Germany: Challenges of a Full Transition to Renewable Energy

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Abstract The transformation of the German electricity sector to a near-total renewable supply ("Eneigiewende") by 2050 or earlier was embodied into law in 2012. This seemed to consecrate a development which began with the passage of the Renewable Energy Act of 2000. Naturally, such a major transformation needs considerable vision, and over time needs determination from political and social forces to overcome resistance from established ideas, interests, practices, and organizational arrangements. After a historical overview of the institutional politics of RES-E (renewable energy sourced electricity), this chapter will look at three major challenges that German politics and society was/is faced with: launching very rapid, indeed disruptive RES-E growth (disrupting carbon lock-in); building or maintaining political support and an actor network capable of supporting this change; and reshaping the electricity system to accommodate fluctuating generation by wind and solar power.

1 Introduction: The Political Context of RES-E Policy

The first Electricity Feed-in Law (*Stromeinspeisungsgesetz*) entered into force in 1991. It was only a first step, but it amounted to an important revision in the renewable energy policy of the Conservative (CDU/CSU)-Liberal government, which was in power from 1982 to 1998. This policy—formulated by the Ministry of Economic Affairs—limited support to renewable energy (RE) to R&D only,

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supposedly in line with market principles. The Feed-in Law changed this by supporting market creation at least in a modest way, something that few governments did at that time. It introduced tariffs differentiated by technology and the obligation of utilities to purchase renewable electricity at a price set by law as a percentage of household prices (65–80 % for small hydro, 90 % for wind and solar power). Parliament—where the law was introduced as a private member's bill, against the preferences of the government—passed it without opposing votes (Jacobsson and Lauber 2006).

When the Social Democratic–Green Coalition came to power in 1998, it was determined to decisively accelerate the deployment of renewable energy as well as to phase out nuclear power by about 2020. The Renewable Energy Act of 2000 (EEG or *Erneuerbare Energien Gesetz*) was a law for supporting the transition to renewable energy, among other things by making it easy for citizens to become RES-E producers, thanks to a modest but highly predictable revenue stream for 20 years, and a strong position vis-à-vis electric utilities that had to accept all RES-E on offer. Other political goals of the Act included the replacement of fossil fuel imports by a domestic high-tech industry providing innovation and employment. The adoption of this act was surrounded by intense conflicts: Conservatives and Liberals opposed the legislation because it supposedly went against the principles of the market economy and the EU Treaty, and vowed to overturn it in case they should return to power. Similarly, intense conflicts prevailed at the first important amendment to the Act in 2004.

After the 2005 parliamentary elections, Conservatives and Social Democrats formed a grand coalition government. Given the close election results, the two parties agreed to continue with EEG and the nuclear phase-out. In fact, the main actors' positions came to be more alike (Buschmann 2011). In 2007−2008, EEG underwent a reasonably harmonious amendment process ("EEG 2009"). Preparatory steps were taken to allow self-marketing and—for solar generators—self-consumption in the name of greater reliance on market integration, reducing the scope of support by regulation.

The 2009 elections produced the first Conservative-Liberal coalition since 1998. The Liberal leadership (though not the majority of its voters) had opposed EEG all along while in opposition. Within the Conservatives, the economic wing[1] had maintained some scepticism but had become more moderate after 2005; the environmental wing wanted to maintain EEG on condition to further strengthen market integration. But in 2009, the two parties agreed on thoroughly revising RES-E policy and on postponing by about one decade (until around 2030) the nuclear phase-out decided in 2000. This led to several efforts to slow down RES-E deployment between 2009 and early 2013. The postponement of the nuclear phase-out in late 2010 was meant to be the key to reducing market space for renewable electricity.

[1] As opposed to the environmental wing of the party.

The Fukushima accident led to a policy U-turn on this point in the spring of 2011 (i.e., to reinstating the earlier nuclear phase-out) but the efforts to slow down RES-E continued nonetheless, even gaining in intensity in 2012 and 2013. It became clear that opposition against fast RES-E growth had intensified in the ranks of the Conservative–Liberal government; on the other hand, the chiefs of the *Länder* (territorial subunits) represented in the upper house of parliament strongly supported even faster growth and in 2012 forced the government to a compromise. In early 2013, a government proposal to cap the EEG surcharge which passes on the supposed extra cost of renewable electricity to consumers challenged basic elements of EEG; however, a decision was postponed until after the September 2013 elections.

2 The Challenges Unfolding Over Time

We view challenges as situations requiring commitment and/or major decisions which are crucial for a full transition to renewables but did not come easily to the actors of the political system caught in their own logic. These actors are political parties and state structures with their drive for power, their ideological and policy traditions and positions privileging a certain clientele; a great variety of economic actors (from electricity incumbents to highly differentiated new entrants into the field of renewable energy), citizens with their values and beliefs, environmental organizations, churches, etc.

The first challenge was to launch the rapid growth of RES-E deployment on a trajectory that would in principle allow the near-total replacement of fossil and nuclear sources in time to cope with peak oil and mitigate global warming, by installing a regulatory framework capable of setting the necessary incentives. This challenge was met in the period 2000–2004.

The second challenge was to build or maintain political support and an actor network capable of supporting this change. Political support for wholesale transition to renewables was already evident in public opinion surveys in the 1990s, and it remained so until early 2013. At the same time, it was important to convey the idea that renewable energy—and the equipment for generating it—could be produced domestically, even give rise to a whole new sector of industrial activities with new employment and exports. Such a sector would also be a natural ally of *Energiewende* against the attacks that could be expected from incumbents. Finally, costs needed to be plausibly justified and kept down to acceptable levels. This became a problem around 2009, a time when photovoltaic installations surged beyond all expectations and drove up costs and imports of modules from abroad, and led to intense political controversies in the subsequent years. But PV was not the only cause of the problem, as we shall show.

The third and most recent challenge which has only emerged in the present and has not been dealt with so far is to develop appropriate structures to deal with the problem of fluctuating generation by wind and solar power installations, and more generally to design a new electricity market scheme which—while no longer geared to the needs of fossil generation—will allow such generation to survive even as it is gradually phased out, a process likely to take some decades.

2.1 Challenge One: Launching "Disruptive" RES-E Growth with an Appropriate Regulatory Framework

2.1.1 Targets to Build Confidence and Commitment

The first challenge was to launch the rapid growth of RES-E deployment on a trajectory that would displace fossil and nuclear sources in time to cope with peak oil and mitigate global warming, by installing a regulatory framework capable of setting the necessary incentives.

This occurred in 2000 with the adoption of the Renewable Energy Sources Act or EEG and the more or less simultaneous decision to phase out nuclear power taken in 2000–2002. The explanatory memorandum attached to EEG (FME 2000) speaks of the urgency to shift to a sustainable energy supply to deal with the problems of environment and climate change, the problems of dependence on and costs of fossil fuel imports, the potential of an innovative industrial policy to create jobs and development, the need to compensate for external costs and subsidies of conventional generation and finally the need to break the vicious circle of high RES-E equipment prices and small production volumes by launching mass production. There was a target for 2010 (to at least double total renewable energy production) but the act clearly aimed further.

Soon, a pattern developed regarding RES-E targets and their fulfilment. RES-E deployment—all technologies taken together—regularly exceeded the targets laid down in the Renewable Energy Act and its 2004 and 2008 amendments; this was welcomed by the Ministry of Environment (which in 2002 took over the RES-E agenda from the Economic Affairs Ministry) and led to yet more ambitious targets. Thus, the goal of EEG 2004 was for renewable electricity to reach a 20 % share by 2020 (Section 1 of EEG 2004; see BMU 2004); actually this was reached in 2011. EEG 2008 proclaimed a 2020 target of 30 %. This was stepped up by the Conservative-Liberal government before it proclaimed the need to moderate deployment.

In its energy concept of 2010 (BMWT and BMU 2010), this government for the first time set long-term targets for RES-E growth (*see* Table 1). These targets were enshrined in EEG 2012 which was adopted in mid-2011 (EEG 2012a[2]).

In mid-2012, just a year after the unanimous adoption of that act, many *Länder* chiefs protested against the low level of ambition reflected in this target and the drastic plans of the government to impose regional caps on wind and solar growth,

[2] Another EEG amendment was adopted in mid-2012 (here referred to as EEG 2012b).

Table 1 RES-E targets in Energy Concept 2010 (BMU 2011) and in EEG 2012a, b

Target ("at least"), %	Deadline ("at the latest")
35	2020
50	2030
65	2040
80	2050

constraining many new *Länder* plans prepared after Fukushima. In 2012, the share of RES-E was about 23 %, up from 17 % just 2 years earlier. Environment Minister Altmaier proposed to slow down deployment, supposedly to avoid problems of energy balancing, grid stability and costs, by means of target corridors[3] on deployment on a regional basis, especially for wind and solar power. The heads of the *Länder,* determined to implement their recent deployment plans, disagreed strongly with this approach (Zeit online 2012). In June, however, in a compromise in the parliament's conciliation committee, they agreed to a 52 GW cap on PV (EEG 2012b). Once this limit is reached, EEG-style feed-in tariffs will no longer apply to PV; new support rules should be announced in time (PV capacity reached 30 GW in the summer of 2012). But the *Länder* chiefs opposed a similar cap, or regional allocation of new capacity, for other technologies, particularly for wind power. The federal government then started a negotiation process with the *Länder* chiefs to find a consensus during 2013, to be reflected in a new EEG amendment after the 2013 parliamentary election. This reflexion process was interrupted when the Liberals launched the conflict over the EEG surcharge described below.

2.1.2 Tariffs and Other Regulations to Stimulate Broad Deployment

The feed-in tariff system of the EEG is based on several principles which were designed to stimulate aggressive RES-E deployment: differentiated and highly predictable prices for RES-E based on a "full cost" model of an efficient installation; unlimited purchasing obligation and priority dispatch by grid operators; costs borne by electricity consumers, not taxpayers; and administrative simplicity. This was supplemented by low-cost credit and a highly predictable permitting system. The whole system was also meant to compensate RES-E generators for the fact that fossil and nuclear operators do not pay for substantial external costs and are/were subsidized on top of that (see Sect. 2.2).

The adoption of the feed-in tariff contained in the 2000 Act placed a clear emphasis on effective deployment. This tariff was highly differentiated by source (wind power, PV, biomass, etc.); size and vintage of the installation; quality of the site (for wind power). Tariffs were designed so that all well-built and well-

[3] Corridors are evolving targets with a minimum and a maximum value.

managed plants could expect to produce a reasonable return on investment (while not defined in any law, figures ranging around 6–9 % were discussed in this context). This meant that different technologies could be deployed simultaneously, not just the cheapest (such as waste combustion, which proved important under quota-cum-certificate systems), so they could all progress downward on the learning curve simultaneously. Windfall profits in the best locations were limited by differentiating for size (PV, hydro, biogas) or locational qualities (wind). Annual degression meant that the tariff paid for any given installation does not change for 20 years while subsequent vintages received somewhat less to accelerate learning by putting pressure on the RES-E equipment industry, which otherwise was expected to benefit from steadily expanding demand for its products. The fact that the tariff was laid down by a formal law and thus by parliament[4] offered a good guarantee against abrupt changes.

Unlimited purchasing obligation means that grid operators have to connect all RES-E installations in their territory and purchase all RES-E tendered to them at the tariff laid down in the law, without need for a contract. Grid operators in turn had to give priority dispatch status to RES-E, before taking on fossil or nuclear power.

The extra cost of the feed-in tariff to the grid operator is paid by electricity consumers in form of a surcharge, with no part of it coming from the state budget (something that conservative politicians frequently ignored in their criticism). Budget contributions would probably not have remained in place for so long, given the problems of public finances and of state aid.

All this created a simple, stable support system that made it possible for many people to become RES-E generators. Indeed, just more than half of all RES-E capacity is owned by private individuals and farmers (trend:research 2011, 45). With EEG in place, banks were perfectly happy to give loans for such a secure investment. A public development bank—KfW (Kreditanstalt für Wiederaufbau)—played an important role in providing low-cost loans to cover part of the necessary funds. Approximately 1.3 million people were engaged in renewable electricity installations (mostly PV) as owners or investors in late 2012 (Fig. 1).

Additional support came from the construction code which privileged RES-E generation installations, and from a regulation that required local communities to set aside zones appropriate for wind power ahead of construction requests. Tax regulations contributed to local support for RES-E projects since 70 % of the local industry tax on wind farms go to the community where the turbines are located, even if the owner resides elsewhere (Witt 2012a).

[4] In some countries support is set by administrative decrees which are changed more easily, something that tends to deter RES-E equipment producers. An attempt to introduce this in Germany just for PV was turned down by parliament in 2012.

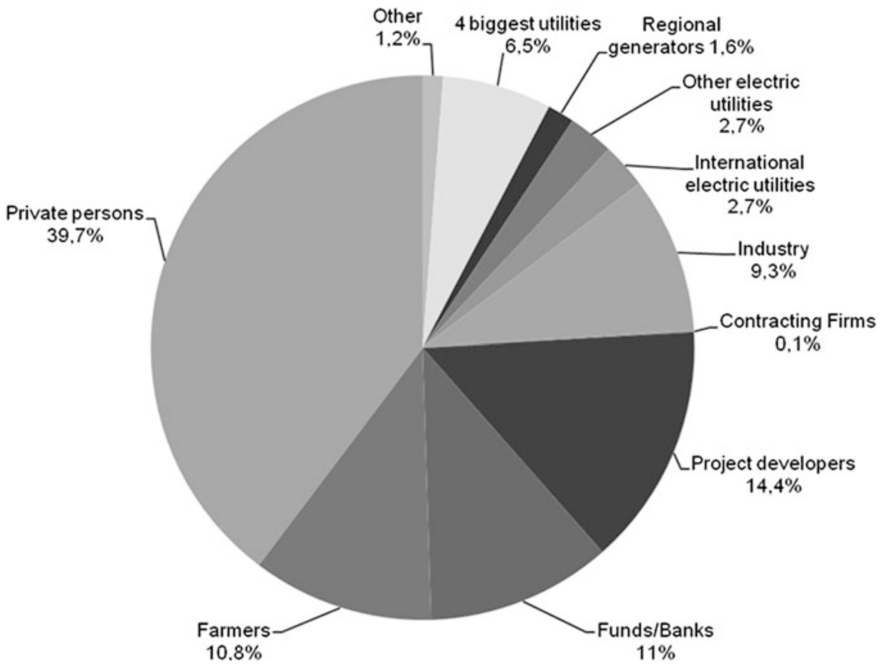

Fig. 1 Ownership structure in 2010 of renewable electricity installations in Germany (not including pumped storage) (Total installed capacity: 53.0 GW). *Source* Trend:research (2011)

2.2 Challenge Two: Ensure Political Support for a Long-term Deployment Framework

This challenge includes maintaining support by the public by making clear the larger goals and objectives at stake, keeping costs at acceptable levels, secure support by political parties and setting up networks that have an active interest in RES-E growth, particularly industries related to RES-E equipment production or installation, plus potential and actual owners of RES-E installations.

At the intellectual and emotional level, support for a transition to renewables was very strong in Germany even before the advent of the EEG; this is illustrated by a large number of surveys. Chernobyl, acid rain, and climate change made a deep impression in Germany and inspired various citizen movements. Many of them were looking for real-life alternatives to fossil and nuclear power. This was true for early groups working on biogas and wind energy back in the 1970s and 1980s; in the 1990s, similar groups paved the way for photovoltaic power by motivating municipal governments in a number of cities to require their electricity companies to provide special compensation for citizens producing electricity from PV installations on their roofs. Involvement with and support for renewable energy became remarkably widespread.

Of course, there were also critical stories in parts of the press of ugly wind farms and hugely expensive solar panels, but they were usually met with criticism and were not taken too seriously. Still, in the case of wind energy, it was felt in 2004 that onshore expansion could not continue much longer; this led to an increase for offshore wind. The dire predictions by electricity incumbents regarding high costs of balancing energy, dangerous grid problems, and enormous costs were soon disproven.

Once the Environment Ministry was in charge of renewable electricity (after 2002), it published valuable information about the cost of renewable power, its growth and its contribution to economy, environment, and society. During the years of the Conservative-Social Democratic coalition (2005–2009), the Conservatives seemed to arrive at a pragmatic acceptance of EEG although they maintained their commitment to a stronger market orientation. Even the Liberal Party leadership was instructed to support EEG by a vote of its membership at a party convention in May 2009, following a motion from the floor. However, it reneged on this commitment not very long afterwards. When in fall 2009, the Conservatives and Liberals formed the new government, their radical course on energy policy (postponing the nuclear phase-out, curtailing RES-E growth) came somewhat unexpected.

By that time, however, several new developments had changed the picture: the financial crisis of 2008 made for a new sense of financial fragility, and the PV surge in 2009 started to impact surcharge payments; worse, the share of imported modules (mostly from China, and quite possibly due to dumping or export subsidies incompatible with WTO rules) increased, while German cell and module producers entered a period of substantial difficulties; even some prominent firms (Solon, Q-Cells. Bosch) went bankrupt or left the business. This upset one of the political rationales underlying EEG, namely that EEG was supposed to replace imported fossil energy by domestic RES-E.[5] At the same time, the merit order combined with the new expansion of wind and solar electricity reduced prices on the electricity exchange and thereby drove up the EEG surcharge (which covers the difference between tariff payments and the sales value of EEG electricity on the exchange).

Finally, the Conservative-Liberal government generously increased exemptions from the surcharge for industry; this too increased the surcharge which is paid mostly by households. The net result was a steep rise of the surcharge for which the government, in rather simplistic but effective fashion, blamed the high extra cost of renewables, ignoring the other factors. In fall 2012 for the first time, a poll showed that a majority of respondents considered the surcharge to be excessive. This proved to be a window of opportunity for the energy conservatives of the governing coalition calling for a fundamental reorientation (*see* below).

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[5] While German cell and module producers shrank, silicon and PV production equipment producers did well, partly due to strong Chinese demand; also, installers are usually local. Some observers estimate that close to two thirds of PV investments in Germany are still German-made.

Support for RES-E and more particularly EEG undoubtedly benefited from the ownership distribution of RES-E capacity (see Fig. 1). The "Big Four" oligopolists dominating electricity supply[6] rely on coal and nuclear generation and have been fighting EEG (and its predecessor law StrEG) for over two decades. But by 2010, all utilities taken together owned only 13.5 % of renewable capacity, while private persons and farmers owned about half of it. There were about 1.3 million RES-E generators in Germany in early 2013. They cannot be passed over easily. If RES-E deployment goes on, the Big Four will most likely fall behind even further (Becker 2011).

More support comes from the associations of business and labour in the areas of RES-E equipment and installation industry, farmer associations, and the big environmental and nature protection associations. Employment in the sector rose from some 66,000 jobs (AGEE 2011) to about 380,000 jobs in 2011 (FME 2012, p 49). After Fukushima, most *Länder* governments also became strong advocates of rapid RES-E deployment, taking the opposite course from that of the federal government.

2.2.1 Containing the Cost of EEG and Energy Transformation

From the beginning, the supposed extra cost of renewable energy deployment was one of the major arguments of its opponents. In the late 1980s, the Economic Affairs Ministry opposed RES-E market creation via feed-in tariffs with the argument that this would become a case of perpetual subsidies (Jacobsson and Lauber 2006). Most of the extra cost comes from feed-in tariffs and takes the form of a surcharge on electricity bills paid mostly by households and small business. Due to recent increases and also because of the Conservative-Liberal government's politicising this issue, acceptance of this surcharge became a significant problem for the first time in 2012.

Since 2010, the surcharge consists of the difference between the payments of grid operators to RES-E generators according to the EEG and the price they receive from the sale of EEG electricity on the exchange (where it is sold as gray, not as green electricity). From 2003 to 2009, it rose from 0.41 to 1.13 Eurocent/kWh. In the four subsequent years though it increased steeply to 5.3 ct in 2013, even faster than the RES-E share in total electricity generation (see Fig. 2).

Many critics—particularly from the Liberals or the business wing of the Conservatives—concluded that the cost of energy transformation was getting out of hand, supposedly due to rapid growth of PV installation. But the full story is quite different and considerably more complicated.

First, the (operational) costs of conventional generators used here do not include external costs. If those costs were included, only offshore wind and some

[6] The four oligopolists are E.on, RWE (Rheinisch-Westfälisches Elektrizitätswerk), Vattenfall Germany and EnBW (Energie Baden-Württemberg).

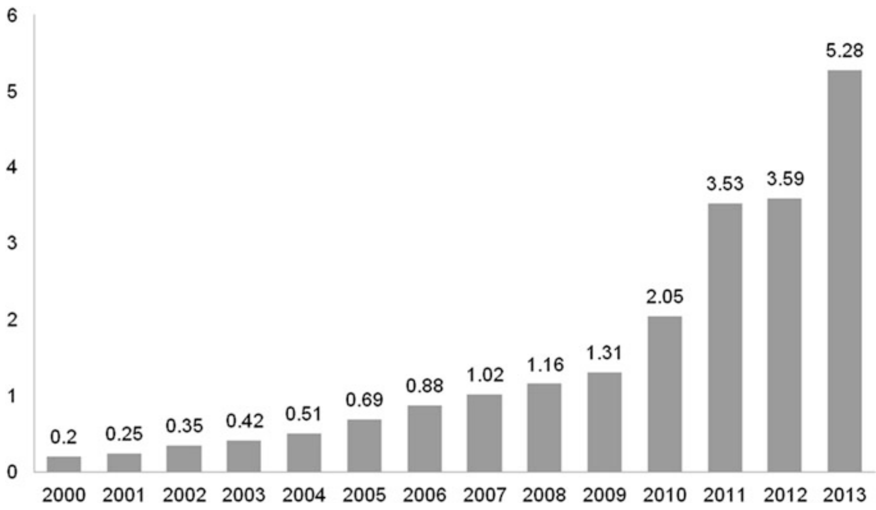

Fig. 2 Evolution of RES-E surcharge, 2000–2013 in ct/kWh. *Source* Ahmels (2012), p. 15

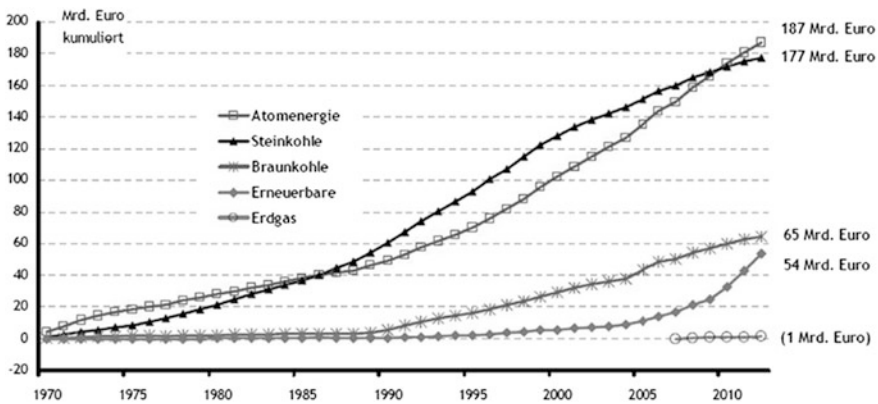

Fig. 3 Cumulated state subsidies to nuclear, hard coal, lignite, and natural gas generation and support for renewable generation including EEG support, 1970–2012. *Source* Küchler and Meyer (2012)

PV would still need EEG support in 2013. Küchler and Meyer (2012), relying on a study by Fraunhofer ISI (2012), report the following external costs: 8.9 Eurocent/kWh for electricity from hard coal, 10.7 ct/kWh from lignite, 4.9 ct/kWh from natural gas. For nuclear power, Küchler and Meyer (2012, p 25) assume a range of 10.7–34 ct. By comparison, the external costs for RES-E are: wind, 0.3 ct, hydro 0.2 ct, PV 1.2 ct. By January 2013, tariffs for bigger PV plants were below the full cost of coal.

Second, the operational costs for conventional generation do not include subsidies—i.e., extra cost of fossil and nuclear (direct financial support, tax breaks, other regulations with positive financial impacts such as free CO_2 certificates). Applied to electricity generation only, from 1970 to 2012, hard coal received 177 billion Euro, brown coal 65 billion and nuclear energy 187 billion in such subsidies, financed mostly via taxes from the state budget and—unlike the EEG surcharge—not communicated to the electricity consumer. Total support for new RES-E so far amounted to 54 billion, including payments outside the EEG such as government R&D funding or low-cost loans (Küchler and Meyer 2012, see Fig. 3). Clearly, those subsidies extending over several decades helped conventional generators to establish their market dominance. But in most public debates of *Energiewende*, only RES-E carries "extra costs".

Third, the calculation method of the EEG surcharge not only does not take the price reducing effects of renewable generation on electricity spot market prices into account ("merit order effect," *see* Sensfuß et al. 2008), but turns them into price increases—disproportionately so for small consumers. Under the merit order, generators are dispatched according to their marginal cost of operation. Given its marginal costs close to zero, wind and solar power push the more expensive thermal plants out of the market; this reduces overall prices at the exchange. This same price reduction then increases the difference between feed-in tariffs and spot prices and thus increases the surcharge by the same amount.

Fourth, a large number of industrial firms (theoretically "energy-intensive and exposed to international competition") are practically exempted from this surcharge. This exemption, originally introduced in 2003 by the red-green coalition for a limited number of firms, was expanded by later governments and finally doubled again by the current government in 2012 (Nestle und Reuster 2012, pp 14–15) and includes railroads, breweries, a fast food chain, etc. Small consumers paid already about 0.6 ct/kWh for this in 2011 and proportionately more in 2012. At the same time, industrial firms benefit from the lower prices resulting from the merit order system plus the lower costs of carbon emission certificates as RES-E reduces certificate demand from idling fossil fuel power plants. By contrast, household consumers do not benefit from the merit order effect as there is a lack of competition among suppliers. In fact, exempted industrial firms now pay lower electricity prices due to RES-E deployment, not higher ones. Yet the political rhetoric of the "energy conservatives" portrays industry as a victim of EEG.[7] On the whole, the surcharge no longer reflects the "extra cost" of RES-E growth accurately (see Fig. 4).

There is, however, one factor in RES-E supply that really did affect the surcharge in a major way, at least temporarily: The surge of PV in 2009 and 2010 when module price declined rapidly while tariffs were still governed by the relatively slow degression (about 9 % annually) of EEG 2009. New installations surged to a

[7] In late November 2012, the European Commission announced state aid proceedings against the EEG exemptions.

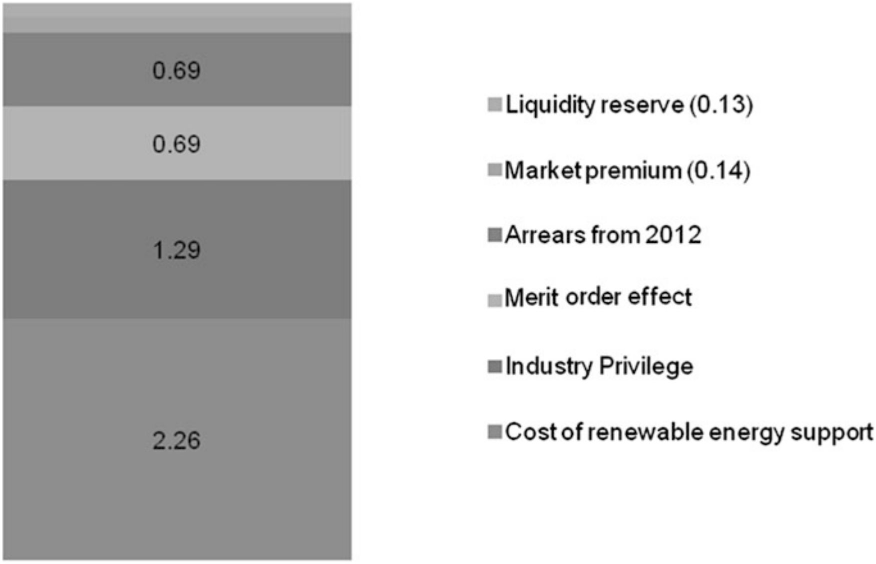

Fig. 4 Breakdown of renewable electricity surcharge paid by consumers in 2013. *Source* Ahmels (2012), p. 62

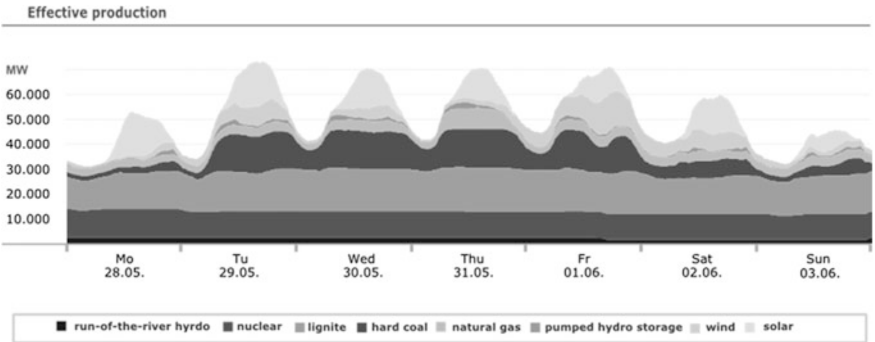

Fig. 5 Breakdown of electricity generation by source of daily loads during a sunny week in May/June 2012 (28 May through 3 June). *Source* Burger (2012), slide 192

level about six times higher than expected—7,400 MW in 2010. PV became the biggest cost item of the EEG surcharge increase in 2010. Many prominent members of the renewable energy research community feared that the legitimacy of this act might be seriously affected and in late 2010 RES-E wrote an open letter to the government to reduce this growth to acceptable limits (Figs. 5 and 6).

Between spring 2010 and summer 2012, the government responded to the PV surge by cutbacks of tariffs and by making degression strongly dependent on new build. The idea was to cut new annual installations to about 3 GW. Still, new

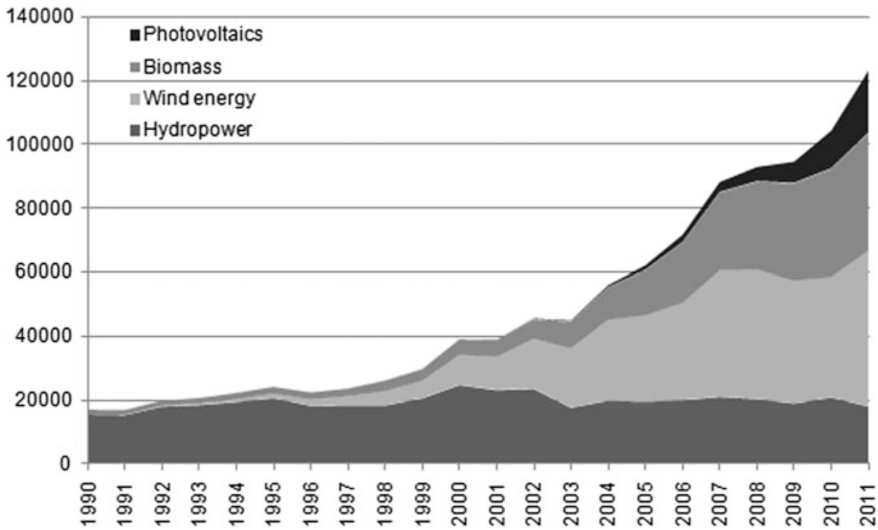

Fig. 6 Development of renewable-based electricity generation in Germany, 1990–2011, in GWh. *Source* FME (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety) (2012)

installations in 2011, after a record installation of 3 GW in December, remained at the level of 2010. Even though new PV tariffs had already declined considerably by early 2012, reducing the impact of further PV installations on EEG costs, the economic wing of the Conservatives and many Liberal leaders[8]—most of them advocates of the life extension for nuclear power in 2010 and still regretting its phase-out—responded to the December figure with demands for more radical steps, in particular a firm cap of 0.5–1 GW on new annual installations and a more drastic reduction Liberal Economic Affairs Minister. Rösler at first had even demanded a 40 % cut in one step (Süddeutsche Zeitung 2012). This time Environment Minister Röttgen (author of the flexible cap regulation) had to yield. He now proposed reducing new PV build to 0.9–1.9 GW by 2017 (BMU 2012) as well as stepping up flexible degression which in the extreme case would have driven PV tariffs down to 2.9–3.16 ct/kWh in 2018 (Witt 2012b).

Eventually, the reform was made more moderate by the *Bundesrat*, the upper chamber of the German parliament in which *Länder* governments are represented and which voted against the bill by a two-thirds majority (a rare event[9]) which included Conservative-governed *Länder* from East Germany (chief location of the

[8] This included Michael Fuchs, one of the leaders of the Conservatives (CDU) in the lower house of parliament, and Rösler, Economic Affairs minister from the Liberal Party.

[9] In this case the *Bundestag* (lower chamber) also needs a two-thirds majority to override the *Bundesrat* (upper chamber) should the latter make a formal objection. The government could not have achieved such a majority.

solar cell and module industry) whose leaders protested against a policy that was bound to lead to deindustrialising their region. The compromise made tariff degression more moderate (*see* above), set an overall hard cap for EEG tariff support at 52 GW (higher than in the Bundestag bill; a new form of support would be developed in time), and obtained the assurance from the government that it would step up R&D for PV and launch a support program for batteries to store PV power. It also asked for (but did not obtain) a local content regulation to help German producers (Broer 2012a, b); but minister Altmaier subsequently came out in favor of anti-dumping proceedings.[10] Outraged at the compromise, the Liberals claimed that it was time to eliminate EEG principles such as priority feed-in or fixed rates; only the market could stop this systematic waste. As most PV critics, the Liberals chose to ignore its rapidly declining cost and hence the limited impact of new PV installations on consumers.

The surcharge crisis of 2012 intensified in January 2013 with renewed Liberal attacks on EEG. Repeating a demand by EU Energy Commissioner in summer 2012, Liberal Economic Affairs Minister Rösler called for a cap on the EEG surcharge; this had the potential of bringing deployment to a halt. Altmaier eventually gave in and called himself for a "stabilization" of the surcharge at its 2013 value. At a summit meeting in late March 2013, the *Länder* chiefs turned down the federal government's plans; EEG reform was postponed until after the parliamentary elections of September 2013. These plans had the potential of seriously undermining EEG implementation.

2.3 Challenge Three: Fluctuating Renewables and a New Electricity Market

Another challenge had emerged by this time: the clash between fluctuating renewables and inflexible nuclear and coal generation.

Before electricity liberalization, Germany's power plant portfolio consisted of two types of power plants. First, base load plants with almost no operating flexibility, combining high fixed costs with low marginal costs, such as nuclear or lignite plants. Second, power plants covering medium or peak load, not only more flexible but also more costly to operate, mainly fired with hard coal or natural gas. Planning and dispatch of power plants was in the hands of big energy utilities which at the same time controlled the electricity grid. RES-E was negligible.

Market liberalization did not really change the use of power plants. The daily load curve reflected marginal prices on the electricity exchange, leading to power plant operations according to merit order. Hours with low demand meant low prices at which only plants with low marginal costs could operate profitably. Hours

[10] Provisional anti-dumping duties were imposed by the European Commission in June 2013.

of high demand and high prices meant that power plants with high marginal costs could also achieve profits.

The recent rise of RES-E sources with fluctuating production and priority dispatch challenged this electricity market order dramatically. Daily load peaks are filled more and more with electricity from PV. Within a foreseeable future, demand for electricity from fossil fuels will no longer peak parallel to overall demand and high prices, thus reducing revenue for fossil plants; the peak for overall demand may even come to coincide with a trough for fossil demand and prices. The surging supply of renewable electricity with priority dispatch and marginal costs close to zero led to a significant wholesale price decrease on the electricity market (IZES 2012). Increasingly, natural gas and to some extent hard coal plants operate profitably only when high demand coincides with low production from wind and solar. As a result, the average operating times of these power plants—particularly at peak hours with their higher prices—fell dramatically in 2011 and 2012, bringing even written-off power plants into trouble. Thus, E.on, Germany's biggest utility, in November 2012 announced the closure of two big gas fired power plants[11] due to lack of profitability. So far, only hard coal and natural gas plants suffer from the decrease in operating hours. With further increases in RES-E generation, lignite power will come under pressure as well. The incumbents are bound to press for a solution that will remedy this problem from their perspective.

The post-Fukushima shutdown of old nuclear plants had led many to expect that Germany would face higher electricity prices, increase fossil generation, and import electricity to avoid blackouts. None of this happened after the first 2 months: prices went down, and so did fossil generation (strong reduction of natural gas use for power generation, slight increase for coal), while electricity exports reached an all-time high, quadrupling between 2011 and 2012 (IWR 2012c).

Apart from the profitability problem, there is a bigger systemic problem: shutting down fossil fuel plants permanently may threaten the security of supply. These power plants are still needed, e.g., on cold winter days with low wind speeds and little sun radiation but high electricity demand, at least until electricity storage becomes available on a large scale. In order to avoid blackouts in such situations, many politicians and experts call for a so-called "capacity market" under which operators of such plants are paid (e.g., via tenders) for standby power. As fluctuating production increases, more and more fossil capacity would need some financial support to remain on standby.

One possible way to deal with this situation—proposed, e.g., by the utilities' association BDEW—would require the following market design: In keeping with

[11] The plants Staudinger 4 and Irsching 3. In 2011, Staudinger 4 (622 MW) had only run for 65 h under full load, Irsching 3 (415 MW) 41 h. Strangely enough they were not even started up in December 2011 when one of the blocs of nearby nuclear plant Grundremmingen had an emergency shutdown; instead E.on—one of the four oligopolist, see fn. 9—imported electricity from a more distant and more expensive plant in Austria (IWR 2012a).

the current practice (electricity exchange based on merit order system relying only on marginal costs of production), RES-E installations with almost no marginal costs such as wind, solar, and hydro power are the first to be dispatched. Since this is likely to lead to regional over-investment in those technologies, regional caps on such sources could be envisioned, or reductions in compensation payments for RES-E which cannot be fed into the grid. To make sure that enough fossil fuel capacity is available without displacing electricity from renewable energies, power plants could be dispatched centrally by the grid operator (as currently for balancing energy). Generating technologies able to offer stand-by power—such as power plants fired with fossil fuels or biomass but also hydro storage plants—would draw additional revenue from auctions for maintaining standby power capacity.

The federal government favors a different solution: A decree of October 2012 requires fossil generators to announce their intention to retire a particular plant 12 months ahead of time; during this period, the Federal Grid Agency may reject such a retirement while providing for appropriate compensation for keeping the plant on standby (IWR 2012b). In both cases, the new design means eventually a phase-out of inflexible, base load-only power plants—such as nuclear and lignite power (Fraunhofer ISE 2012).

But the fluctuation problem can also be handled quite differently. A special market section not based on marginal costs could be set up for wind, solar, and hydro (Leprich and Hauser 2013). Fossil generators would still be subjected to marginal cost-based merit order, but at one point, shifting to 100 % RES-E will require renouncing fossil solutions unless carbon capture and storage enters the picture, which at present does not look likely in Germany. Various forms of power storage (from 6 h storage to seasonal storage, with storing an electricity surplus in summer and withdraw it in winter) and of other technologies capable of balancing demand could then deal with the fluctuation problem. This would require a significant expansion of storage capacity, which currently is limited in Germany. Hydro storage currently has a maximum capacity of about 7 GW and about 40 GWh (corresponding to less than two full load hours of total installed PV generation in mid-2012); this is about to be expanded by some 50 % over the next decade. Biomass power plants could add about 5.3 GW of capacity if equipped with the necessary storage facilities.

Some relief is available from hydro storage facilities in France, Switzerland, and Austria (Fraunhofer ISE 2012, pp 46–50). There is the idea of using Norway's vast hydro storage facilities—much bigger than storage facilities in Germany—for pumped storage to serve the German (and other European) markets. However, this would require not only installing pumping facilities but also vast power lines on land and across the sea (which could be coordinated with offshore wind build-up); a first cable linking Norway and Germany is scheduled for completion by 2018 (Fraunhofer ISE 2012, p 47).

Combined heat and power plants could serve both as generators and as sinks for RES-E electricity, transforming it into storable heat. Battery storage and pressurized air storage are further possibilities for short-term storage. Power-to-gas and power-to-liquids storage are at present more costly and less efficient, but could be acceptable if limited to supplementing highly efficient intra-day storage (Rasmussen et al. 2012; Welter 2012). They would draw on the surplus generation available during the summer from PV. The gas grid alone would allow storage of about 200 TWh (Welter 2012, p 50)—many times more than hydro storage can achieve. If capacity payments to standby fossil power plants are not to constrain progress towards these and other solutions (Fraunhofer ISE 2012), it will be necessary to design a new electricity market scheme which while no longer geared to the needs of fossil generation will allow a diminishing share of such generation to survive during its period of gradual phase-out (which may well last for several decades).

It seems likely that promising market designs will have to deal with the need to reform an electricity market based on marginal (operating) costs while fluctuating sources destined to supply the biggest share of electricity have mostly investment costs and nearly no operating costs. Integrating RES-E at its pure operating costs would drive prices toward zero and would not allow recuperating RES-E investment costs. Hence, the need to provide separate selection mechanisms (the counterpart to the current merit order) for RES-E, fossil generation, and storage systems (Leprich and Hauser 2013).

3 Discussion—Conclusions

Out of these three challenges, Germany has certainly met the first one very successfully (launching “disruptive” growth with an appropriate framework).

As regards the second challenge (securing acceptance and support), things seemed to go quite well until 2009 when the global overcapacity crisis of PV and Chinese market conquest made the EEG formula of replacing imported energy with domestic RES-E problematic. The Conservative-Liberal government coalition in power since 2009 reduced excessive PV tariffs (Bundesverband Solarwirtschaft 2012) though it kept treating PV as if it were still extraordinarily expensive. But deeper problems were also developed; falling exchange prices for electricity paradoxically drove up the surcharge, industry privileges did the same. Utilities and energy conservatives blamed it all on PV.

As to the third challenge (dealing with fluctuating generation and reforming the electricity market), it is too early to say how well Germany is doing on this account. It is struggling with the fossil standby power solution but has also launched a big research program for electricity storage. Success in our view would mean keeping the existing system viable (including the maintenance of sufficient fossil back-up capacity) while not impeding further growth of RES-E toward the 80–100 % target. Much of the transformation is a question of visions and imagination, technical, political, legal, and organizational. Though a huge project, it is far from being just a top–down process. In some ways, it resembles a huge citizen initiative, a bottom–up movement that is transmitting its energy to the political system and may actually be displacing an electricity system which combined industrial concentration, political connections, high profitability, and oligopolistic market power with a certain amount of insensitivity on social and environmental issues (Becker 2011). It is no wonder that the radical nature of its challenge would meet with opposition at some point. The year 2013 is likely to become a fateful year for *Energiewende*.

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