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Electricity Policy – the website ElectricityPolicy.com and the newsletter Electricity Daily – together comprise an essential source of information about the forces driving change in the electric power industry.

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Germany has committed itself to closing its remaining nuclear power plants by 2022 and to essentially eliminating fossil fuels from its power sector by 2040-2050. To implement the latter, Germany has been aggressively supporting the deployment of renewable energy since about 2000. With over 37 GW of solar PV, Germany is now the world leader in installed capacity, one of the top countries with respect to renewable capacity in absolute and relative terms more broadly, and more or less on track to meet its goals.

The consequence is an ongoing and fascinating experiment in how rapid changes to an electric system impact both reliability and cost. After more than a decade of strong support for renewables to support this "Energiewende" (energy transition), US-based observers are increasingly drawing lessons from this experiment. Perhaps unsurprisingly, these lessons tend to conform neatly to each analyst's prior beliefs (or affiliations) and consequently tend to portray Germany's experience to date as either a model of how to transition to a fossil free electricity sector, or as an unbridled disaster to be avoided at all cost.

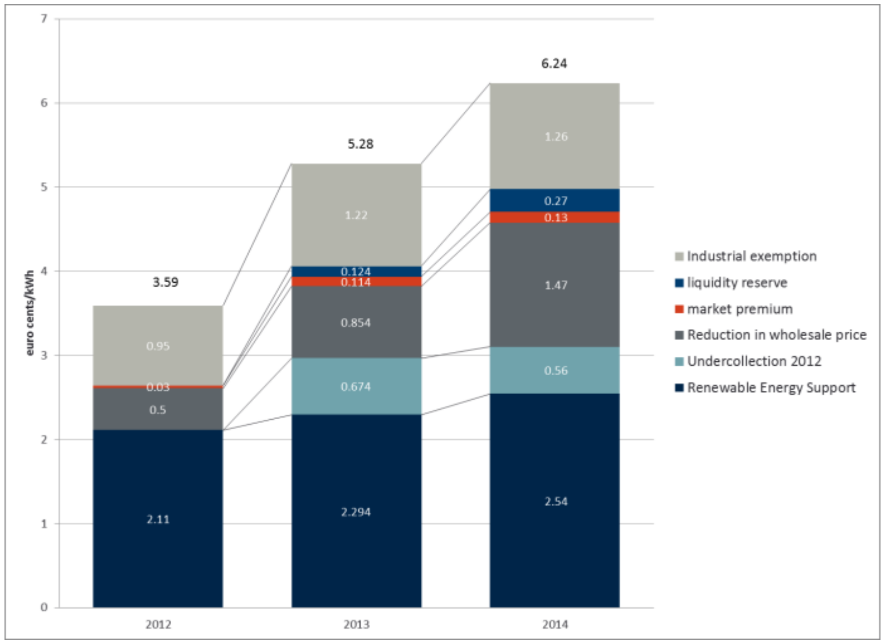

Figure 1a: German renewables levy (nominal)

Earlier this year, I was asked by the Solar Energy Industry Association (SEIA) to take an in-depth look at the German experience. Similarly EEI commissioned a report from a Swiss M&A consulting firm and the Brooking Institute issued a study looking at the experiences of both Germany and Japan.

The NARUC annual meeting in San Francisco this past November included a panel discussion on the topic, intended to identify a set of common themes from all of these reports and to examine the range of potential interpretations. In short, the question of what if anything can or should be learned from a decade or renewable support in Germany has been identified as relevant by many US observers, independent of their perspective, warranting a somewhat deeper look.

Ambitious goals broadly supported

Before drawing parallels (or a lack thereof) between the German experience and that of the United States, it is important to understand that the relatively aggressive policies to increase renewable generation in Germany are part of a larger and long-term national strategy to de-fossilize the power sector (and the economy overall) between now and 2050. This strategy is enshrined in German and European law, which sets aggressive targets of 40% renewable energy in the power sector by 2020 and 60% by 2030

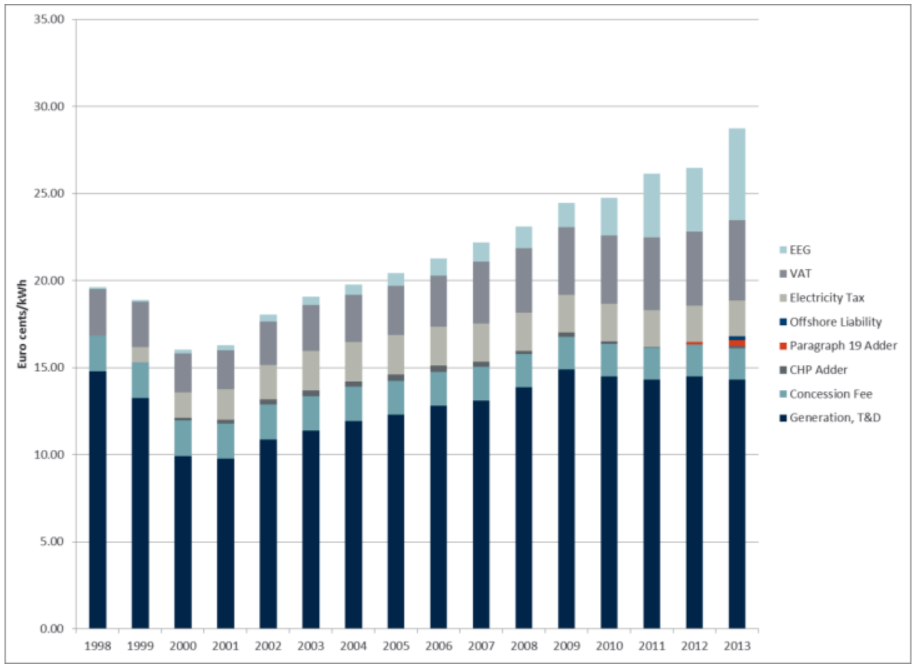

Figure 1b: German residential retail rates (nominal)

(and essentially 100% by 2050). However, and perhaps even more importantly, it is also very broadly supported by the general population, as is the decision to phase out nuclear power by 2022—a decision taken quickly and definitively after the Fukushima accident, but based on a long-term uneasy relationship with nuclear among the general population. This does not mean, however, that there aren't interest groups lobbying hard for their points of view, or that politics is absent from the energy debate in Germany. Just like in the United States, people (and companies) prefer lower to higher energy costs, and utilities are worried about recovering their investment costs.

What's really happening?

To understand what (if any) lessons can be learned from the German experience, it's important to understand how German renewable support actually works. At a basic level, Germany has been using a system of Feed-in Tariffs (FITs), which guarantee the owners of renewable energy projects a fixed price per kWh of generation over 20 years. These FITs are set according to the dictates of technology and adjusted over time, more frequently in recent years (as a result of changes to the law) than early on. The FIT payments are made by the four transmission system operators (TSOs) for the renewable generation, which is measured using a separate meter (no net metering). The TSOs, in turn, sell the renewable energy that's purchased on the wholesale market. They collect, in addition to wholesale revenues, a renewables levy ("*erneuerbare Energie Umlage*," or EEG) from all their customers. The levy is set annually at a national level, with part of the levy making up for shortfalls or over-collections in previous years. In essence it is electricity consumers who pay the full cost of the renewable energy, with practically no taxpayer-funded support in the form of tax credits or rebates. Large electricity consumers operating in trade-sensitive industries are largely exempt from paying the renewables levy.

As **Figures 1a** and **1 b**[1] show, the renewables levy has been increasing over time, along with renewable energy, which is expected to approach 30% of total electricity production in Germany (in MWh) this year. The levy is currently above 6 eurocents per kWh and now represents about 20% of the total electricity rate for residential customers, which is above 30 eurocents/kWh.

Both the increase in levy and the amount of renewable energy produced, with corresponding impacts on the overall electric system, have led to a serious discussion about reform. This discussion is not over, but in the renewables area some reforms were implemented effective August 1, 2014. These reforms replace the FITs with a system that requires renewable projects to directly sell their output into wholesale markets. Renewable projects then receive a premium over market prices, differentiated by technology. The reforms also address certain issues associated with negative prices – e.g., no market premium can be collected if market prices remain negative for six or more consecutive hours – and envision a transition towards auctions for larger projects for all technologies after 2017. These reforms are by and large seen not as an acknowledgement of a failure of the previous system of support, but rather as a consequence of renewable energy having reached a level of scale and maturity that requires a different set of regulatory incentives. Related reform efforts

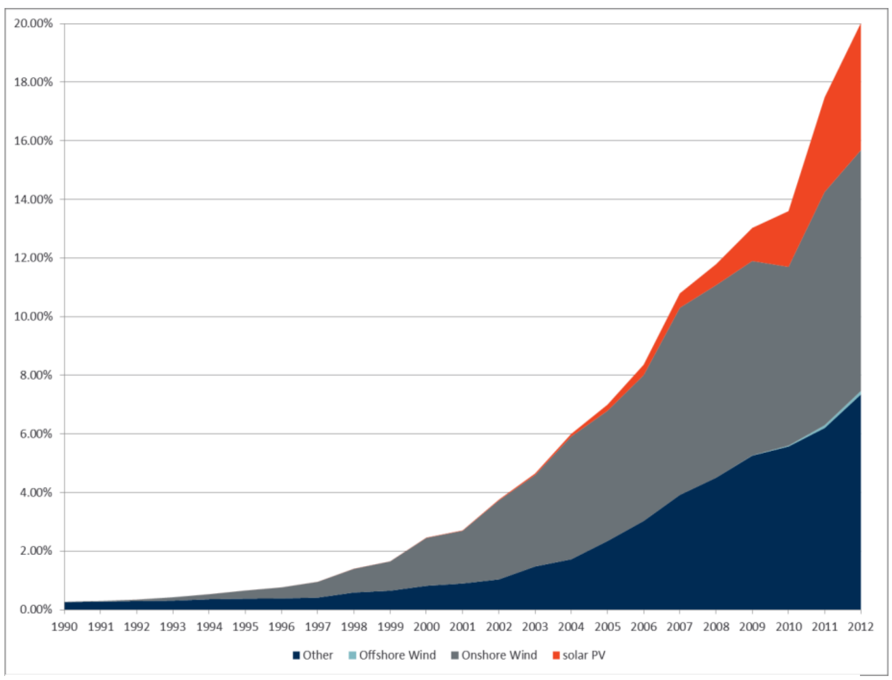

Figure 2: Renewable energy as share of Germany's total electricity production

[1] Sources: Bundesverband Erneuerbare Energien, BEE-Hintergrund zur EEG-Umlage 2013, BDEW Strompreisanalyse November 2013, Worldbank (GDP Deflators), *The Brattle Group* analysis.

of broader energy markets, including the question of whether or not some form of a capacity market is needed, and the design of an "electricity market 3.0" are ongoing and expected to lead to further changes in 2016 and 2017.

The experience in fact

So what has happened in Germany, really? First, as shown in **Figure 2**[2], above, renewable energy production under the system of FITs has increased very rapidly indeed. Germany is on track to meet its 2020 and longer term goals. Importantly, relative to those goals, the ramp-up is just about sufficient to meet those goals, assuming that deployment over time cannot be sped up significantly.

Over the past decade Germany's retail prices, especially for residential customers, have increased significantly, having approximately doubled since 2000. Several important issues need to be kept in mind, however. First, while the renewables levy remains significant, its 6.24 eurocents per kWh amounts to about 20% of the total rate, yet is only one of the factors that have led to the currently high residential tariffs. Other rate components, notably various taxes and fees, have increased at least as rapidly and represent a comparable 20% share of the residential retail rate. Given this, German residential rates would be very high compared to typical US rates even without any renewables levy.

Perhaps most importantly, while Germany's rates average nearly three times those of average US rates, average electricity usage per household is about one-third of the average US usage, so that household expenditures as a percentage of disposable income are quite comparable. Part of the difference in usage is likely idiosyncratic – Germans have smaller houses and are much more likely to live in apartments – but part is also a deliberate effort to increase already substantial energy efficiency efforts, which are in part a response to high rates. While few would argue that it would be in the interest of the US to triple residential electric rates, especially over a relatively short period of time, it is nonetheless important to keep in mind that higher rates don't translate one-for-one into higher expenditures, since higher rates do promote more energy efficient behavior.

Another reason why residential rates are high is that energy intensive customers working in trade-sensitive sectors are partially or entirely exempt from paying the renewables levy. The result is not only higher residential rates than would exist without these exemptions – since residential customers in essence cross-subsidize those firms – but also that some key German industrial sectors have been relatively

[2] Source: ZSW, Zeitreihen zur Entwicklung der erneuerbaren Energien in Deutschland, Dec. 2013; *The Brattle Group* analysis.

insulated from the costs of ramping up renewables. In fact, the large amount of renewable energy injected into the grid has led to strong declines in wholesale prices, along with flat or declining demand and sharply increasing supply. This benefits the largest users of electricity, who are not only exempt from the renewables levy, but also can buy directly from the wholesale market. As a result, claims that Germany's renewables policy has had catastrophic effects on the German economy are difficult to support. The German economy has done better than most other EU member states, with unemployment rates lower than those in the US, and with record exports.

Germany's support for renewables is likely not a major reason for this performance. Even though the renewable energy program is in part industrial policy and creates many jobs in renewable and related industries, it is not clear that the overall policy can be considered a big success in those terms. For example, Germany has lost much of its solar panel manufacturing to China. On the other hand, Germany holds a large global market share for the machines used to manufacture solar panels. In sum, while support for renewables has probably not been a huge success in terms of industrial policy, it also has not had a demonstrable negative impact on the German economy.

The FITs have been quite cost-effective in attracting renewable energy investment when compared to alternative approaches, such as quota regimes (like RPS) or tax incentives, i.e., the two primary mechanisms for supporting renewable energy development in the United States. The rapid rise in Germany's renewable generation has been extraordinary. Given the country's ambitious and in theory legally binding targets, the relevant question is not whether the FIT was expensive relative to not building out renewables, but rather whether it was more expensive than some other realistic policy.

Since Germany didn't use alternative policies at the same time, the question is hard to answer empirically. What can be said, however, is that compared to other FIT systems, notably the ones employed in Spain and Italy, Germany's system seems to have done relatively well, with the notable exception that between 2009-2011 FITs did not decline in step with the rapidly declining costs of solar PV. Since the FIT payments are guaranteed for 20 years, this resulted in significant financial commitments above those that were likely needed to attract the same levels of solar PV. In that sense, Germany became victim to one of the trickiest issues with FITs – the famous Goldilocks problem: for them to work and not be overly costly, they need to be set "just right." In the 2009-2011 time frame, costs declined much faster than the FIT was adjusted, resulting in a very large amount of solar PV being installed at what turned out to be quite generous FIT levels when compared to actual costs. Since then, Germany has modified its FIT adjustments. Over the past few years they have been adjusted downwards much more frequently in response to observed levels of installation. FIT levels decline more rapidly if installation levels increase more rapidly than anticipated.

A separate issue that is often brought up is that the rapid increase in renewable – in particular, solar – generation is hurting utilities. Today's wholesale prices paid to generators are indeed too low to cover the costs of many of Germany's fossil-fueled power stations. As a result, the share prices of Germany's large publically traded electric utilities have fallen sharply. For example, shares of E.On, Germany's largest utility, have lost 50% of their value since 2010. This likely prompted E.On's decision, announced in early December 2014, to spin off its nuclear, coal, oil and gas businesses, while focusing on renewable energy.[3] The share price of RWE, Germany's second largest utility, has fallen even more rapidly.

Also, low wholesale prices are leading to the retirement or mothballing of significant amounts of fossil-fueled generating capacity, including precisely the relatively new and flexible natural gas-fired plants originally assumed to be needed to integrate the increase in renewable generation. However, it would be inappropriate to put the bulk of the blame for this situation on Germany's renewable energy support policy.

First, low electricity prices represent not only the additional supply from renewable capacity, but the large amount of excess capacity already in the market, and in many ways made worse by the investment decisions in new fossil generation by German utilities over the past decade, *i.e.*, at a time when Germany's renewable targets were already well understood.

Second, the failure to reform the European Union Emissions Trading Scheme (EU-ETS) has led to very low CO_2 allowance prices, which, given the much higher natural gas prices in Europe when compared to the US, meant that new and flexible natural gas-fired power plants are the least profitable and were naturally at risk to be shut down or mothballed.

A third important topic concerns the impact of rapidly increasing renewable generation on reliability or resource adequacy. This issue has a short-term and longer-term component. The longer-term question is whether with much lower wholesale prices the current market design will provide sufficient incentives for new generation – and the right kind of generation – to be built when older plants and especially all the nuclear generators retire. The German government is in the middle of determining whether significant reforms to existing market rules, including potentially the introduction of some kind of a capacity market mechanism, are needed to

3 See, e.g., http://www.dw.de/german-energy-giant-eon-to-focus-on-renewables/a-18104023

ensure long-term resource adequacy. These discussions mirror similar discussions in the United States, perhaps most directly those in Texas, which, like Germany, has a fully liberalized retail market and an energy-only wholesale market.

> *The longer-term question is whether much lower wholesale prices under the current market design will provide sufficient incentives for new generation to be built.*

In the short run, most parties including the government and the TSOs have concluded that the intermittency of the existing renewable generation can be managed with existing tools. This conclusion is remarkable in itself, given that Germany will have a renewables share of close to 30% in 2014, a level often deemed to be high enough to cause serious strain on the management of power grids. It is worth noting that, in addition, the German electricity system experiences just 10% of the outages of the US and has been and continues to be extremely reliable. Over the past few years, reliability, as measured by scores like SAIDI (System Average Interruption Duration Index), has actually increased even as solar PV capacity has skyrocketed.

Nonetheless, as the share of intermittent renewables has grown, so has the need for the TSOs to use market-interventions such as renewables curtailments, re-dispatching and contracting for additional reserves to maintain the high level reliability Germans are used to. Current efforts to reform both incentives for renewables and the broader energy market framework as well as a significant program of strengthening the transmission systems are seen as required longer term actions, since re-dispatching and renewables curtailment are seen as both undesirable and ultimately more costly as the share of renewables continues to increase. It is important to emphasize that at present the short-term measures used by the TSOs to deal with intermittent renewable generation are both sufficient to maintain high levels of reliability – for example, the TSOs have explicitly stated that there is no need to build new capacity to maintain reliability – and relatively inexpensive, with less than €100 million per year spent on such measures, a tiny fraction (less than 0.5%) of the over €20 billion in annual FIT payments for renewables.

The Real Lessons

So what can or should the US learn from observing Germany's rapid move towards a very high share of renewable generation in the electricity sector? First, Germany is likely relatively unique among large economies in its population's collective belief that transforming its electricity (and broader energy) sector, away from fossil fuels and nuclear and towards renewable energy will be in the long-term interest of Germany and hence worthy of short-term sacrifice. Many of Germany's policies must be understood in that context. Since the US in general, and even most individual states, likely lack this sort of overwhelming support for such a view, it is unlikely that Germany's approach could be embraced here.

As renewable technologies gain market share, it is important to strengthen the incentives for renewable generation to be located in the right places.

Many of the technologies Germany has been supporting to transition to a low- or no-carbon electricity system are beginning to compete economically with conventional fossil power generation, even without generous subsidies. Since especially solar PV is typically a distributed resource – and the vast majority of solar PV systems in Germany are connected to the distribution grid – these technologies highlight a potential shift away from a model primarily based on central station power supply. It also provides deep insights into the potential impacts – both negative and positive – on a shift of generation from the transmission to the distribution level, including impacts on distribution system reliability.

Undoubtedly German policy has hastened the more rapid emergence of renewables and distributed generation broadly as a part of this growth, with the consequences on rates, utility stock prices and reliability challenges discussed above. Even though the Energiewende proceeded in large part because of broad public support, it is likely that even where there is less overwhelming support, as in the US, the same technologies will exert increasing disruptive pressure on the US electric system. In places with lots of wind or sun, this is already happening, as evidenced by the fact that PPAs signed with solar and wind resources in some parts of the US are at prices so low they would be cheaper than conventional power even without the support of tax credits, accelerated depreciation, or renewable portfolio standards. Germany's efforts to reform both its renewable support and its overall market design in response to increasing penetration levels therefore may serve as a preview to what may ensue in the United States. And how well Germany does in adapting its system to those changes may be instructive for the US and help avoid costly mistakes.

Yes, a FIT that adjusts more quickly to renewable technology cost declines would have helped Germany save billions of dollars in support payments. The lesson here is that where support is needed –

and a good case can be made for such support based both on climate and other environmental externalities, as well as on market failures associated with development of new technologies – the design of support systems matters. On that front, properly designed FITs are likely more effective and more efficient that tax instruments or quota systems, especially during the ramp-up phase of new technologies.

But the more important lessons are likely forward looking. As renewable technologies gain market share, it becomes important to strengthen the incentives for renewable generation to be located in the right places (for example by moving away from support that focuses on maximizing output to maximizing value), that strike the right balance between generating electricity and providing ancillary services. For example, both solar and wind can provide regulation down, i.e. reduce output rapidly in response to short-term declines in demand – and wind may be able to provide both regulation up and down, i.e. increase or decrease output in response to very short term changes in demand, by rotating the blades away from or into the wind. These are examples of flexibility that can be bolstered with incentives, as may be necessary, for each component of the power system to minimize total cost.

There is an immense body of work remaining in Germany and in the US – for example, in fixing less-than-optimum functioning energy and ancillary services markets, by rewarding flexibility, by increasingly taking advantage of demand-side measures, and by encouraging optimization over larger geographic areas to take advantage of resource diversity and flexibility. Germany is in the midst of trying to figure out how to deal with many of these issues. The US would be wise to follow the developments there carefully. ■

Much work remains in designing energy and ancillary service markets, to reward flexibility, take advantage of demand-side measures, and encourage optimization over larger geographic areas.