worldwide first trial installation for a CO_2 poor brown coal fired power plant based on the Oxyfuel-procedure was built. The pilot installation started work in 2008 and was run by the energy provider Vattenfall. The aim was to test and further develop the technology in order to make it commercially viable. In a parallel effort Vattenfall also developed a 300 MW-demonstration project, which was supposed to start operation in the years to come. It was planned to be again situated in Brandenburg, this time at Jänschwalde. In contrast to the Norwegian situation the driving forces for the development of CCS clearly came from the incumbent actors of the field. Insofar innovation activities followed an established incremental course typical for this type of field, based on the interests of the incumbent actors and their networks. It soon became clear, however, that the second step in the CCS-development process (looking for suitable sites to store the captured CO_2) run into difficulties. For this part no established mechanisms were available and the approval of actors became necessary, which hitherto did not play any role in the calculations of the coalition driving forward CCS. The commercial exploitation of CCS at the end had to cope with severe acceptance problems which threatened the success of the whole innovation process. Massive resistance against the exploration of possible storage sites became organized. Various citizen initiatives came into existence, which gradually gained the support of environmental organizations, but also from other associations, like the „Farmers' Association" and the Association of Water Power Companies (Schulz/Scheer/Wassermann 2010). After massive protests, the regional (state) governments became reluctant in their support for the Federal Government's plans to push CCS. Especially the resistance of the state government of Schleswig Holstein made it impossible to pass a federal law on CCS. As a consequence the energy provider RWE stopped its plans for building a demonstration power plant using the CCS technology in Hürth (Northrhine Westphalia). Even before this decision RWE had failed in its attempt to gain EU support for the project. The EU named as a justification for its decision the resistance against the search for storage sites in Germany. The only existing legal approval for the exploration of potential commercial CO2 sites, two sites in the state of Brandenburg, were based on state regulations, given the absence of federal rules. The permission was granted, however, with the idea in mind that a new federal law would soon be passed, which would then grant legitimacy to the state's actions. Since the federal law did not materialize, the state government announced that the exploration permit can only be considered as temporarily valid. As of now all attempts for a new federal regulation have failed and as such the technology implementation process looks doomed. Similar to the situation in Norway the technology development process was advanced by established industrial actors, based on political decisions favoring the technology. Just like in Norway climate policy consideration in line with the established networks consisting of the Ministry of Economic Affairs and the incumbent actors in the field, worked out the respective plans. Unlike in Norway, however, CCS did not succeed in building a solid support coalition reaching beyond the established field actors. Decision making took place in closed circles until the necessity arose to go public in the search for storage sites. The CCS support coalition basically consists of the incumbent actors facing a growing and influential counter movement consisting of citizen initiatives, NGOs, who succeeded in broadening their coalition (in contrast to the incumbents). Whether Germany will be able to implement CCS in the years to come, in spite of the fact that technology and knowledge is available as well as political priorities, seems very doubtful at the moment. The field CCS in Germany at the moment can thus be best described as an unorganized social space. Actors are unsure what to do and how to proceed. Most likely only a decision by the European Commission will restart the process.

3.2 The Governance of Photovoltaics in Germany and Japan

Contrary to the more incremental innovations in the area of climate friendly technologies for coal and gas fired power plants, the development and diffusion of renewable energies includes a variety of new actors – especially in Germany. These new actors encompass new producers, electricity traders as well as owners of decentralized electricity generating units. Discussions about global warming and general environmental concerns have led to political attempts to create and manage a new energy market and the newly developing energy mix. New political instruments were developed and at least in Germany new actor constellations can be observed, which in consequence have led to the development of a specialized governance structure for renewable energies.

3.2.1 Photovoltaics (PV) Development in Japan

The beginnings of PV research in Japan date back to the 1960s. The company Sharp was engaged in the development of solar cells for space research. As a result of the oil crisis in the 1970s, which Japan due to its near complete dependence on the import of fossil struck especially hard, the Japanese government started in 1973 a first political program, the so called "Sunshine Program", with the aim to explore possibilities to reduce the dependence on energy imports. A small part of the overall program, ca. 6 Mio $, was devoted to PV research for terrestrial applications.

At the center of the Japanese innovation system is a small number of big, vertically integrated as well as diversified companies, which are specializing in incremental innovations in products and production processes. The second most important actor for the governance of innovation is the government. It is much more directly involved and makes much more direct attempts to coordinate innovation processes than its counterpart in Germany for example: „Japan and Germany clearly display different social systems of innovation, and this is why these countries showed contrasting patterns of evolution during the last quarter of the twentieth century" (Boyer 2003: 148). Vogel (2006) furthermore points to the important differences between German and Japanese innovation policies: „The German government merely facilitates private-sector coordination, whereas the Japanese government organizes and guides the private sector more directly. The German government has codified its economic model into law, whereas the Japanese model relies more on informal norms and standard practices." (Vogel 2006: 308).

The Japanese government has interfered actively with a variety of measures and strategies in the development of the energy sector. This can be shown for the energy sector as a whole but also very clearly for the case of PV. Following the 2nd oil price shock of 1979, the government in 1980 created the *New Energy Development Organization* (NEDO) with the aim to reduce Japan's dependence on foreign oil. NEDO is an adjunct to the Ministry for International Trade and Industry (MITI), which is also responsible for energy questions. In 1988 NEDO was renamed to „*New Energy and Industrial Technology Development Organization*" and thus stressed even more its coordinating role for the industry (cp. Ristau 1998: 81). Members of NEDO were recruited from the state apparatus but also from industry. As such the energy provider *Tokyo Electric Power Company* e.g. played an important role in the formulation of the energy policies and strategies of the organization.

Over the 1980s NEDO fulfilled two important functions for the development of PV: on the one hand it sponsored research projects for the improvement of the efficiency of solar cells. On the other hand NEDO became also the biggest buyer of commercially produced solar cells. In the 1980s there was neither a domestic nor an export market for PV- applications. The state sponsored demand was a decisive benefit for the Japanese industry, which was aiming at developing a world leader position in the development of this technology. With the eventual development of a world market for PV, Japan was able to satisfy the growing demand and expand its market share on the world market substantially. „In 1983 23% of the worldwide sales of modules originated in Japan. Two years later the European Solar Association calculated that the contribution had grown to 45%"(Ristau 1998: 81; own translation G.F.).

The strength of the Japanese innovation system which can also be demonstrated for the case of PV is not to be seen only in the type of cooperative policy support but also in the political instruments used for technology diffusion (e.g. the financing of demonstration projects, incentive programs). In order to give the industry incentives to expand production capacities, MITI initiated in 1994 the so called 70.000 roofs program („*Monitoring Program for Residential PV Systems*"; Shum/Watanabe 2009: 3536). It was implemented by the *New Energy Foundation* (NEF). Within the scope of this program the government financed 50% of the installation costs for PV-modules of private households. Under specific conditions firms could also participate in the program. The financing of the overall program was done with the help of a surcharge on regular electricity tariffs. The energy providers furthermore were obliged to buy PV-electricity at market prices. In 2003 the program was further developed. But now the government took over only 15% of the installation costs. Before that in 1997 a new energy law was passed („*Law on Special Measures to Promote Use of New Energies*"). It consisted of a broad mix of subsidies and other policy measures to support the spread of PV and other renewable energies. A clear target for the expansion of PV was also stated. PV was supposed to grow from 500 MW to 5000 MW until the year 2010 („*Long-term Energy Supply/Demand Outlook*"). Other laws naming targets for the spread of PV ensued as well as a number of projects which were especially supposed to boost public demand for PV (e.g. installations on public buildings). The Ministry of Education e.g. passed an ECO-School project, the Ministry for Infrastructure Development a *Green Government Office Project* and between 1992 and 1998 a *Field Test Project on Photovoltaic Power Generation for Public Facilities* was done, which later on was merged into the *Field Test Project on Photovoltaic Power Generation for Industrial and Other Applications* (Anderson et al. 2006: 26). The public expenditure for the support of PV in the 1990s was significantly higher than in all other comparable nations. The public budget in 1997 for the support of PV amounted to 150 mio Euro. In Germany at this time no public money of any significance was spent for this purpose. Less than half of the Japanese support money went into R&D support; the bigger part was used for the stimulation of demand (Ristau 1998: 92). Since 1997 the support was extended with a further „*Program for the Development of the Infrastructure for the Introduction of Residential PV Systems*". In the following years (from 1997 to 2001) the support grew from 11,11 Mrd. Yen to 23,5 Mrd. Yen (Shum/Watanabe 2009: 3536). The technology developed and implemented in Japan resembled a standardized mass product without any significant adaptations to the needs of specific customer groups (Shum/Watanabe 2009: 3540). The dominant Japanese type of an integrated innovation process can thus be observed for the case of PV. This included the integration of the „last mile", the installation or de-installation of PV-modules by artisans and architects. Shum and Watanabe refer in their analysis of the Japanese governance of PV-innovations to the image of a „closed development"(Shum/Watanabe 2009: 3540). The development of PV in Japan therefore resembled other comparable innovation processes in Japan. In the center of attention is the cooperation between the incumbent actors from government and industry. They are aiming at developing products which can also be exported and sold on the world market and thus help the domestic industry. For the realization of the aim of PV development established channels and methods of cooperation were used, in order to push the innovation forward in an incremental and piece-meal fashion. In spite of the first mover position of Japan both with respect to technology and commercial development, a position which Japan could hold on for quite some time, the amount of installations realized in Japan was not overwhelming. In this regard it is important to understand that Japan did not succeed in creating a real domestic market for PV installations. PV installations are primarily to be found on public buildings. The incumbent actors, the same companies that were doing e.g. nuclear power development were also doing PV, had their prime orientation towards exporting products, but did not favor a significant change of the domestic technology mix. The composition of the coalition deciding on the further development of the energy sector remained stable, new challenger groups (e.g. from civil society) did not play a significant role and as such more wide ranging changes were not envisioned. In Japan the type of coordination used for PV therefore resembled the established patterns in the electricity generating field. The development was towards a technological add-on option, but was not intended or used to break up the existing way of coordinating strategies. The actors concentrated on strategies that would not endanger their existing position and business models which were dominantly oriented towards developing and using nuclear energy.

3.2.2 PV Development in Germany

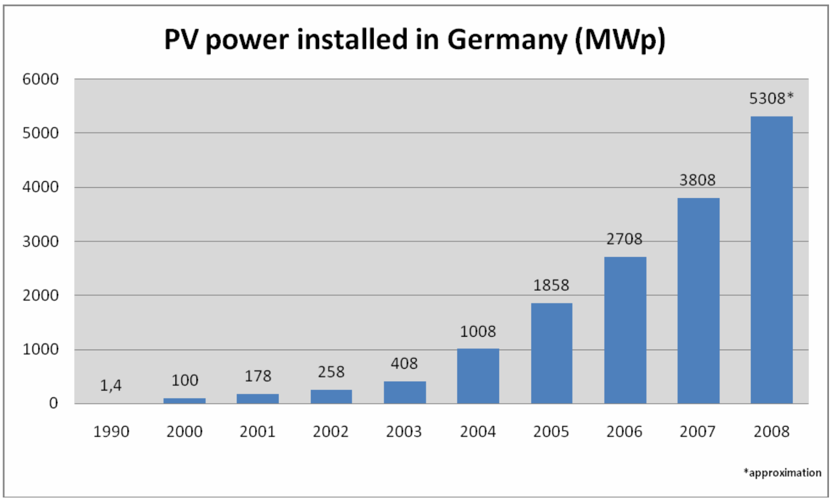
The German PV development in contrast to the Japanese case is characterized by severe conflicts, radical innovations and marked breaks and changes in governance. In the already discussed examples we detected more or less continuous efforts to sustain R&D and support efforts based on coordinated and cooperative efforts of the main actors from government, science and industry. The German PV picture looks different. For a long time government support was rather reluctant and difficult to predict and liable to sudden changes and shifting priorities. In contrast to Norway and Japan as well as the CCS development in Germany, the momentum for the development of PV was kept alive by so called non- conventional actors. In this case the social movement character of governance change becomes clearly visible.

Initiated by the oil crisis, Germany started first programs related to PV and other new energy options in the 1970s. At this point in time the responsibility for promoting PV was with the Ministry of Research and Technology. With the ensuing decline of oil prices and following a change in the composition of the federal government – it was now led by the conservative party -, the programs to support PV were severely curtailed. The first programs for PV nevertheless had certain successes. The industrial partners (AEG-Telefunken, Siemens-Solar) having received most of the public money, succeeded in establishing a competitive expertise and technological prowess. The German PV-research could be established and gained an internationally leading position along with Japan and the US. Unlike in Japan, however, the little public money available was widely dispersed, experiments with various technologies and procedures were supported and universities as well as applied research centers, like the Fraunhofer Institute for Solar Energy Systems (ISE) (founded in Freiburg in 1982) were participating. Research projects became financed which were not evaluated from the side of the funding institution with respect to what technological option would be the most desirable one and what would be the best option for industry and/or society. In the end, however, the efforts were seriously hampered by the fact that technologies were developed up to a pre-market stage, but given the lagging or non-existent domestic demand combined with little political interest in supporting an uptake of the technology, this led to a stalemate and no significant role for the technology in electricity generation could be established. On the contrary: the further development of the technology was opposed by the incumbent actors of the energy system equipped with good networks and contacts to political and administrative decision makers. Clear policy guidelines were furthermore difficult to establish due to conflicting positions of the Ministry for Economic Affairs, who claimed responsibility for market oriented support schemes and which until the present day sees PV very critically and the Ministry for Research and Technology which had and has a more favorable view of PV (Ristau 1998: 44ff.).

The general support for technology development therefore was rather weak and divided. The support coalition for PV mainly consisted of concerned scientists who wanted to develop an alternative way of generating electricity. Their engagement very often grew out of an opposition to nuclear energy. The Association for Solar Energy (DGS) (founded in 1975) tried to pool their interests and became more important due to external events. The Chernobyl accident in 1986 made nuclear energy very unpopular and initiated a new search for alternative energy resources and a discussion about the future outlook of the energy system as a whole was restarted. Within two years the opposition against nuclear energy among the population at large rose from 50 to 70% (Jahn 1992). The scientists favoring PV were trying to influence the public discussion and put PV on the agenda as a possible new option, as an important element of a transformed energy system. PV was labeled as a clean, environment friendly source of energy. This made it possible to merge the interests of different social groups: the anti-nuclear power movement and environmental groups could quickly agree on such an option, which made it also possible for them not only to be against something, but to be in favor of a true alternative option. In comparison to other countries the social movements and the general opposition to nuclear energy after the Chernobyl accident was more wide spread and also found a political support in the party “The Greens/Die Grünen”. Given this changing environment the federal government felt obliged to offer some carrots in the form of a first, small market oriented program for supporting PV. In 1991 the 1000-roofs program started. It was financed by a state controlled bank (Kreditanstalt für Wiederaufbau) and offered loans for private households, which were interested in participating in a big test of grid connected PV-installations. NGOs like the aforementioned DGS, the Association for the Promotion of Solar Energy and Eurosolar used this situation to influence the political agenda. They developed various models for the financial support of PV and the technical options for connecting decentralized generated solar energy to the general grid. Besides these national developments other institutional innovations on the global and the European level were important, which also had an effect on the German PV scene. On the European level the deregulation of the energy system was driven forward by the European Commission and the global discussion about climate change, which led to the Kyoto protocol (1997), altered the framework within which PV could be developed. The groups favoring solar energy became more firmly organized and built up new political coalitions especially on the local and regional level. On the federal level, however, things looked different. After the heavily over-subscribed 1000 roofs program was terminated, the demand for PV installations plummeted again and decreasing energy prices seemed to make PV an economically unviable solution. The market nearly disappeared and the relevant industry threatened to or actually left Germany to move to locations that would provide a more stable regulatory framework. It became clear that without a long term oriented regulatory framework and support scheme no significant demand for PV could develop in Germany. This was again a situation in which the role of non-conventional actors proved decisive. Greenpeace paid the Ludwig-Bölkow-Foundation for doing a study on the feasibility of constructing a production facility for PV modules in Germany. The study came to the conclusion that it would in fact be economically viable to produce and use PV modules in Germany (cp. Welt online 1995). Considering economies of scale and an automatisation of production processes the price for PV-installations could be reduced by 40%. Even a small production unit with the capacity to produce only 2000 PV units would be able to work profitable. These results were used by Greenpeace to look for people interested in helping finance such a plant. Within a short period of time 4000 people showed their interest. Greenpeace then put ads in leading newspapers to look for entrepreneurs to realize their plans and suitable persons actually showed up. The major importance of Greenpeace's activities was in sensitizing the potential demand for PV and showing ways for a viable implementation of a PV production strategy. It had become clear that PV installations could be produced more cost efficiently than previously thought and the discussion thus also gained an industrial policy component (cp. Fuchs/Wassermann 2012).

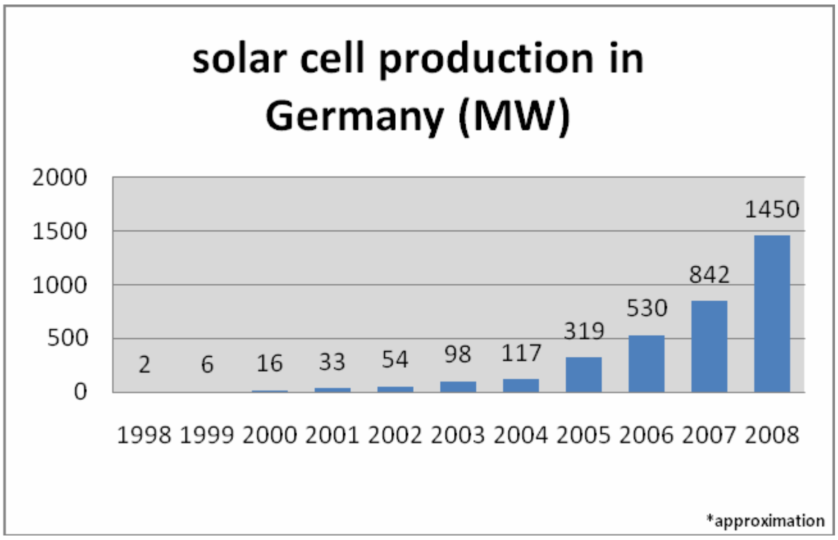
Once it had become clear that PV modules could be produced more cost effective than initially thought, especially medium sized companies began to become interested in PV – companies like RAP Microsystems in Wernigerode or the Solar Factory in Freiburg (Ristau 1998: 57). The new small and medium-sized PV companies did concentrate from the beginning on grid connected installations. They began to produce modules, mounting frames for roofs and inverters. In this way the activities instigated by the various social movements mentioned above, led to the development of a new innovation path and strengthened the specific characteristics of PV development in Germany (Jacobsson/Lauber 2006: 266). Many of the new PV start-ups had their origins in PV-research institutes. The close networking between science, environmental groups and small, initially environmentally and energy politically motivated entrepreneurs was especially valid in the case of PV.

Fig 1: PV power installed in Germany (MWp)



Source: Bundesverband Solarwirtschaft e.V. (BSW-Solar 2009)

Fig 2: Solar cell production in Germany (Mw)



Source: Bundesverband Solarwirtschaft e.V. (BSW-Solar 2009)

In 1998 the development became a new push. Another change in the composition of the Federal Government brought a red-green coalition into power. The window of opportunity now was wide open. The expanding PV support coalition saw its chance. It did not need any longer do lobbying work from the outside. Members of the PV coalition now could effectively influence policies from the inside. Its aim was an institutionalization of the support for renewable energies. The red-green coalition in fact initiated two new policy instruments for the support of PV. Firstly a successor to the terminated 1000 roof program was started, now called 100,000 roofs program, demonstrating the new emphasis and importance of promoting PV. The program was passed in 1999 and it was again administered by the bank KfW. It offered cheap loans covering a period of ten years of which two years were totally free from interest payments. For a long time the PV industry had waited for such a signal. In 2000, secondly, a new electricity feed-in law was passed (Renewable Energies Law). It set the conditions under which generated electricity could be fed into the general electricity grid and also regulated the issue of financial compensation. The Federal Government was trying to establish a broad support for the new law, but nevertheless some of the energy providers and their trade associations went to the courts and tried unsuccessfully to block the law. When in 2003 the 100.000 roof program ran out, a new amendment to the Renewable Energies Law increased the compensation for individuals generating electricity from PV modules, making PV even more interesting from a commercial point of view. When in 2005 a new shift in the composition of the Federal Government took place (now a coalition led by the conservative party with the social democratic party as a junior partner), no fundamental changes were put in place. Originally opposed to PV promotion schemes, the conservatives meanwhile looked more favorable on PV. This was essentially due to the influence of regional politicians from the Eastern parts of Germany, where most of the new PV companies had set up business and were also attracting foreign direct investment.

	Incumbent Energy Governance	***Renewable Energy (Photovoltaics) Governance***
Aim	**Incremental innovation, continuous improvements**	**Radical innovation, new „architectures"**
Actors	**Government, incumbent energy providers, incumbent manufacturing firms (MNC), established mainly university based research**	**Government, mainly newly established medium sized companies, regional and local energy providers, strong position of extra-university research, interested individuals and environmental associations**
Networks	**Strategic networks, functionally specialized and complementary institutional institutions, clientilism**	**Heterogeneous interactive networks, experimental regimes of institutional learning, extended bargaining systems and new coalitions, heterogeneous expert groups, communities of practice**
Policies	**Regulation, subsidies for research of established actors and pilot installations, financing of public deliberation activities**	**Energy Feed In law, indirect subsidies financed by consumers, cheap credits for buying installations people, small amount of research subsidies**
Level of regulation	**Central (national) level**	**Increasing importance of decentralized levels (local, regional)**
Technological characteristics	**Centralized large technical systems with long planning horizons**	**Small to medium sized, decentralized units, flexibly and easy to install, short planning periods**
Role of „customers" in the process of	**Primarily intermediate actors (energy providers), consumers have little impact**	**Private consumers, consumer can become producer, intermediate actors (machine tool industry, artisans etc.)**

Table one: Changes in the Governance of Electricity Generation in Germany (Differentiation)

Another political change in 2010 (now a conservative-liberal coalition took office) has made the further development of PV look unpredictable. Various regulatory changes were implemented and opinions - especially voiced again from the Ministry of Economics, the four energy providers and network operators - gained importance, claiming that PV is not a suitable option for

Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	20
Germany	3	5	6	8	11	18	23	32	76	186	296	439	1074	1980	2931	42
Japan	19	24,3	31,2	43,4	59,6	91,3	133,4	208,6	330,2	452,8	636,8	859,6	1132	1421,9	1708,5	191

Table two: Installed PV capacity in Germany and Japan (inGW)

the German electricity system. Prior to the Fukushima catastrophe the operating times for nuclear power plants were prolonged and contracts made by the previous governments were cancelled – damaging the prospects of PV. After Fukushima an end to nuclear energy was proclaimed, but up until now the conditions for the promotion of PV have not become stable and calculable again. In 2011 7,5 GW PV-capacity were installed in Germany, which shows the popularity of solar energy in spite of decreasing financial returns for the investors. The Federal Government wants to reduce this build up to 1 GW per year in the future.

4. Conclusion: Governance of Innovations in the Energy Sector

In this contribution we have traced the development of two technological innovations in three countries. The emphasis on the one hand was on analyzing how technological developments are embedded in specific national and sectoral contexts for which we used the concept of governance. On the other hand we have put the emphasis on a process perspective. The process perspective is informed by the theory of strategic action fields (Neil Fligstein/Doglas McAdam). We started with the assumption that a change in governance structures has to find its expression in a change within the dominant actor constellation. Changes in actor constellations are the product of a period of contention. Actors from neighboring fields or the state attempt to change the existing field consensus and thus the position of the incumbent actors. Incumbent actors (like the four big energy providers in the German PV case) will try to defend their position and damage the position of the challengers. The outcome of such a process cannot be easily predicted. It depends on the ability of the actors to frame the situation in a light that is beneficial to their strategy, to organize around this frame and develop (innovative) instruments to push forward their aims even against resistance. For the case of Germany, we could show that the development of PV was dependent on the establishment of a new support coalition, which against the opposition of incumbent actors and interests, created a new form of governance for the promotion of renewable energies. The support coalition gradually broadened, and consists meanwhile of a broad, sometimes with respect to interests, diffuse group of actors, but which occasionally still succeed in formulating common goals. We can observe the development of a governance structure from bottom up.

The CCS technology in Germany on the other hand was supposed to be executed “from above” with the help of the established actors and networks consisting of energy providers, research institutes, hardware producers and political actors. They tried to push through a technological option against growing public opposition. The eventual failure to commercialize CCS is signified by the successful attempts of the opponents of CCS to organize and a lacking capacity of the established actors to co-opt them (like in Norway). The result is unorganized social space. In Norway the CCS development was driven forward by a broad coalition of actors which initially came primarily from outside the electricity generating sector. Successful co-optation strategies brought together a coalition of actors from neighboring fields, the general public and the incumbent actors.

	Field Change	***Field Stability***
Technology Adaptation	Norway/CCS	Germany/CCS
Technology Exploration	Germany/PV	Japan/PV

Table three: Technology and Field Development

PV development in Japan on the one hand was successful acknowledging that the main aims for spreading PV within Japan were realized. The aims were to promote the use of PV without any fundamental changes to the governance structure and the position of the incumbent actors. Of prime interest was to develop a new technology for export, which for reasons of establishing a point of reference, was also to be used in Japan. The effect, however, has been a constant, but comparatively slow development of domestic PV. PV plays a negligible role for electricity generation in Japan and no stable new market was built up. Prior to the Fukushima accident the contribution of renewables to the overall energy mix in Japan had actually decreased.

Within this article the case studies could only be presented in a highly stylized way. They hopefully served the purpose, nevertheless, to show the validity of a new analytical approach to study energy transitions.

Bibliography

Alphen, van, Claas/Ruijven, van, Jochem/Kasa, Sjur/Hekkert, Marko/Turkenburg, Wim (2009): The performance of the Norwegian Carbon Dioxide, Capture and Storage Innovation System. In: Energy Policy 37 (2009): 43-55

Anderson, Kent/Nottage, Luke R./Wolff, Leon T./Yamanaka, William (2008): Japan's Gradual Transformation in Corporate Governance. Research Paper No. 08/29. Sydney: Sydney Law School

Beckert, Jens (2007): The Social Order of Markets. In: Theory and Society 38 (2009), 245–269

Benz, Arthur/Lütz, Susanne/Schimank, Uwe/Simonis, Georg (eds.) (2007): Handbuch Governance. Theoretische Grundlagen und empirische Anwendungsfelder. Wiesbaden: VS Verlag

Benz, Arthur/Dose, Nicolai (2010): Governance – Regieren in komplexen Regelsystemen: Eine Einführung. 2nd. Ed. Wiesbaden: VS Verlag

Bergek, Anna/Jacobsson, Staffan/Hekkert, Marko (2008): Functions in innovation systems: A framework for analysing energy system dynamics and identifying goals for system-building activities by entrepreneurs and policy makers. In: Foxon, Timothy/Köhler, Jonathan/Oughton, Christine (eds.): *Innovation for a Low Carbon Economy: Economic, Institutional and Management Approaches.* Cheltenham: Edward Elgar, p. 79-111

Boyer, Robert (2003): The Embedded Innovation Systems of Germany and Japan: Distinctive Features and Futures, in: Yamamura, Kozo/Streeck, Wolfgang (eds.): The End of Diversity? Prospects for German and Japanese Capitalism. Cornell: Cornell University Press, 147-183

Carlsson, Bo (Ed.) (1997): Technological Systems and Industrial Dynamics. Boston/ Dordrecht/ London: Kluwer Academic Publishers

Carlsson, Bo/Stankiewicz, Richard (1991): On the nature, function and composition of technological systems. In: Journal of Evolutionary Economics, 1(2), p. 93–118

Coenen, Lars /Diaz Lopez, Fernando.J. (2010): Comparing systems approaches to innovation and technological change for sustainable and competitive economies: an explorative study into conceptual commonalities, differences and complementarities. *Journal of Cleaner Production*, 18(12), p. 1149-1160

Dosi, Giovanni/Freeman, Christopher/Nelson, Richard/Silverberg, Gerald/Soete, Luc (eds.) (1988): *Technical Change and Economic Theory*. London/New York: Pinter.

Fligstein, Neil/McAdam, Doug (2011): Toward a General Theory of Strategic Action Fields. In: Sociological Theory 29: 1, 1-26

Fligstein, Neil/McAdam, Doug (2012): A Theory of Fields. Oxford: Oxford University Press

Fuchs, Gerhard (2012): Path Dependence and Regional Development: What Future for Baden-Württemberg? In: Georg Schryögg/Jörg Sydow (Hrsg.): The Hidden Dynamics of Path Dependence. Institutions and Organizations. Houndmills: Palgrave Macmillan, 178-196

Fuchs, Gerhard/Shapira, Phil (eds.) 2005: *Rethinking Regional Innovation*, Springer, New York

Fuchs, Gerhard/Wassermann, Sandra (2012): From Niche to Mass Markets in High Technology: The Case of Photovoltaics in Germany, in: Bauer, Johannes M./Lang, Achim/Schneider, Volker (eds.): Innovation Policy and Governance in High-Tech Industries, Berlin, Heidelberg: Springer, 219-244

Gould,Stephen J (2002): The Structure of Evolutionary Theory. Cambridge: Harvard University Press

Hall, Peter/Soskice, David (Hrsg.) (2001): *Varieties of Capitalism*. Oxford: Oxford UP

Hekkert, Marko P./Suurs, Roald/Negro, Simona/Kuhlmann, Stefan/Smits, Ruud (2007): Functions of Innovation Systems: A new approach for analyzing technological change. In: *Technological Forecasting and Social Change*, 74 (4), p. 413-432

Henderson, Rebecca/Clark, Kim (1990): Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Existing Firms. In: *Administrative Science Quarterly,* 35(1), p. 9-30

Jacobsson, Staffan/Lauber, Volkmar (2006): The politics and policy of energy system transformation – explaining the German diffusion of renewable energy technology, in: Energy Policy 34 (2006), 256-276

Jahn, Detlef (1992): Nuclear power, energy policy and new politics in Sweden and Germany, *Environmental Politics* 1,3, 383-417

Kersbergen, Kers/ van Waarden, Frans (2001): Shifts in Governance. Nijmegen: NIG

Mahoney, James/Thelen, Kathleen (2010): A Theory of Gradual Institutional Change. In: Mahoney, James/Thelen, Kathleen(eds.): *Explaining Institutional Change: Ambiguity, Agency, and Power.* Cambridge: Cambridge University Press, p.1–37.

Malerba, Franco (ed.) (2004): *Sectoral Systems of Innovation.* Cambridge: Cambridge University Press.

Markard, Jochen/Truffer, Bernhard (2008): Technological innovation systems and the multilevel perspective: towards an integrated framework. In: *Research Policy*, 37(4), p. 596–615

Martin, John Levi (2011): *The Explanation of Social Action*. Oxford: Oxford University Press.

Mayntz, Renate/Hughes, Thomas P., (eds) (1988): *The Development of Large Technical Systems.* Frankfurt a. M.: Campus.

Mayntz, Renate (2004): Governance Theory als fortentwickelte Steuerungstheorie? MPIfG Working Paper 04/1. Max Planck Institut für Gesellschaftsforschung, Köln

Mayntz, Renate (2009): The Changing Governance of Large Technical Infrastructure Systems. In: Mayntz, Renate (ed.): *Über Governance. Institutionen und Prozesse politischer Regulierung.* Frankfurt / New York: Campus, p.121-150.

Meyer, John W./Rowan, Brian (1977): Institutionalized Organizations: Formal Structure as Myth and Ceremony. In: *American Journal of Sociology* 88, 340-63

Padgett, John/McLean, Paul (2006): "Organizational Invention and Elite Transformation: The Birth of Partnership Systems in Renaissance Florence," American Journal of Sociology 111: 1463-1568

Pahle, Michael (2010): Germany's dash for coal: Exploring drivers and factors, in: Energy Policy 38, 3431-3442

Ristau, Oliver (1998): Die solare Standortfrage. Der technologische Wettstreit zwischen den USA, Japan und Deutschland, Bad Oeynhausen: Bröer-und-Witt-Solarthemen

Rogge, Karoline/Hoffmann, Volker (2009): The impact of the EU ETS on the sectoral innovation system for power generation technologies – Findings for Germany, Paper submitted to DIME Workshop on "Environmental Innovation, Industrial Dynamics and Entrepreneurship, May 10-12, 2009, Utrecht, Netherlands

Schulz, Marlen/Scheer, Dirk/Wassermann, Sandra (2010): Neue Technik, alte Pfade? Zur Akzeptanz der CO2- Speicherung in Deutschland. In: GAIA 19(4), 287-296

Scott, W.R. (2001): Institutions and Organizations. 2nd edition. Thousand Oaks, CA: Sage

Shum, Kwok L./Watanabe, Shiro (2009): An innovation management approach for renewable energy development – the case of solar photovoltaic (PV) development. In: Energy Policy (37), 3535-3544

Umweltbundesamt (2011): Strommix in Deutschland, in: http://www.umweltbundesamt.de/energie/archiv/strommix-karte.pdf, zugegriffen am 10. September 2011

Verbong, G.P.J. & Loorbach, D. (Eds.). (2012). *Governing the Energy Transition : Reality, Illusion or Necessity?*. New York: Routledge

Victor, David G. (2002): Electric Power, in: Steil, Benn et al (eds.) Technological Innovation and Economic Performance. Princeton: Princeton University Press, 385-415

Vogel, Steven K. (2006): Japan Remodeled. How government and industry are reforming Japanese capitalism, Ithaca: Cornell University Press.