Solar Energy Support in Germany

A Closer Look

PREPARED FOR

Solar Energy Industries Association

PREPARED BY

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THE Brattle GROUP

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Executive Summary

The Solar Energy Industries Association ("SEIA") asked *The Brattle Group* to prepare a report outlining the major lessons learned from the past decade of solar PV energy support in Germany.

Recent reports about the rising cost of Germany's feed-in tariffs (FITs) for solar PV and about resulting reform efforts have led some to view the German solar support programs as having been too expensive, resulting in oversupply of solar PV, having led to an unreliable electric system, having hurt the competitiveness of the German economy, or all of the above, and hence as being a poor role model for other countries to follow.

The costs of Germany's renewable support (including solar PV) program have indeed been significant – and higher than expected - and the success of those programs have led to penetration levels of renewable energy sources high enough to require modifications to both the renewable program itself and to overall electricity market design. However, a closer look at the German solar support program and its impacts shows that those programs, while having had some flaws (now in need of correction), have proven relatively successful, especially given Germany's overall commitment to significantly and rapidly expanding renewable energy production.

The core of Germany's solar PV program consists of a set of FITs for solar PV installations of various sizes ranging from residential rooftop installations to utility-scale projects. FITs guarantee a fixed compensation for electricity produced from solar PV facilities for a period of 20 years. The program requires that transmission system operators (TSOs) purchase all the power produced from these PV systems. TSOs in turn sell the power on wholesale markets and are made whole through a renewables levy ("EEG-Umlage" in German), which is collected from most customers. Heavy electricity users in trade-sensitive areas are (partially) exempt from this renewables levy. Under the program, solar PV installations have increased dramatically, reaching a total installed capacity in excess of 35 GW by year-end 2013.

Over the years and in response to unexpected growth in installations above expectations, the program has undergone several reforms, the most recent of which is currently awaiting final legislative approval. Previous reforms included a cap on aggregate solar PV capacity of 52 GW, after which support in excess of market revenues is supposed to end. At that point, electricity production from solar PV would represent about 7% of total German wholesale generation. The

35 GW of solar PV capacity installed at year-end 2013 represent about 2/3 of that target. With annual installations exceeding 7 GW in several of the past few years, the current reforms also introduce a narrower corridor of annually targeted solar PV additions between 2,500 MW and 3,500 MW[1] and automatic and frequent adjustments to the FIT downward, more strongly so if those target corridor levels are exceeded. Currently installed solar PV represents close to 20% of total installed capacity and close to 50% of peak demand[2] and has begun to have significant impacts on grid operations during periods of low demand and high generation from solar PV, such as during sunny spring weekend days. The current reforms therefore also include a number of measures gradually moving solar PV and other renewables towards being more tightly integrated with electricity markets. Finally, the increasing levels of renewable power generation have put downward pressure on wholesale prices received by existing fossil generators, which highlight both shortcomings of existing market rules – in terms of adequately incentivizing those plants needed to ensure reliability of supply – and the need to further adjust market mechanisms to ensure reliable supply in a system with a significant portion of intermittent power generation.

The primary lessons from the German experience are that a system of FITs such as the one used in Germany can be highly effective in promoting the growth of solar PV, that the impact on trade-exposed heavy electricity users can and perhaps should be mitigated, but that FITs for new installations should be adjusted regularly and perhaps automatically in response to observed relative to targeted deployment levels so as to avoid undue increases of electricity rates for retail customers.

In hindsight the German FITs for solar PV did not adjust quickly enough to rates of installations far in excess of what had been expected, even though reforms to the renewables law in response to those installations ultimately did introduce much more frequent and steeper reductions in those FITs, which allowed Germany to avoid a complete crash of PV installations along what happened in Spain and Italy. Several important lessons can be learned from the German experience.

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1 The annual additions between 2009 and 2013 exceeded this corridor: 4,446 MW in 2009; 6,988 MW in 2010; 7,485 MW in 2011; 7,604 MW in 2012 and estimated 3,600 MW in 2013.

2 Peak Demand is approximately 81.7 GW. See Bundesnetzagentur, Feststellung des Reservekraftwerksbedarfs für den Winter 2013/14 und zugleich Bericht über die Ergebnisse der Prüfung der Systemanalyse, September 16, 2013, page 14.

First, there is widespread acknowledgement that Germany's solar PV support program has been instrumental in bringing down the cost of solar PV. Since 2007, average installation costs have fallen from close to €5 per Watt to between €1-2 per Watt. In that sense, earlier investments are paying off in terms of much lower installation costs today.

Second, associating the high residential retail prices of electricity in Germany purely with the solar PV and other renewable support programs would be misleading. It is true that retail prices (for residential, commercial and small industrial customers) are among the highest in the world. However, while the renewables levy, now above 6 €cents/kWh, represents a significant portion of those rates of approximately 30 €cents/kWh, other tariff elements such as taxes and fees are of comparable magnitude and have increased at similar rates. Therefore, Germany's residential retail tariffs would be among the highest in the world even without paying for Germany's renewable let alone solar program.

Third, it is also true that payments for solar PV have increased substantially in the past few years. Until 2007, annual payments to solar PV installations under the FIT program remained below €2 billion, but increased rapidly to close to €10 billion by 2013 and are expected to increase to about €11 billion per year before leveling off and ultimately decline. To put these payments into perspective, assuming all power generation cleared at wholesale prices and given average wholesale price levels of €50/MWh, the value of total power generation in Germany would be approximately €30 billion per year. Total payments for solar PV generation therefore would represent almost 1/3 of these total costs for only about 5% of total power production. Measured against retail rates, on the other hand, payments under solar PV FITs represent about 10% of total sales[3], or roughly twice the share of PV production. Over the same timeframe, average FITs paid to new installations dropped from 47 €cents/kWh to 12 €cents/kWh. The increases in FIT payments were driven significantly by the large expansion of solar PV between 2009 and 2012. In hindsight, they can largely be attributed to downward adjustments to the FIT for new installations not being more rapid in response to installations exceeding targets. That being said, Germany's FIT was designed to be adjusted over time as needed, and it ultimately did. In that sense, Germany's FIT program for solar PV did not lead to the boom-bust cycle undergone by

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3 See Statistisches Bundesamt (German Statistical Office), which reports average final proceeds from the sale of electricity (excluding various taxes, but including network and renewable energy related charges) to be 14.74 €cents/kWh in 2012.

other countries experiencing rapid solar PV expansion under FITs, such as Spain and Italy.[4] Nonetheless, it would have been preferable to have designed automatic adjustments to the FITs based on known criteria at the outset rather than having to adjust the program on the go.

Fourth, it is important to note that heavy electricity users in industrial sectors exposed to international trade have been exempt from a significant portion of the renewables levy and generally face electricity prices in line with or even below other European competitors. In addition to the exemptions for this group of customers, heavy electricity users also benefit directly from decreasing prices on wholesale markets, caused primarily by solar and other renewable energy production and hence a direct by-product of the renewable support program. As a result, there is little reason to expect that Germany's solar PV support program has hurt the competitive position of German industry to date, including the relatively few remaining very energy intensive industrial sectors. While renewable energy policy likely remains a relatively minor contributor to Germany's overall economic performance, Germany is experiencing an economic boom with higher than ever exports and low unemployment rates when compared to most EU countries and also when compared to the United States.

Fifth, even if ex-post a somewhat optimized FIT design might have lowered the cost impact of Germany's solar PV program for retail customers (except the exempt industrial users), high costs incurred to-date are not a good reason to abandon the solar PV program now. Since PV costs have come down dramatically, at least partially as a result of the program, building the remaining roughly 16 GW of solar PV to reach the 52 GW target as part of Germany's broader commitments to lowering and ultimately essentially eliminating greenhouse gas emissions from its power sector will lead to only a very small additional costs to customers.[5]

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4 For an in-depth discussion of the Spanish and Italian experience and a comparison with Germany, see Pablo del Río and Pere Mir-Artigues, A cautionary tale: Spain's solar PV Investment Bubble, February 2014.

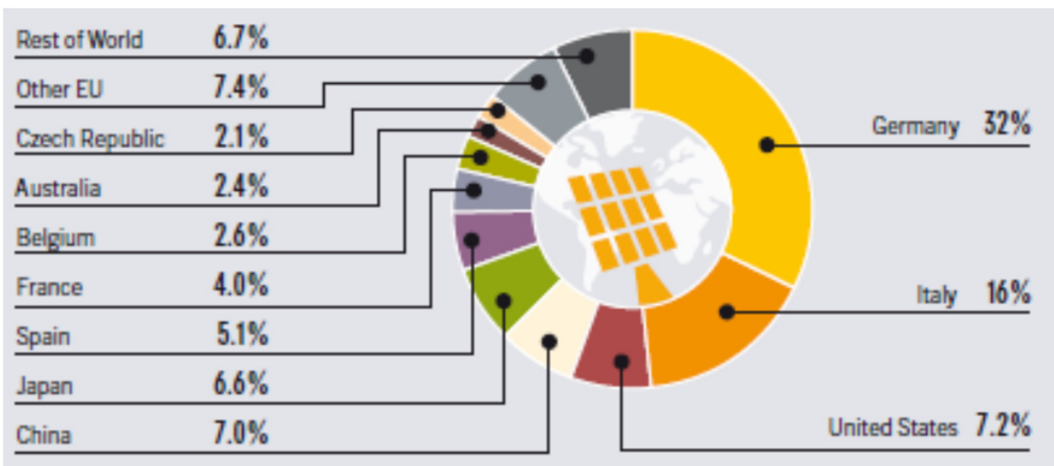
5 A full assessment of the incremental cost of additional solar PV to customers needs to go beyond estimating any incremental increases to the renewables levy, i.e. to the payment to compensate for the difference between feed-in tariffs and wholesale prices. Additional solar PV will likely lead to further reductions in wholesale prices, which directly benefit some customer groups (large industrial) and also result in customer savings partially offsetting higher any increases in the renewables levy. Also, incremental solar PV likely impacts investments at the transmission and distribution level and may impact other costs such as those for redispatch or for ancillary services.

Finally, the reform efforts of the solar PV and renewable support programs in Germany should not be interpreted as an acknowledgment of a broad failure of the Germany system of FITs. Rather, while the reforms are indeed an effort to improve the design of the FIT system, for example by introducing more rapid adjustments of FITs to observed deviations of actual from desired installation levels, they are also a sign of the solar PV sector maturing. Germany is unique among OECD countries in having managed to significantly increase the share of renewables in its electricity mix – by now a power generation share of some 25% has been reached. There is broad political support for a continued aggressive move towards an essentially carbon-free sector by 2050 with a renewables share above 50% by 2030. Therefore, after the *market introduction* phase, Germany is entering the *market penetration* phase of its renewables deployment, shifting from a primary goal of supporting the early technological development with an emphasis on affecting cost reductions through scaling and learning to a phase of developing complementary technologies and market mechanisms that make a future electricity system powered essentially by renewable technologies alone feasible. Aggressive greenhouse gas reduction targets are widespread, including in the United States. Germany's experience therefore likely provides an opportunity to "look ahead" and see how electricity systems and the rules governing them will have to adapt when penetration rates of various renewable energy sources reach levels similar to those in Germany today and beyond.

I. Introduction

By year-end 2013, Germany had installed 35.7 GW of solar PV capacity. With almost a third of global installed capacity, this makes Germany by far the country with the largest installed solar PV capacity, as shown in Figure 1 below. The 29.7 TWh of electricity produced by PV represented 5.7% of total energy production in Germany. At times, output from solar PV plants in Germany now covers in excess of 50% of demand.[6] Earlier this year, the European Commission initiated procedures against Germany for providing illegal state aid by exempting many industrial companies from paying for extra costs related to renewable energy support.[7] As of the writing of this report, negotiations between the federal government and the EC have however led to a solution.[8]

Figure 1: Global Installed PV Capacity (2012)



Source: Reproduced from REN21, Renewables 2013 Global Status Report, Figure 12.

Finally, Germany is in the process of fundamentally changing its system for supporting renewable energy development. The reform efforts are largely the result of the perception that the cost of renewable energy support has grown to unsustainable levels and also that after more

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6 See Fraunhofer ISE, Recent Facts about Photovoltaics in Germany, April 10, 2014

7 http://energytransition.de/2013/12/state-aid-investigation-into-german-renewables-surcharge-reduction/ (accessed May 28, 2014)

8 See http://www.europeanpublicaffairs.eu/germanys-energy-transformation-2-0-on-track-to-become-a-legislative-reality/ (accessed May 28, 2014) for a recent summary of the status.

than a decade and significant progress in renewable energy development the time has come to phase out support and begin the process of fully integrating renewable energy into the energy system without subsidies. However, the proposed reforms remain highly controversial in Germany. The perceived high cost of renewable support is at least partially viewed as a consequence of exempting significant portions of industry from paying "their fair share", and in part due to an increasing renewables levy ("EEG Umlage" in German) viewed in isolation. As of the writing of this report, the reform of the renewable energy law (EEG) is well underway, yet not completed. In April 2014, a basic compromise was reached and the government proposed a reformed renewable energy law with several key features. Notably, there continues to be consensus about the need to decarbonize the electricity sector. The proposed reforms contain goals of a renewable electricity share of between 40-45% by 2025 and of 55-60% by 2035.[9] The reform efforts also acknowledge that the original renewable energy law was successful. A review of the renewable energy law conducted by the government in 2011 explicitly states so, citing in particular the fact that Germany is unique among industrial countries in actually having accomplished a significant increase in the share of renewable energy in total electricity production.

Indeed, since 1990 the share of core renewable energy sources – biomass and biogas, wind and solar PV – in Germany has increased from essentially zero to 20% by 2012, as illustrated in Figure 2 below. The report also points to the fact that existing market structures were not designed to accommodate large amounts of intermittent renewable generation and hence need to be adapted going forward. It is suggested that as the share of renewable energy grows, renewable sources themselves should increasingly be capable of contributing to overall system stability.[10] The report also mentions that in the long run there is a question of whether or not existing market rules create sufficient incentives for investment in new generation capacity of any kind, an issue we return to later in this report. In summary, there is evidence that renewable energy support in Germany has been highly effective in significantly increasing renewable energy as a share of total electricity supply. As the share of renewable energy has grown, the cost of

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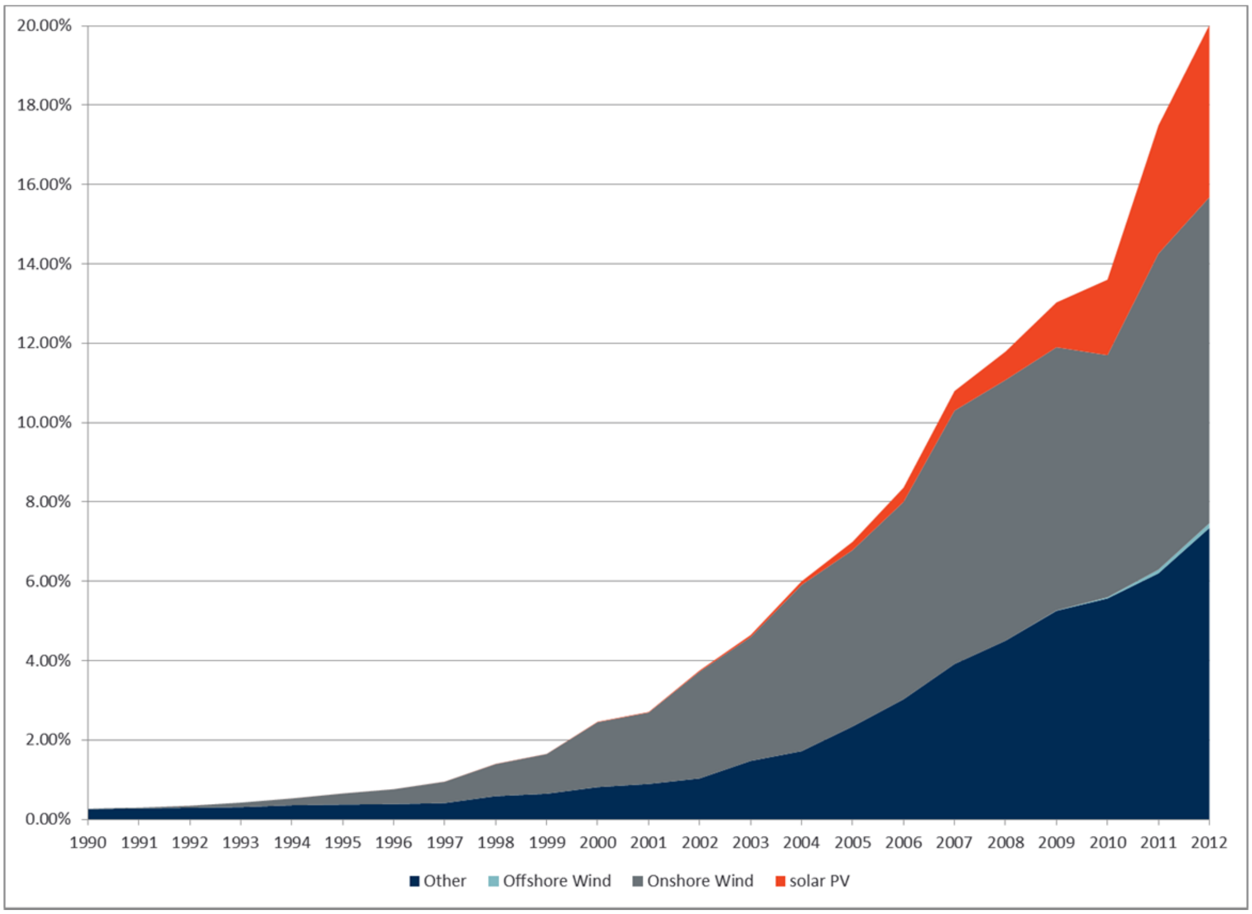
[9] Gesetzentwurf der Bundesregierung, Entwurf eines Gesetzes zur grundlegenden Reform des Erneuerbare-Energien-Gesetzes und zur Änderung weiterer Bestimmungen des Energiewirtschaftsrechts, page 2.

[10] Erfahrungsbericht 2011 zum Erneuerbare-Energien-Gesetz (EEG-Erfahrungsbericht) gemäß § 65 EEG vorzulegen dem Deutschen Bundestag durch die Bundesregierung, page 5.

supporting the total amount of renewable resources has also grown, and the achieved levels of renewable energy penetration begin to raise questions about future market design and renewable energy support. There seems to be relatively broad support for the notion that past programs have been successful. There is also some consensus that going forward changes are required, although there is an ongoing debate about what exactly those changes should be.

Figure 2: Evolution of renewable energy as a share of total electricity production in Germany



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

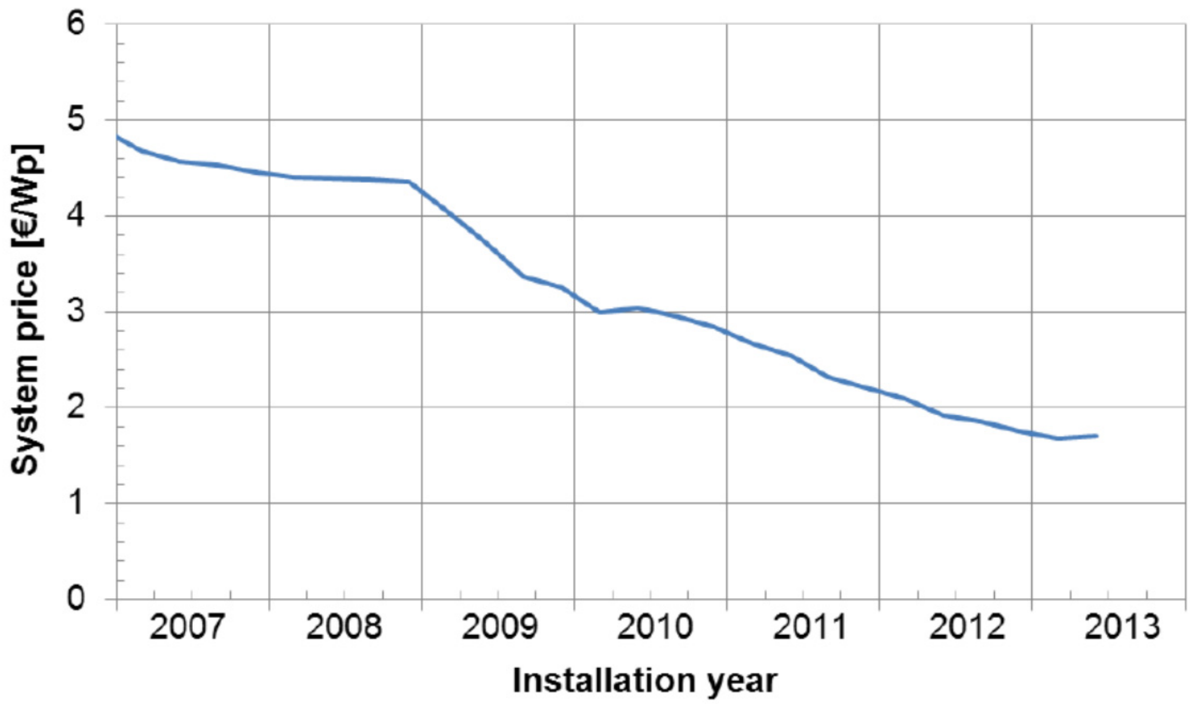
In the remainder of this report, we examine the German program for renewable energy (and in particular solar PV) support in more detail. In particular, we look at the impact of the German program on the cost of PV, on retail rates, on German competitiveness, on GHG emissions and on system reliability.

II. The Cost of Solar PV and Germany's FIT Program

A first and important topic relates to the cost of solar PV energy in Germany and the impact Germany's solar PV FITs, might have had on the evolution of PV costs.

As can be seen from Figure 3 below, the installed cost of solar PV systems in Germany has been declining steadily and significantly over the past decade. Installed costs between 2006 and 2013 declined by an average of 16% per year. By Q1 2014, the typical cost of solar PV in typical rooftop applications had fallen to € 1,640/kWp from over € 5,000/kWp in 2006.[11]

Figure 3: Evolution of Installed Costs of solar PV in Germany

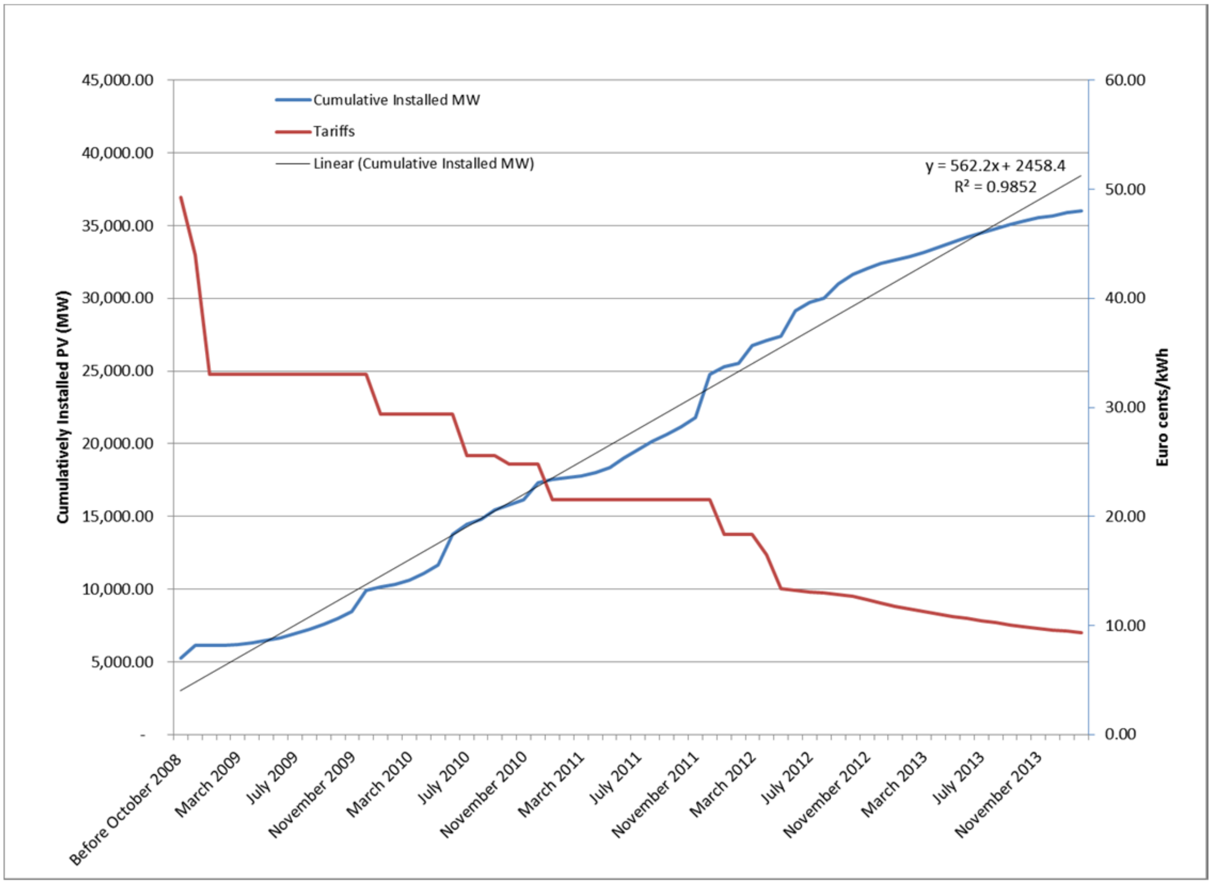


Source: Reproduced from Figure 3, Recent Facts about Photovoltaics in Germany, Fraunhofer ISI, April 10, 2014.

This decrease in installed cost has taken place at the same time as installed capacity has increased and as FIT rates have declined dramatically, as can be seen in Figure 4 below.

11 See http://www.solarwirtschaft.de/fileadmin/media/Grafiken/pdf/BSW_Preisindex_1304.pdf

Figure 4: FITs and cumulatively installed solar PV capacity in Germany



Source: Bundesnetzagentur, *The Brattle Group* analysis.

FITs declined from approximately €0.50/kWh in 2008 to around €0.10/kWh[12] by early 2014. While Figures 3 and 4 above suggest a direct inverse relationship between increasing installations and declining cost, this relationship is likely only partially causal. In other words, it is likely that installation costs in Germany are lower today than they were 6-7 years ago in part because the large scale, in annual and cumulative terms, of PV installations in Germany have directly led to cost reductions as a result of learning and scaling effects. It is however also likely that some technological advances would have occurred in the absence, or at lower levels of installation.

12 FIT levels depend on project size. According to the pending overhaul of the EEG law, soon to pass the legislative process, as of August 2014 FITs for solar PV are 9.23, 11.49, 12.8 and 13.15 €ct/kWh, for peak capacities attaining a maximum of 10 MW, 1 MW, 40 kW and 10 kW respectively.

The importance of the scaling and learning effect for cost declines in Germany has been well documented, and is likely a significant contributor to the lower installed cost of solar in Germany when compared to many other countries including the United States.[13]

III. The impact of the German solar PV generation on retail prices

A second important topic relates to the retail rate impact of the German FIT program for solar PV. There is no doubt that support for renewable energy production is having an impact on retail prices in Germany. The magnitude of this impact is significant, especially when compared to typical American retail rates for power, even in places such as California or the Northeast, where retail rates tend to be high. However, there are four important factors that need to be kept in mind and we will address each of these more specifically below:

1. The renewable levy continues to represent a significant but still moderate portion of overall rates and cannot be directly compared to wholesale prices;
2. The costs of renewable energy is not evenly split across all customers;
3. The impact of earlier renewable projects is much higher than the cost of current/more recent projects;
4. Renewable Energy has caused a decrease in the wholesale price of electricity.

A. Renewable Support Represents a Moderate Portion of Rates

Electricity rates in Germany, especially for households, are among the highest in the world. Average residential electricity rates in Germany were €0.26 per kWh in 2012, or approximately $0.35/kWh. Commercial and industrial rates generally ranged from €0.12 to €0.15 per kWh[14], or from $0.16 to $0.2/kWh. In 2013, average residential rates increased to €0.29 per kWh.[15] These

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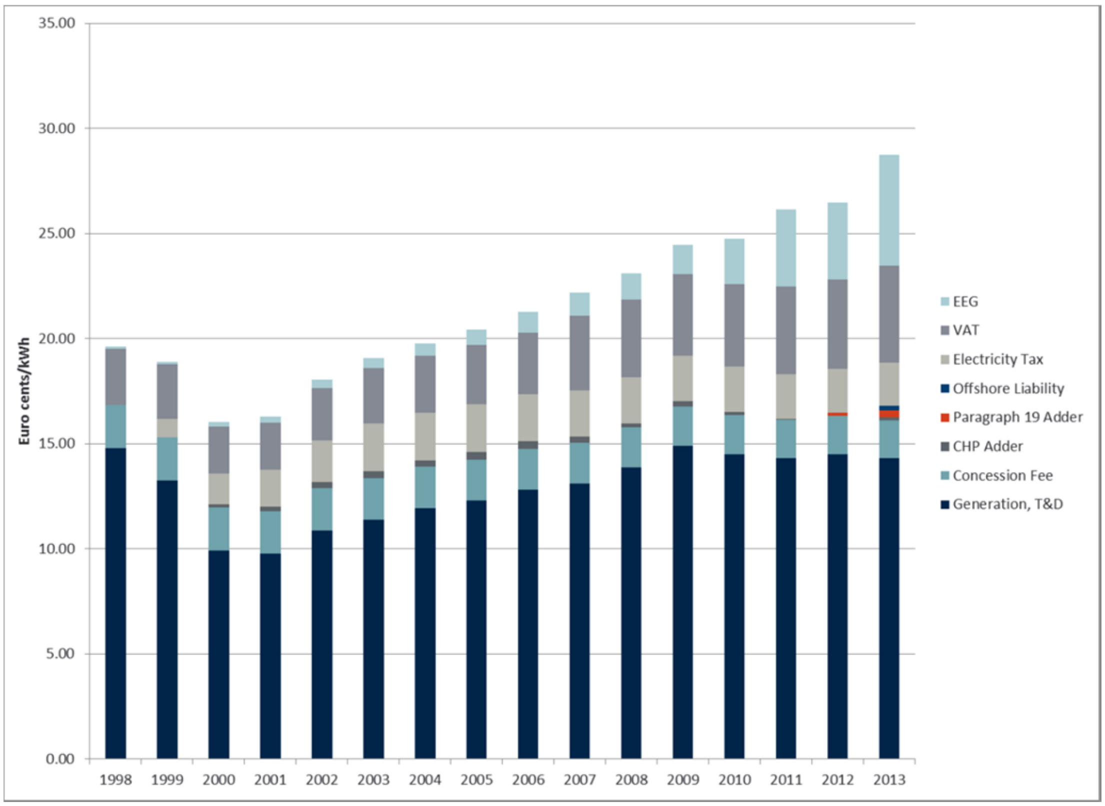
13 See Joachim Seel, Galen Barbose, and Ryan Wiser, Why Are Residential PV Prices in Germany So Much Lower Than in the United States? Lawrence Berkeley National Laboratory, February 2013 Revision

14 Especially very large industrial customers (above one GWh per year) tend to face significantly lower and falling prices below 6 €ct/kWh, as their rates closely reflect falling wholesale prices, an issue further discussed below. See Leipziger Institut für Energie GmbH, Energiepreisbericht für Baden-Württemberg 2012/2013, Figures 53 and 54 on page 63.

15 See Eurostat, Electricity prices for domestic consumers, from 2007 onwards - bi-annual data, accessed May 15, 2014 (http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_pc_204&lang=en)

rates are approximately twice average U.S rates and significantly exceed residential rates in the most expensive US states with the exception of Hawaii. They also exceed the rates in most other EU countries with the exception of Denmark, which still has slightly higher residential rates than Germany.[16] It is easy to attribute these high residential rates to the high cost of renewable energy support in Germany. However, while renewable energy support is indeed contributing to high (and especially increasing) retail rates for electricity, such attributions have to be made with several important caveats. Figure 5 below shows the evolution and composition of residential electricity rates in Germany since 1998 on an inflation-adjusted basis.

Figure 5: Average Residential Tariffs for 3-person Household consuming 3,500kWh of electricity per year (€ 2012)



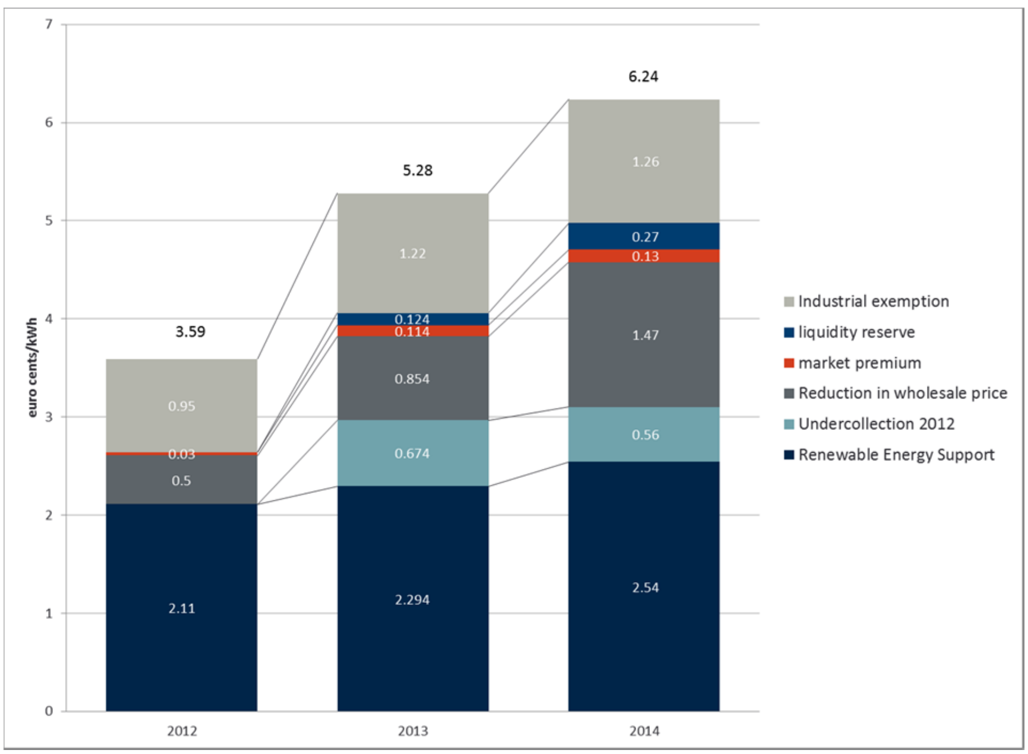
Sources: BDEW Strompreisanalyse November 2013, Worldbank (GDP Deflators), *The Brattle Group* analysis.

Figure 5 shows that average retail rates have increased by close to 10 €cents/kWh or approximately 50% since 1998 in inflation-adjusted terms. At first glance, approximately half of

16 Ibid.

this increase is due to the renewables levy, the surcharge on bills to recover the costs of payments under FITs for various renewable technologies including solar PV. The remaining drivers of increasing retail rates have primarily been taxes and other surcharges. The costs of procurement (energy and transmission and distribution costs) have remained relatively stable in aggregate. By 2013, the renewables levy reached 5.28 €cents/kWh, or 18.4% of the typical average retail cost of electricity, and 6.24 €cents/kWh in 2014.[17] Hence, while renewable energy related costs represent a significant portion of retail tariffs for typical German households, retail prices would be high when compared to the US even without any support for renewable energy. A closer look at the decomposition of the renewables levy as shown in Figure 6 provides some additional important insights.

Figure 6: Decomposition of renewables levy (nominal)



Source: Bundesverband Erneuerbare Energien, BEE-Hintergrund zur EEG-Umlage 2013, *The Brattle Group* analysis.

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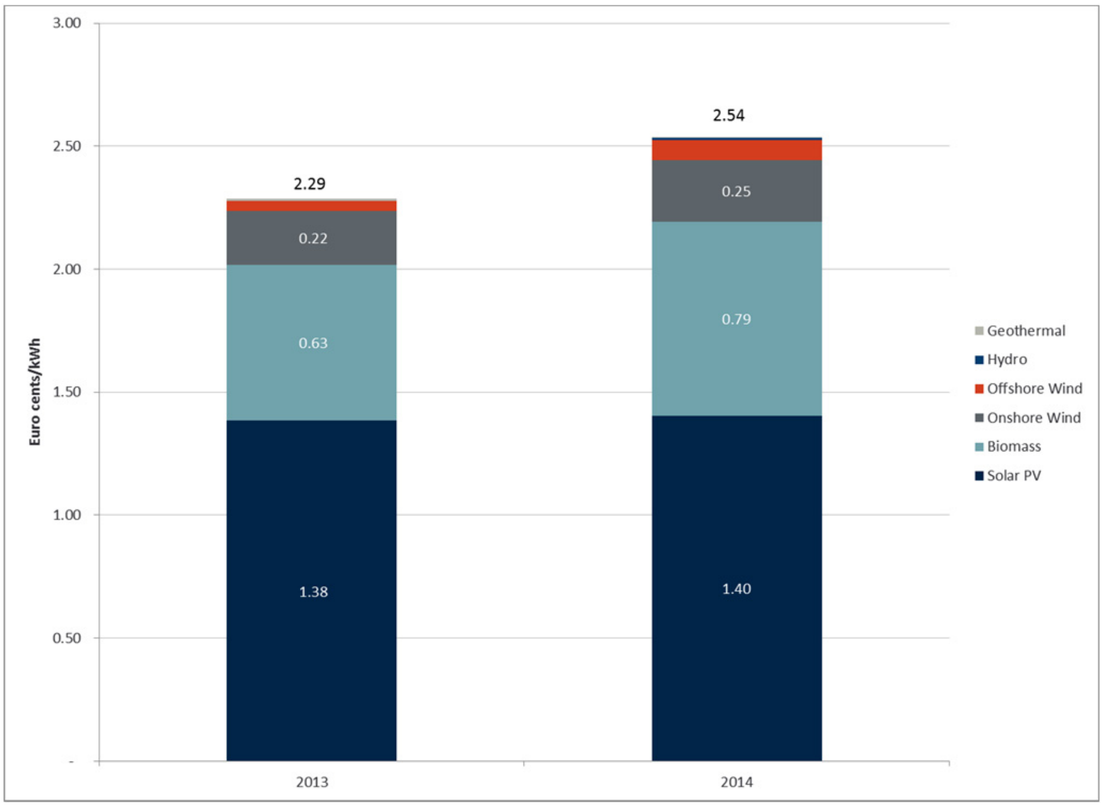
17 BDEW, Strompreisanalyse November 2014, page 10.

As Figure 6 shows, only approximately 41% of the 6.24 €cents/kWh of renewables levy in 2014 represents the regular support payments for renewable energy. 0.56 €cents/kWh or 9% represent a catch-up payment due to the fact that renewable energy additions during 2013 were faster than anticipated so that the 2013 renewables levy was insufficient to cover the required payments. Importantly, 24% and 20% of the renewables levy represent price reductions in the wholesale market due to renewable energy production and the exemption of certain industrial facilities from fully paying the renewables levy, respectively. The former is a reflection of the fact that renewable energy production creates additional supply (at zero or trivial variable cost), which in turn lowers wholesale electricity prices, at least for some period of time. The figure represents extra payments under FITs that are necessary to make the transmission service operators (TSOs), who have to compensate renewable energy producers under FITs, whole relative to the wholesale market value of the renewable energy, when renewable energy actually reduces that wholesale market value. The "true" support level is therefore more likely the renewables levy minus this wholesale price effect.

The industrial exemption simply means that residential consumers are picking up the share of payments from which certain industrial companies are exempt. It is a transfer of payments from certain rate payers to residential customers. Compared to 2012, when the renewables levy was 3.59 €cents/kWh, the increase in core support for renewables was only about 0.43 €cents/kWh or 16% of the increase between 2012 and 2014, while the increase of the renewables levy due to lower wholesale prices was 0.97 €cents/kWh (37% of the increase), and the increase of the cost due to the industrial exemption was 0.31 €cents/kWh (12% of the increase). In sum, a closer look at a decomposed renewables levy shows that less than half of the charge is for the core support of renewable energy, while the remainder is either a one-time charge (the catch up payment for 2013), related to cost shifting or whole sale price reductions due to the merit-order effect.

A final way to gain a better understanding of the renewables levy is to look at the components by technology, as is done in Figure 7 below. Of the 2.29 €cents/kWh for direct renewable energy support as part of the 2013 renewables levy (from Figure 6 above), 1.38 €cents/kWh are for the support of solar PV. In 2014, the renewables levy increase for new solar PV was only 0.02 cents/kWh, from 1.38 €cents/kWh to 1.40 €cents/kWh, for an expected increase in installed solar PV capacity of 3.5 GW. This shows that given the now much lower FIT rates for solar PV, the impact of incrementally supported solar PV on the renewables levy will likely be quite small. It also shows that as a percentage of the overall renewables levy, and much more so as a percentage of overall retail rates, the support for solar PV represents a relatively small percentage – 26% of the renewables levy in 2013, decreasing to 23% in 2014, and less than 5% of total retail rates for non-exempt customers. It is therefore difficult to argue that support for solar PV in Germany places a very heavy burden on German consumers or, as further discussed below, German competitiveness.

Figure 7: Renewable Energy Support by technology



Sources: Bundesverband Erneuerbare Energie, *The Brattle Group* analysis.

B. Renewable Support Not Equally Split Across Rate Classes

As can be seen in Figure 6 above, approximately 20% of the renewables levy (1.22 €cents/kWh out of a total of 5.28 €cents/kWh in 2013) is the result of certain companies being exempt from paying the full amount of the renewables levy for their entire electricity consumption. As discussed in the introduction, the exemption of certain industries from paying the full amount of renewable support was the subject of an investigation by the European Commission into whether or not this exemption constitutes illegal state aid earlier in 2014.[18] The question is not whether or not an exemption is possible in theory – it is, but rather whether the exemption is too generous, i.e. covering too many companies. The issue has been settled very recently as a result of intense negotiations between the German government and the European Commission, resulting in a revised program of exemptions going forward and in line with revised guidelines by the EC.[19]

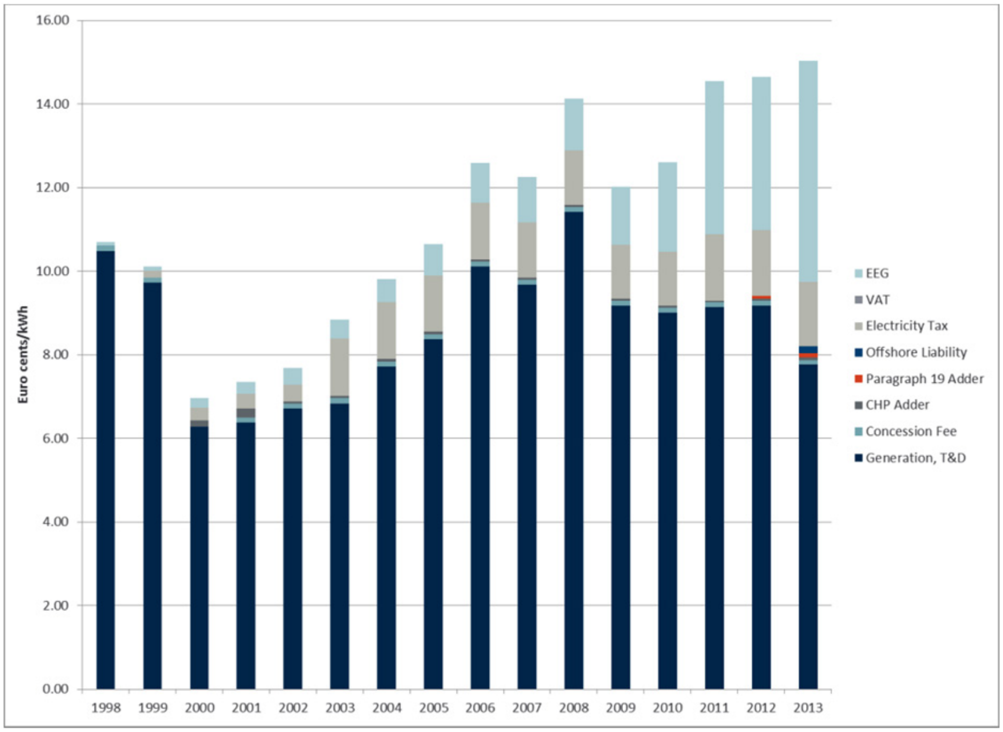
Like in other countries, industrial rates in Germany tend to be lower than commercial and residential rates. Figure 8 below shows the evolution of typical industrial rates over the past 15 years. The Figure shows that average industrial rates (in inflation-adjusted terms) have also increased over the past decade, from approximately 10 €cents/kWh to approximately 15 €cents/kWh in 2013. It is however worth noting that almost the entire increase in rates is due to the renewable energy levy. Furthermore, rates for larger users tend to be significantly lower, even before taking account of the above-mentioned exemptions from the renewable energy levy.

Figure 9 below shows the range of industrial electricity tariffs in Germany for large industrial customers (with 100 GWh or more of annual demand). As can be seen, at the low end of the range electricity prices in 2014 for these costumers are lower than in 2013 and are less than a third of electricity prices at the high end of the range.

18 On April 9 and after lengthy negotiations, the European Commission published new guidelines concerning state aid for environmental protection and energy, which are expected to largely resolve the outstanding dispute between the EU and Germany. See European Commission, Communication from the Commission, Guidelines on State aid for environmental protection and energy 2014-2020, April 9 2014.

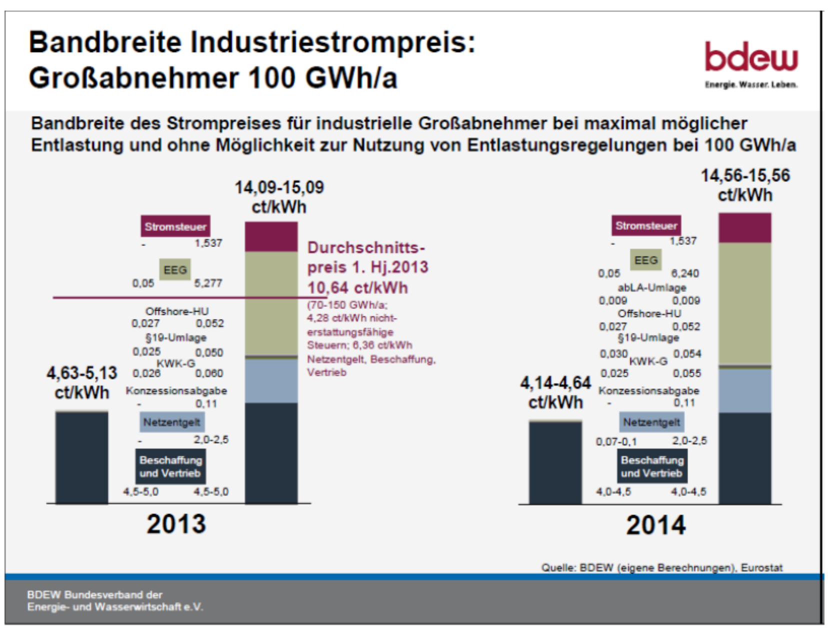
19 The revised guidelines can be found at European Commission, Communication from the Commission, Guidelines on State aid for environmental protection and energy 2014-2020, April 9 2014; The German reforms to the exemptions were approved by the Cabinet on May 7, 2014, Entwurf eines Gesetzes zur Reform der Besonderen Ausgleichsregelung für stromkosten - und handelsintensive Unternehmen. To be exempt, companies need to consume at least 1 GWh of electricity per year and electricity represent between 16-20% of total value added.

Figure 8: Typical Industrial Electricity Rates and their Decomposition



Sources: BDEW Strompreisanalyse November 2013, Worldbank (GDP Deflators), *The Brattle Group* analysis. Assumes annual demand between 160 and 20,000 MWh.

Figure 9: Range of Industrial Tariffs



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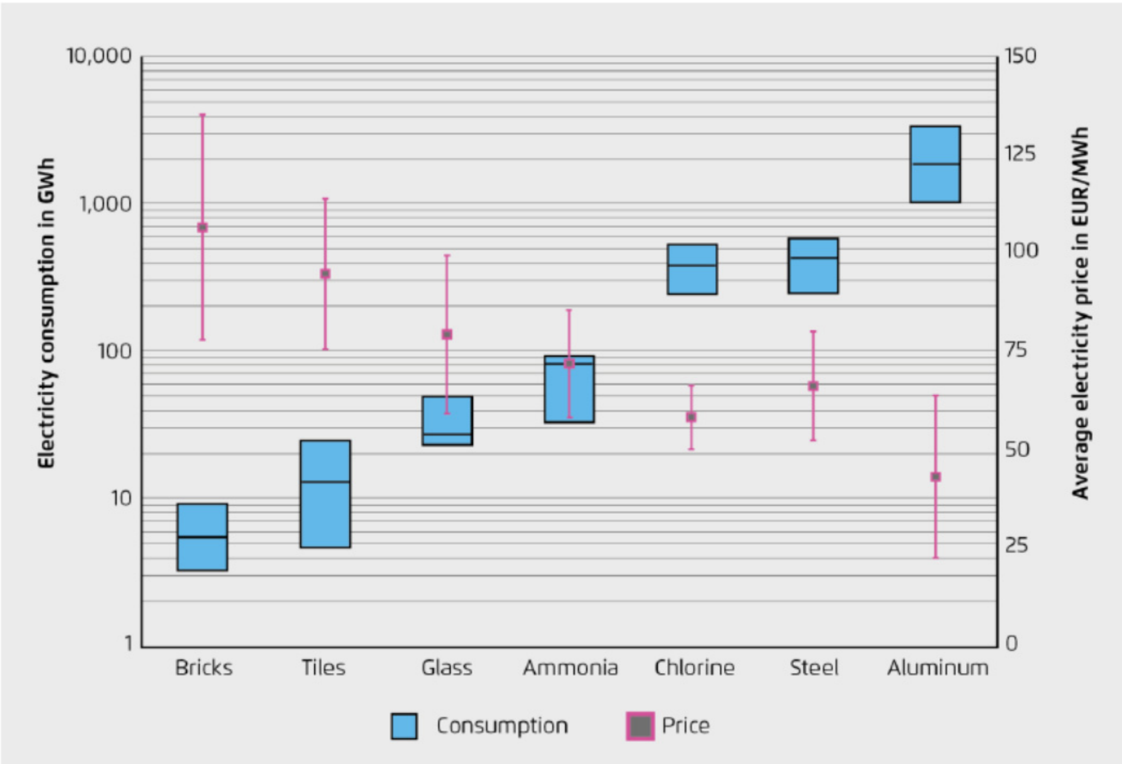
To provide more detail, Figure 10 shows that the larger the demand, the lower the effective price paid by industry for electricity.

Figure 10: Relationship between Industrial Prices and Consumption



Source: Reproduced from Figure 3, Agora Energiewende, Comparing Electricity Prices for Industry, March 2014.

The bottom line is that the renewable energy levy has not had a uniform impact on all customer classes in Germany. Especially heavy electricity users pay electricity rates mostly in line with those paid in other EU countries. As we discuss below, this means that renewable energy support has likely not so far had any material negative impact on the competitiveness of the bulk of German industry. This is because larger industrial users traditionally pay less than smaller residential users and because the amount of power consumption (partially) exempt from the renewable energy levy in Germany increases with total average annual electricity consumption. By actively purchasing on the wholesale market, large industrial customers also benefit directly from the lower wholesale market prices caused in part by renewable generation.

A non-trivial portion of the increase in the average renewable energy levy, fully paid by all residential and commercial and most (smaller) industrial customers is therefore due to the fact that the German renewable energy levy system is designed to insulate trade-sensitive heavy electricity using industrial companies from the negative competitive effects of electricity prices substantially above those paid by international competitors.[20]

C. Renewable Support Increase Not Linear And Will Begin to Decline Soon

A third important factor to be considered has to do with the fact that renewable energy support in Germany takes the form of FITs granted for a period of 20 years with FIT levels periodically lowered for future projects. As Figure 4 above showed, FITs for solar PV have been decreasing steadily and strongly for the past 10 years. At the same time, annual solar PV installations increased dramatically during a time period when FIT rates were still relatively high (compared to wholesale prices). Due to the fact that FITs are in place for 20 years (for any given PV installation), support for past installations, including the large number of PV installed in 2009-2012, are "baked" into the renewable energy levy for many more years.[21] Because FIT rates have declined significantly since then, the impact of recently installed and future solar PV will be relatively modest.

Figure 11 below shows the historic evolution of FIT payments for solar PV installations and projections going forward until the official target level of 52GW of installed PV is reached.

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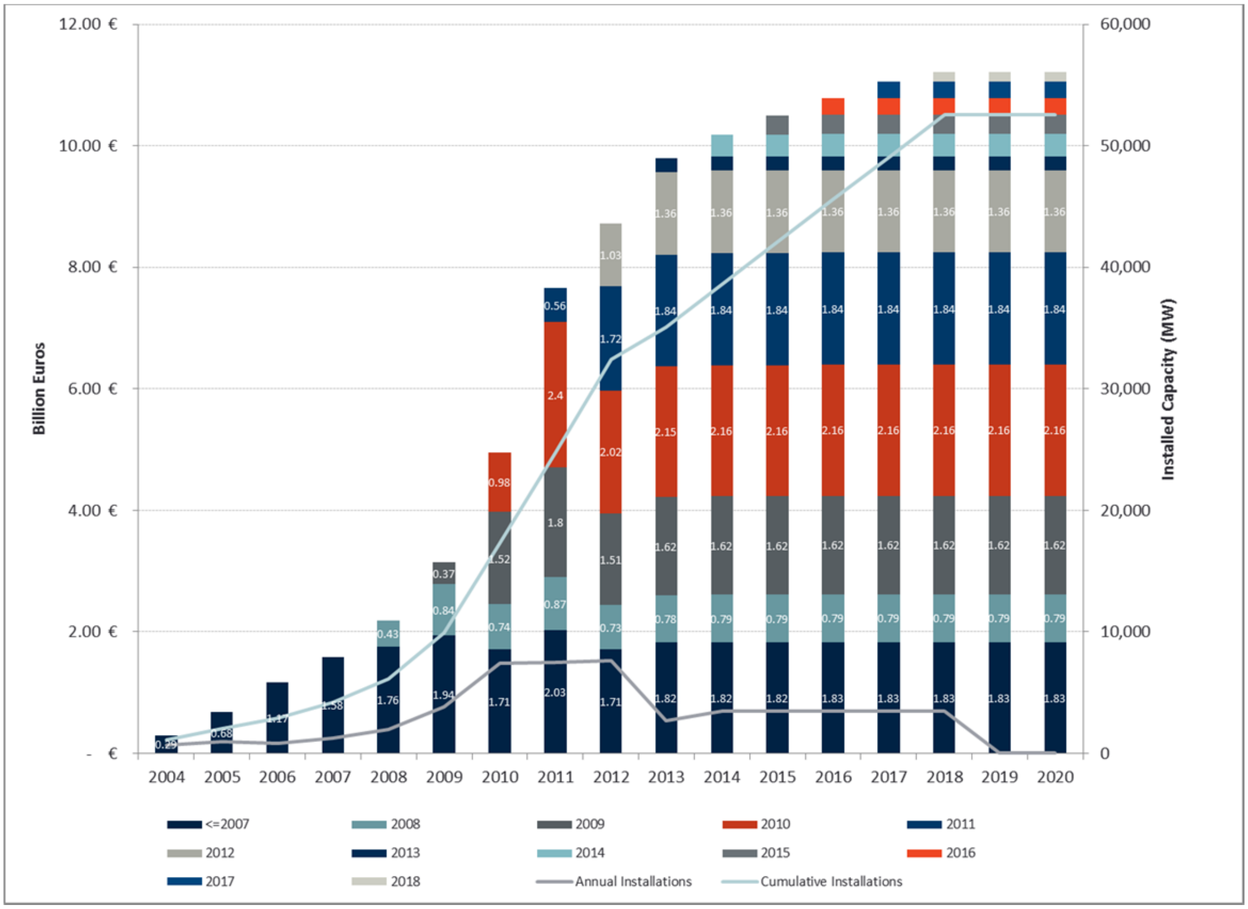
[20] However, to the extent energy-intensive trade-exposed sectors also include smaller companies, the absolute consumption thresholds for benefiting from a (partial) exemption from the renewables levy disadvantages smaller companies on those sectors, and potentially punishes those companies having made aggressive investments in energy efficiency.

[21] During the period of 2009-2012, FIT rate adjustments were likely not quick enough to mirror sharply declining installation costs.

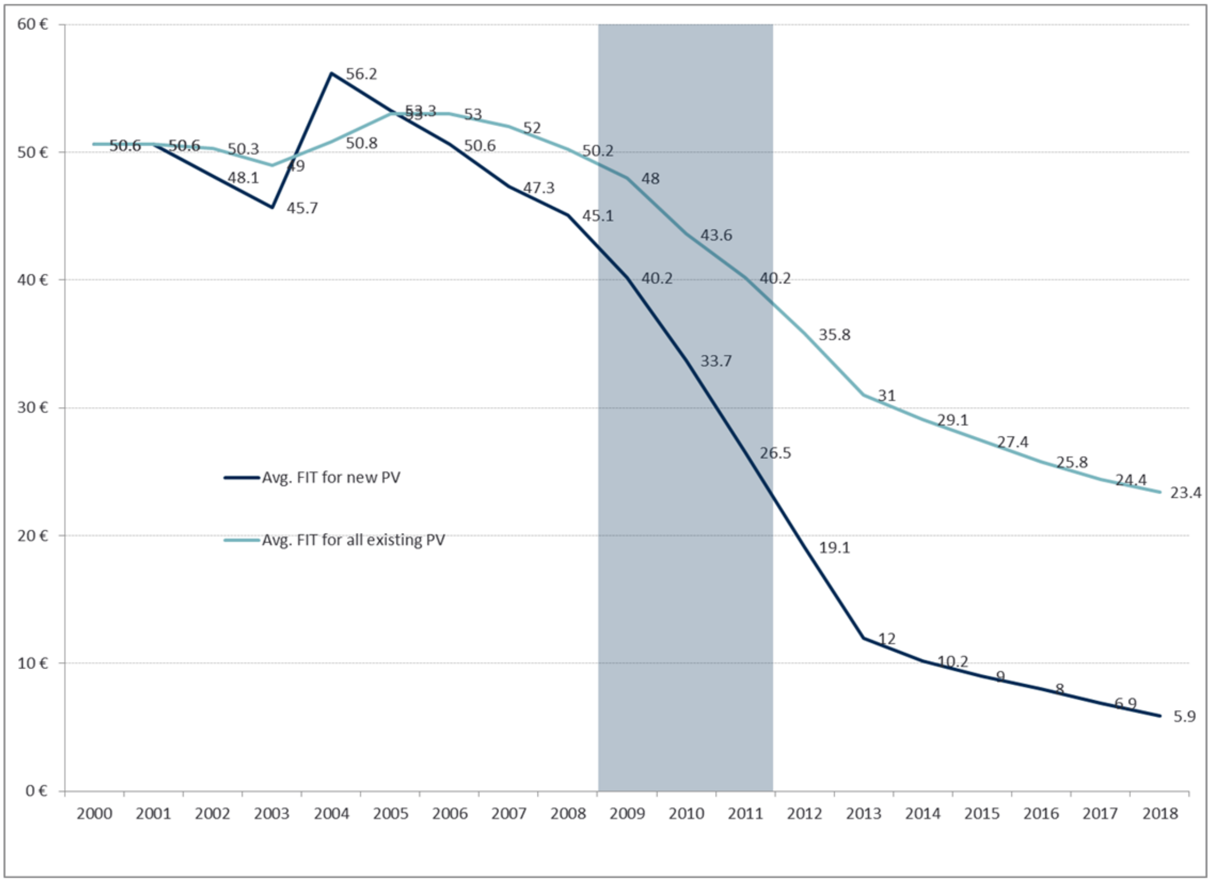
Figure 11: Historic and Projected FIT Payments for solar PV in Germany



Sources: Bundesnetzagentur, Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg, Vorbereitung und Begleitung der Erstellung des Erfahrungsberichts 2014, Vorhaben IIc Stromerzeugung aus Solarer Strahlungsenergie gemäß § 65 EEG, Zwischenbericht, February 2014, *The Brattle Group* analysis.

As Figure 11 shows, total payments under FITs for solar PV currently amount to approximately €10 billion per year. More than half of those payments are to PV systems installed in 2009, 2010 and 2011, when more than 7GW of PV were installed annually. The high annual installations over this time period have led to sharp reductions in FITs, which are expected to continue to decline as can be seen in Figure 12 below.

Figure 12: Historic and Projected FIT Levels for solar PV in Germany (€ cents/kWh)



Sources: Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg, Vorbereitung und Begleitung der Erstellung des Erfahrungsberichts 2014, Vorhaben IIc Stromerzeugung aus Solarer Strahlungsenergie gemäß § 65 EEG, Zwischenbericht, February 2014, *The Brattle Group* analysis.

As of year-end 2013, Germany had installed approximately 35GW of solar PV, or almost exactly 2/3 of the goal of 52GW. The ongoing FIT payments for this amount are equal to about €10 billion Euros per year. Given the sharp decrease in FIT rates, however, supporting the remaining 1/3 of the goal is projected to add only another €1.4 billion per year. Total FIT payments to reach 52GW are expected to stabilize at approximately €11.3 billion per year. In other words, the remaining third of the targeted PV capacity can be achieved with FIT payments that are rather modest when compared to the FIT payments already committed to through existing programs.

Two additional factors contribute to dampening further cost increases of the German program going forward. First, FIT payments are fixed in nominal terms. Even though inflation in

Germany has generally been quite low, the combination of economic growth and some underlying inflation means that when expressed in inflation-adjusted terms, FIT payments for solar PV will likely decline from here on out. Second, eventually the FIT payments for earlier PV installations, guaranteed for 20 years phase out even while it is likely that the PV installations themselves will continue to produce electricity.[22] Since the earliest installations of PV also receive the highest FITs, average compensation for solar PV will decline relatively rapidly after 2020 and in particular towards 2030, when the large amounts of PV installed between 2009 and 2011 stop receiving FIT payments.

In summary, because FITs have declined very rapidly over time, especially following the period 2009-2011, total payments under FITs for solar PV are likely peaking at present and will decline in real terms going forward, eventually quite rapidly as older PV systems receiving higher FITs will no longer be covered by 20-year FIT guarantees. On a per kWh basis, the incremental costs of the remaining PV program in Germany will likely be minimal. This is because out of the 2014 renewables levy of 6.24 €cents/kWh, only approximately 3.02 €cents/kWh represent all payments (above revenues received from selling the energy into wholesale markets) to solar PV, and only 0.08 €cents/kWh represent payments for new PV installations (assumed to be on the order of 3.5GW).[23]

D. Renewable Energy Contributes to Declining Wholesale Prices

The renewables levy reflects the difference between FIT payments to renewable energy producers and the market value of the produced electricity when sold on wholesale markets. Hence, the renewables levy is not only higher the higher the total volume of FIT and market premium payments, but also the lower the market price of electricity. Mechanically, the German TSOs are either required to pay renewable energy producers the FIT price and sell the energy

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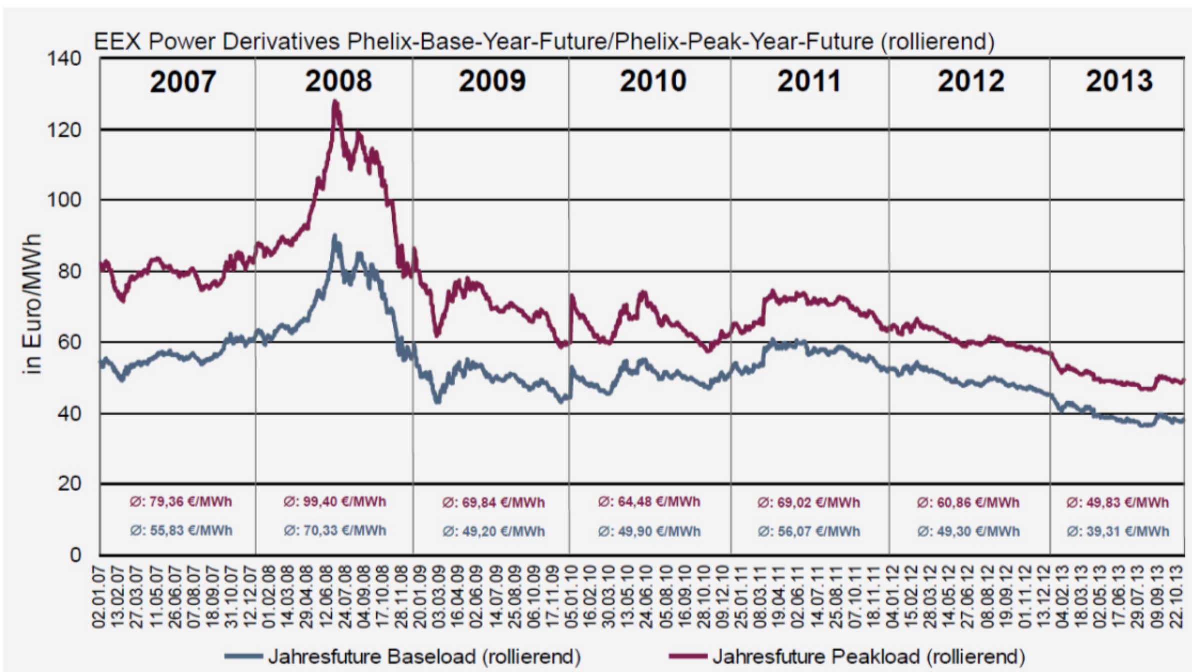
[22] A typical assumption is for solar PV output to decline by 0.5% per year, which suggests that PV modules would still be expected to generate approximately 90% of their output when installed after 20 years in service.

[23] See BDEW, Energie-Info: Erneuerbare Energien und das EEG: Zahlen, Fakten, Grafiken (2014), February 24, 2014, Figure 28, page 48, which also shows that the largest driver of the increase of the renewables levy between 2013 and 2014 is to compensate for lower wholesale market prices. However, as explained above, renewable energy is a major driver of market prices, so that this increase cannot directly be considered a "cost" to ratepayers – since they save an equal amount due to lower energy acquisition costs by their suppliers.

produced on the wholesale market or pay a market premium if the producer choses to sell the generated electricity directly on the market. The TSOs are then compensated for all expenses (FIT + market premium) exceeding the revenues from his sales via the renewable levy.[24]

If wholesale prices are unaffected by renewable energy production, FITs are indeed more expensive the lower wholesale market prices are, all else equal. However, as shown in Figure 13 below, there is significant evidence that increasing power production from renewable energy sources is a major contributor to falling wholesale market prices in Germany.

Figure 13: Wholesale Electricity Prices in Germany since 2007



Sources: EEX, reproduced from BDEW, Strompreisanalyse November 2013.

In 2007, average base load and peak load prices in Germany were €55.83/MWh and €79.36/MWh respectively. By 2013, average base load and peak load prices in Germany had declined to

[24] Apart from the FIT mechanism, in which the TSOs sell the renewable electricity on the spot market, renewable producers are now also allowed to sell electricity directly to the market. In that case they are not awarded a FIT, but are eligible for a market premium equal to the difference between achieved revenues on the spot market and the FIT. In the updated law coming into effect on August 1st 2014, all renewable plants with installed capacity greater than 500, 250 and 100 kW are to market directly as of August 1st 2014, January 1st 2016 and January 1st 2017, respectively.

€39.31/MWh and €49.83/MWh, declines of 30% and 37% respectively. To the extent this decrease is partially or entirely caused by the electricity production from renewable energy sources, it benefits consumers of all types, at least in the short run.[25] While renewable energy production does result in permanent reductions in fuel and operations and maintenance costs of fossil fired generation, it is less clear how sustainable lower wholesale prices are in the longer run. If wholesale prices dip below the average cost of new capacity and if new capacity is needed to guarantee adequate supply, wholesale prices may need to recover over time, or alternative revenue streams may be needed to attract new investments. If wholesale prices are too low to cover the operating expenses of existing plants, then existing plants may retire prematurely, which in turn can lead to concerns about system reliability.

There is clear evidence that wholesale price reductions are having some of this effect in Germany today. As a result of significantly reduced operating hours and lower wholesale prices, much of the existing fossil generation fleet does not cover its operating costs. The big German utilities (E.On, RWE, EnBW and Vattenfall) owning the bulk of fossil generation have seen their share prices fall sharply, and have been suggesting that the operating losses suffered by its fossil generation are not sustainable and will likely lead to significant plant retirements, absent some major adjustments to market mechanisms. One such mechanism, discussed in more detail below, is the creation of a capacity market mechanism that would compensate at least those existing plants needed to maintain reliable supply for their operating costs. Interim legislation is currently allowing the TSOs to procure reserves from existing fossil generation and will likely be replaced by some more comprehensive capacity mechanism in the near future.[26]

Such a mechanism would partially undo the effect of renewable energy lowering wholesale prices in that the additional payments made to fossil generation to ensure reliable electricity supply will also need to be recovered from ratepayers, most likely through transmission and

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25 The lowering of wholesale prices as a result of renewable energy fed into the grid and compensated outside of the market system is often referred to as the "merit-order effect" or as "wholesale price suppression".

26 While this mechanism likely addresses the reliability issue in the short run, in its current form it is quite controversial since it doesn't compensate plant owners during the first year of operation. Consequently, some plant owners claim that revenues under the interim mechanism do not cover costs, as would be needed for such a mechanism to be sustainable in the long run.

connection charges, which in turn could be capacity- or energy based, rather than through energy charges.

The more general impact of renewable and solar energy on the viability of fossil generation plant and the resulting negative impact on the asset value of the large German utilities is a complex issue and a full discussion is beyond the scope of this paper.

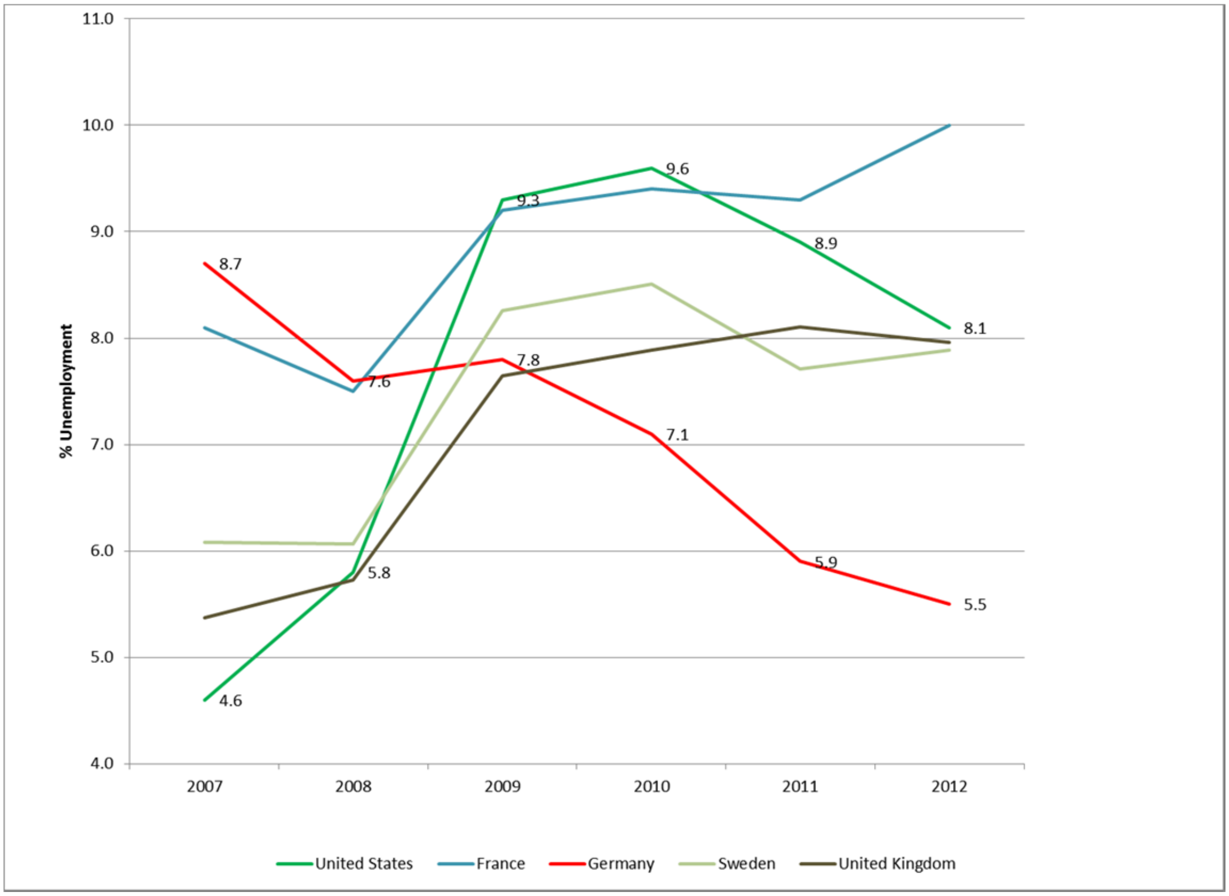
Residential and commercial customers benefit since their suppliers pay less for acquiring power in the wholesale market, assuming that the wholesale price decline is passed on to final consumers. Industrial customers may benefit even more if all or part of their electricity demand is exempt from the renewables levy (as it is for the largest industrial customers, who pay rates close to wholesale price levels) and/or if they can access the wholesale market directly.

Attributing the entire change in wholesale prices to renewable energy would mean that the entire 0.8 €cents/kWh component of the renewables levy collected to compensate the TSOs for the lower value of renewable energy due to lower wholesale prices would be offset by a corresponding benefit of lower acquisition costs for power by electricity suppliers.

IV.The impact on German competitiveness

In this section, we provide some comments related to the effect of German renewable energy support on the competitiveness of German industry. An analytical decomposition of the overall performance of the German economy into the part attributable to renewable energy policies is well beyond the scope of this report (and likely beyond the capabilities of any analytical technique). However, it is nonetheless useful to provide some basic background information to inform the discussion. While there have been some warnings by German industry representatives that rising energy prices could put German competitiveness in jeopardy, there is as of yet little evidence to support this notion. Figure 14 below shows the evolution of Germany's unemployment rate, one measure of a country's economic strength, since 2007, i.e. during the time period of the heavy expansion of German renewable energy support and resulting increases in the renewably levy.

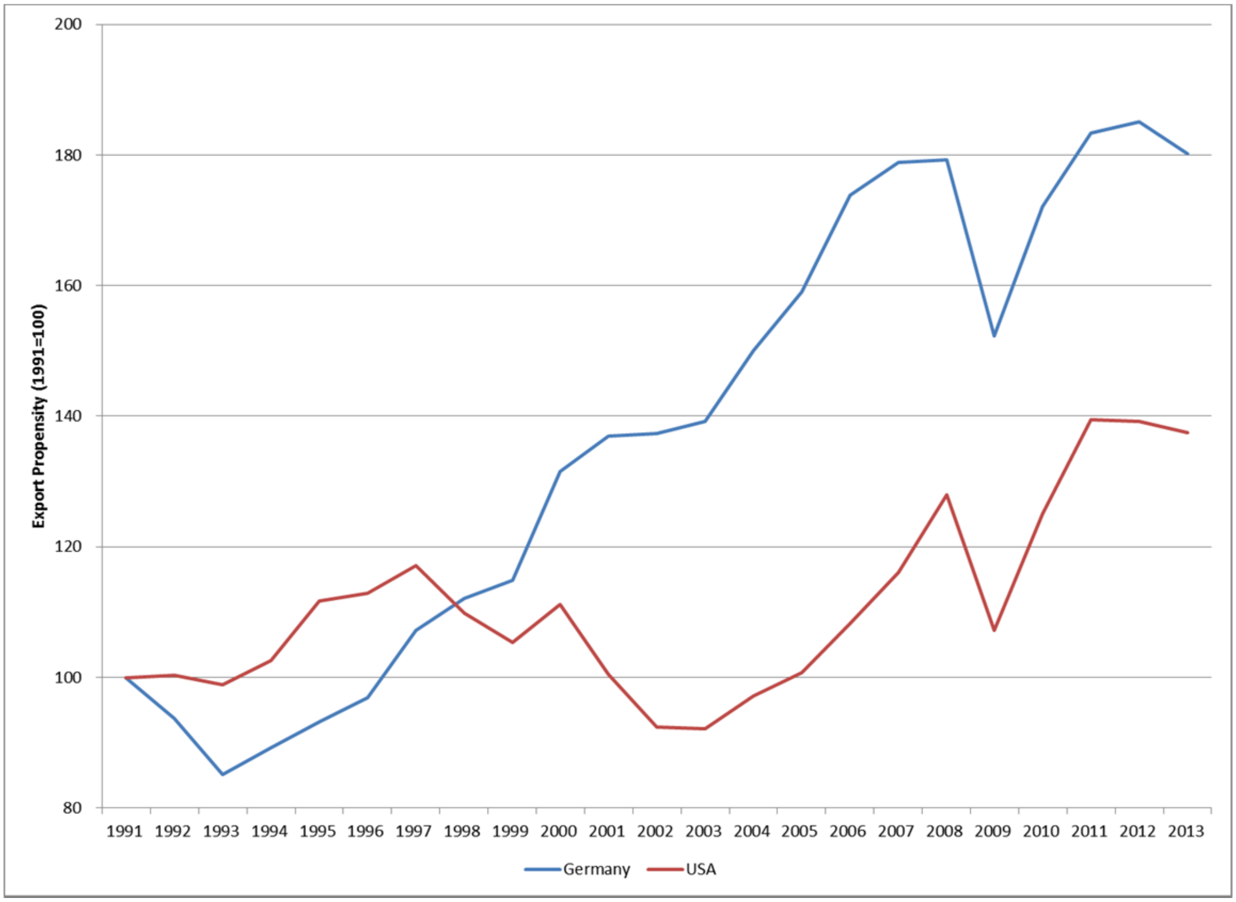
Figure 14: Unemployment rates in selected countries



Sources: United States Department of Labor, Bureau of Labor Statistics; Monthly employment rates adjusted to US concepts.

Another popular measure of a country's competitiveness is the ability to export products made locally. If higher energy costs increase the costs of production in Germany, then over time it should make it less attractive to foreign countries to import German products, all else equal. However, as Figure 15 below shows, there is no indication that higher energy prices have harmed German companies' ability to sell products abroad. As a matter of fact, since 1991 Germany's share of exports in GDP has increased by 80% whereas the United States "export propensity" has only increased by half that much.

Figure 15: Export Propensity in Germany and the United States



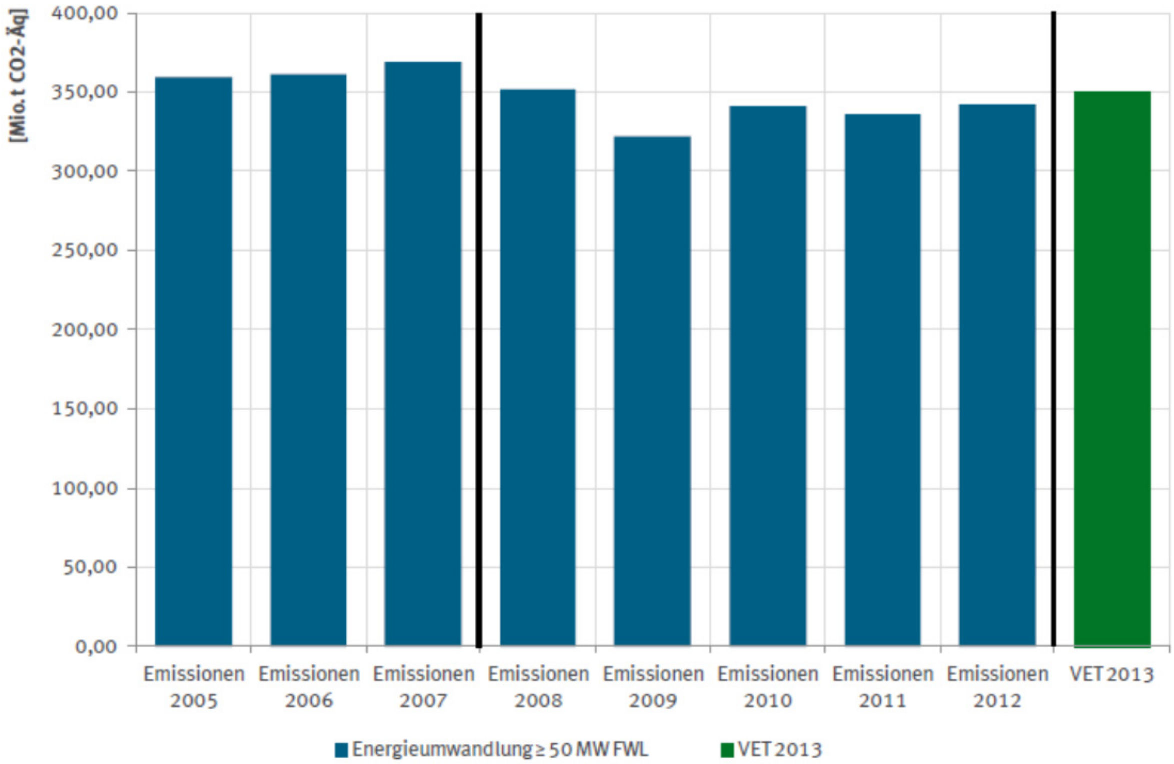
Sources: United States Department of Commerce, Bureau of Economic Analysis, Statistisches Bundesamt, *The Brattle Group* analysis.

While many factors drive the economic performance of any country, these figures at least suggest that a direct relationship between renewable support policies and declining economic competitiveness of Germany is not easily detected.

V. The impact of German solar PV support on greenhouse gas emissions

There is some evidence that in spite of sharply increasing renewable energy penetration, total greenhouse gas emissions in Germany have lately been increasing rather than decreasing. Figure 16 below shows the evolution of CO_2 emissions from stationary power plants with capacities greater than 50 MW.

Figure 16: CO_2 Emissions from Power Plants (50MW and larger)



Sources: Reproduced from Figure 2, Umweltbundesamt, VET Bericht 2013, Treibhausgasemissionen der emissionshandelspflichtigen stationären Anlagen in Deutschland im Jahr 2013.

As can be seen from Figure 16, power sector greenhouse gas emissions have indeed increased by approximately 10% since 2009,[27] i.e. during the period of the most rapid expansion of renewable energy production in Germany. Accordingly, an expert report commissioned by the German government comes to the conclusion that the renewable energy law has not helped reduce greenhouse gas emissions in the power sector beyond those already achieved through Germany's participation in the European Emissions Trading Scheme (EU ETS).[28] The German environmental agency (Umweltbundesamt) reporting the increased emissions points to several factors contributing to the increase, notably the higher power generation from hard coal (Steinkohle) as

[27] 2009 is a problematic base year for a comparison since it is the 2009 emissions were particularly low as a consequence of the economic slowdown following the financial crisis.

[28] See Expertenkommission Forschung und Innovation, Gutachten zu Forschung, Innovation und technologischer Leistungsfähigkeit Deutschlands, Gutachten 2014, pages 51-52.

a consequence of low import prices for this resource following the shale gas boom in the United States.[29] Given the comparatively high prices for natural gas in Europe and the fact that emissions reductions under the EU ETS through 2020 have essentially been met – resulting in low allowance prices[30], Germany has been experiencing a shift in power production from natural gas to coal, given in particular lignite's low cost when compared with natural gas prices in Europe, with the result of increasing CO_2 emissions in spite of, rather than because of increased production from renewable energy sources.

It is also true that in parallel to expanding renewable energy resources several new coal-fired power plants have either come online or are in the process of coming online. However, there are also ongoing retirements of coal-fired power plants. Between 2011 and 2013, 1,764 MW of lignite capacity and 1,232 MW of hard coal capacity were permanently retired, with an additional 260 MW of lignite and 389 MW of hard coal capacity being temporarily retired.[31] In 2012 and 2013, 2,740 MW and 1,471 MW of new coal fired capacity came online respectively.[32] It is expected that between 2014 and 2018 there will be very minor reductions of lignite capacity and a net increase in hard coal power generation capacity by 2,882 MW, almost all of which occurring in 2014 and 2015.[33]

However, it would be incorrect to assume that recent and near-future additions of coal-fired power generation are the beginning of a renaissance of coal-fired power generation in Germany. Rather, the set of recently and soon to be completed coal-fired power generators are the result of many years of planning, originally triggered by what seemed to be a favorable environment for one last round of new and efficient coal-fired generation due to CO_2 allowance allocation rules

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29 See Umweltbundesamt, VET Bericht 2013, Treibhausgasemissionen der emissionshandelspflichtigen stationären Anlagen in Deutschland im Jahr 2013, pages 20-21.

30 For a discussion of the problems with the EU ETS, see for example http://www.economist.com/news/finance-and-economics/21576388-failure-reform-europes-carbon-market-will-reverberate-round-world-ets (accessed May 29, 2014)

31 See Bundesnetzagentur, Kraftwerksliste - Stand 2.4.2014 (accessed May 29, 2014)

32 Ibid.

33 See Bundesnetzagentur, Veröffentlichung Zu- und Rückbau - Stand: 15.04.2014 (accessed May 29, 2014)). The new hard coal plants are Westfalen by RWE, Moorburg by Vattenfall, Wilhelmshaven by GdF Suez, GKM by Grosskraftwerk Mannheim AG and Datteln by E.On, each with capacity per block of approximately 750 MW.

proposed (but ultimately not adopted) around 2006.[34] Public opposition to new (and even some of the currently being completed) coal-fired power generation remains strong, so that it is unlikely that significant new coal-fired generation will be built beyond the current projects under construction.[35]

It is also questionable whether Germany's long-term greenhouse gas emissions reduction targets of 80% by 2050 across all energy sectors, which translates into essentially no carbon emissions from the power sector, can be met without measures in addition to a more aggressive GHG emissions trading system or some other form of carbon pricing. In spite of claims by a German expert group that the renewables energy law has not contributed to further reducing greenhouse gas emissions under the EU ETS, there is significant theoretical support for the notion that carbon pricing alone is not sufficient to cure multiple market failures that prevent socially optimal greenhouse gas emissions levels from occurring.[36]

VI.The impact of German solar PV support on system reliability

Finally, there is some contention that the increasing amounts of renewable generation are jeopardizing the reliability of electricity supply in Germany. There are various ways to assess electric reliability. The most common measures of reliability are various versions of SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index). There are multiple measures of both SAIDI and SAIFI, depending on whether major and/or planned outage events are included or excluded and sometimes data sources report SAIDI/SAIFI scores without specifying what is included.

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34 For a longer discussion of the current and future state of coal fired generation in Germany see Pöyri, Outlook for new coal-fired power stations in Germany, the Netherlands and Spain, April 2013

35 One case study of the difficulties of building new coal-fired power generation is E.On's Datteln power plant, the construction of which was halted in 2009 as a result of various lawsuits. These law suits have just been cleared and the prospects of the 90% completed power station being completed have increased. See http://www.taz.de/!138541/ for an article describing the current situation).

36 A detailed discussion of the rationale for multiple approaches is beyond the scope of this report. For a discussion with references to the corresponding research literature, see for example Weiss and Marin, Reforming Renewable Support in the United States: Lessons from National and International Experience, The Brattle Group, November 1, 2012.

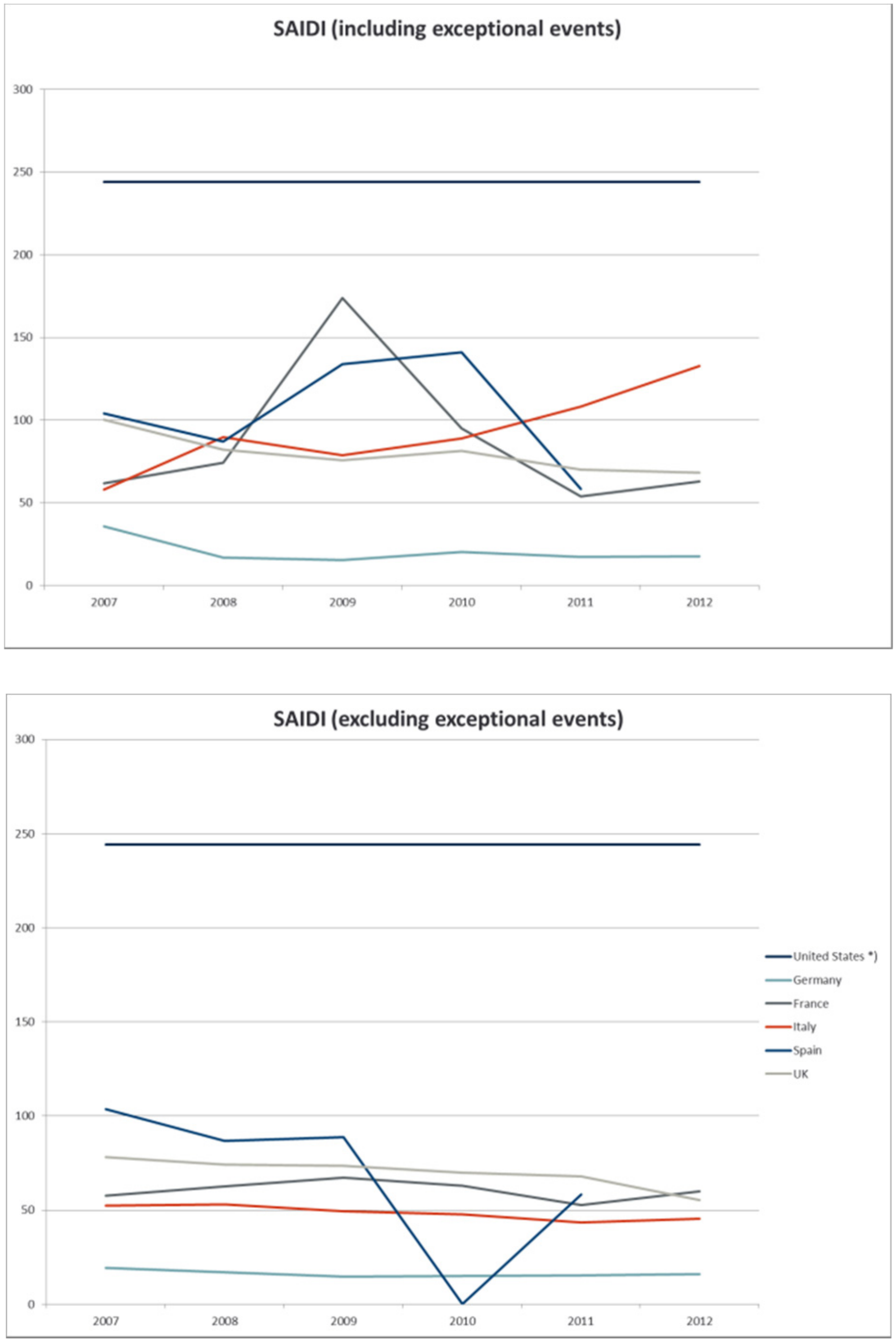
Nonetheless, it is safe to say that until present the reliability of the German (and Western European) power supply tends to be significantly superior to the reliability of the U.S. power system. Several sources report typical SAIDI scores in the United States of about 240 Minutes and SAIFI scores of approximately 1.5. The corresponding scores for major European countries are shown below in Figure 17.

As Figure 17 shows, SAIDI scores in the United States are between 2 and 10 times as high as those in major European countries. Germans suffer, on average, from merely 7% of the outage minutes of average Americans. If US reliability standards were used as the benchmark, Germany's reliability could therefore deteriorate quite significantly before reaching US levels.

What is however perhaps even more insightful is that German SAIDI scores have essentially remained flat or even decreased somewhat since 2007, i.e. during the period that saw very rapid increase in power generation from intermittent renewable sources such as solar PV and wind. Given Germany's historic high level of reliability, it is perhaps not surprising that the German system has been capable to remain highly reliable up to now, even with a significant and rising contribution of intermittent renewable energy sources.

It is however true that the discussion in Germany about the impact of continued increases of intermittent renewable energy production on **future** electric reliability has recently intensified. There are indeed some indicators that increased renewable energy production is having an impact on the operation of the German electricity system. These operational impacts manifest themselves in multiple ways. While system reliability may be unchanged or even improving as just described, the cost of maintaining this reliability may be increasing, for example as a consequence of increasing re-dispatch costs, i.e. the need to use more expensive resources to respond to the constraints created by variable production from solar PV and wind.

Figure 17: Reliability Statistics in Selected Countries



Sources: CEER, CEER Benchmarking Report 5.1 on the Continuity of Electric Supply, Data Update, February 11, 2014; Galvin Electricity Initiative, Electric Reliability: Problems, Progress and Policy Solutions, 2011; Congressional Research Service, Weather-Related Outages and Electric System Resiliency, August 28, 2012; *The Brattle Group* analysis.

There has for example been a discussion related to increases of unscheduled power flows from and to Germany – and loop flows in particular - that may be caused by changes in generation from renewable resources in Germany. Increases in unscheduled flows lower the available transfer capacity between regions and hence potentially limit the resources that can be called upon to balance supply and demand on a short term basis.[37] The issue has become significant in particular on the German-Polish border, where Net Transfer Capacity (net of unscheduled flows) has essentially dropped to zero over the past few years.[38] The welfare loss associated with the reduced Net Transfer Capacity has been estimated at approximately €30 million per year by ACER, the de facto European electricity regulatory agency, which suggests that more research is needed to understand the best response to the issue.[39] ACER has also investigated various other aspects of the costs of integrating renewable energy sources including solar PV into the existing electricity supply system. For example, it has examined the percentage of energy losses due to curtailment of wind generation at the national level. Between 2010 and 2012, less than 1% of wind energy is lost due to curtailments in Germany.[40] ENTSO-E, the European Network of Transmission System Operators, also regularly examines risks to system reliability. In its most recent Summer Outlook Report and Winter Review[41], ENTSO-E generally sees no severe reliability issues in Germany. It acknowledges that under certain conditions (summer, low demand, low levels of PV feed-in, moderate wind), Germany might experience voltage problems.[42] It cites as the most severe consequence of continued increases in renewable (including solar PV) capacity the possibility that "German TSOs may be forced to cancel planned outages of network elements due to conditions worse than anticipated, especially if important nuclear power plants in southern Germany might trip. If necessary, German TSOs expect to make use of the full range of topological and market related remedial actions."[43]

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37 For a discussion, see ACER/CEER, Annual Report on the Results of Monitoring the Internal Electricity and Natural Gas Markets in 2012, pages 98ff.

38 Ibid, page 104.

39 Ibid, page 105.

40 Ibid, page 112.

41 Entso-e, Summer Outlook Report 2014 and Winter Review 2013/2014, May 21, 2014

42 Ibid, page 47.

43 Ibid.

The TSOs have been studying the need for incremental capacity to ensure reliable supply of electricity. Their current conclusion is that even with the high levels of current and expected renewable generation in the near future there is no need to build additional reserve capacities, at least through 2017/2018.[44] The TSOs do identify the need to contract for increasing amounts of re-dispatching capacity, up to 6GW for 2015/2016 and up to 7GW for 2017/2018 for the scenario of high demand and high wind-feed in,[45] compared to current re-dispatch reserves of approximately 3 GW in Germany and Austria.[46] Total re-dispatch costs have been growing from approximately €48 million in 2010 to €165 million in 2012, with figures for 2013 likely somewhat lower due to the lower total amount of redispatched energy (2,278 GWh in 2013 rather than 2,566 GWh in 2012).[47] In addition, the cost of curtailments, which affect predominantly wind, was €33.1 million in 2012.[48] In sum, so far the increased costs of providing reliable electricity supply with sharply higher renewable energy production has been small when compared to the size of the renewables levy itself.

A related issue often discussed is the "50.2 Hz problem". Since 2005 and until 2010, PV modules were required to disconnect from the grid when grid frequency exceeded 50.2 Hz.[49] While unproblematic at small levels of PV penetration, by 2010 it had become clear that in cases of high renewable generation and low demand a very significant portion of the power production, by then over 10 GW, could disconnect simultaneously, which would have far exceeded the ability of the grid operator to maintain power supply. Consequently, reforms were passed that required first new installations and ultimately approximately 400,000 existing PV systems with capacity greater than 10 kW (i.e., mostly exempting residential PV systems) to be updated (mostly through software upgrades, but potentially though new hardware) between 2012 and 2014 so that they can survive short periods of frequency above 50.2 Hz. The costs of the upgrades or

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44 See Achim Zerres, Netzausbau und Versorgungssicherheit aus Sicht der Bundesnetzagentur, Bundesnetzagentur, May 5, 2014, page 24.

45 Ibid, pages 22-23.

46 Ibid, page 21.

47 Deutscher Bundestag, 18. Wahlperiode, Antwort der Bundesregierung auf die Kleine Anfrage der Abgeordneten Oliver Krischer, Annalena Baerbock, Dr. Julia Verlinden, weiterer Abgeordneter und der Fraktion BÜNDNIS 90/DIE GRÜNEN – Drucksache 18/645 – Daten zur Abregelung von regenerativen Stromerzeugungsanlagen, March 13, 2014, page 3.

48 See Bundesnetzagentur/Bundeskartellamt, Monitoringbericht 2013, page 19.

49 The German network frequency is 50 Hz.

retrofits are not borne by individual system owners, but rather are financed through a combination of the renewables levy and network tariffs. The total cost of the change has been estimated at €175 million.[50] The primary lesson from Germany's 50.2 Hz problem is that technical and interconnection standards should be carefully designed and anticipate potential issues arising from higher renewable penetration (such as over-, not just under-frequencies).

As discussed above in the context of renewable energy lowering wholesale market prices, it is also true that partially as a result of large increases in the supply of electricity from renewable resources such as wind and solar PV, the economic performance of much of Germany's fossil generation fleet has significantly deteriorated. This in turn is leading to a fear that absent a permanent approach to ensuring resource adequacy Germany may soon see significant retirements of underperforming fossil power plants, with the result that not enough non-renewable capacity may remain to ensure reliable supply of electricity during periods of low production from renewables, especially post 2022, when the remaining nuclear power plants are scheduled to retire.[51] The result has been an intense debate about changes to existing market rules that may be necessary to ensure sufficient overall generation capacity to guarantee that highly reliable electric service can be provided in the future.

In the short run, the concerns about the availability of (non-renewable) generation during periods of low production from wind and solar PV has been addressed through a number of legislative and regulatory steps. A reform of the energy law passed in 2012 and requires power plants planning to retire to inform the relevant TSO and electricity regulator at least twelve months prior to planned retirement. It also allows the TSOs to require such plants to continue to operate (against compensation). This provision is in effect until 2017. The Reservekraftwerksverordnung (regulation on reserve capacity), passed in June 2013, allows TSOs

[50] For a more in-depth discussion, see http://www.modernpowersystems.com/features/featuredealing-with-the-50.2-hz-problem/. See also Ecofys/IFK, Impact of Large-scale Distributed Generation on Network Stability During Over-Frequency Events & Development of Mitigation Measures, Summary, September 2011.

[51] Some plants have already announced their retirement and are now subject to the interim provisions described above. The situation is expected to become potentially more severe in Southern Germany in 2022, when approximately 8,800 MW of nuclear capacity will go offline due to the phase out of nuclear power in Germany.

to sign contracts for required reserve capacity in coordination with the Bundesnetzagentur, the German electricity regulatory agency.

Beyond these temporary measures, efforts are underway to introduce some form of capacity market mechanism, i.e. a system that would compensate generation capacity required to assure ongoing reliable supply of electricity. The mechanism currently in place and just discussed is one such approach, as are the more formal capacity markets in place in several ISOs in the United States (such as PJM, NEPOOL and NY ISO). Germany is also exploring a focused capacity market concept, where only certain types of generation (new, flexible, etc.) could participate. The European Commission is also active in this discussion and Germany's government has committed to introducing a capacity mechanism that respects the European context, which could be implemented by mid-2016.[52]

To support the further development of renewable energy sources, it will also be necessary to further invest in transmission and distribution infrastructure. The former will primarily be required to transport wind (on- and offshore) from production sites in the north to demand centers further south. The costs of required infrastructure investments in the high voltage transmission system have been estimated at €16 billion[53], i.e. approximately one year's equivalent of the renewables levy. While there is consensus that significant investment in distribution networks will also be necessary, in larger part to integrate increasing amounts of decentralized solar PV generation, there is no consensus on the total amount of investment needed and to what extent other measures such as demand-response may help reduce overall investment. A 2012 estimate by the distribution network operators suggests that total distribution network investment costs by 2030 could reach €25-32 billion.[54] However, a more recent statement by the chairman of the same organization suggests costs could be half as much.[55] To summarize, longer-

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52 For a recent update on the state of advancement of a capacity mechanism, see Reuters, Update 1 – German official signals help for utilities' loss-making plants, June 4, 2014 (accessed June 14, 2014 at in.reuters.com/assets/print?aid=INL6N0OL1Y020140604)

53 See Achim Zerres, Netzausbau und Versorgungssicherheit aus Sicht der Bundesnetzagentur, Bundesnetzagentur, May 5, 2014, page 4.

54 See VKU, Investitionsklima im Zeichen der Energiewende - Probleme und Anforderungen aus Sicht der Verteilnetzbetreiber, December 2, 2013, page 10.

55 VKU Presseinformation, Studie belegt politischen Handlungsbedarf bei Investitionsbedingungen von Verteilnetzen, February 17, 2014.

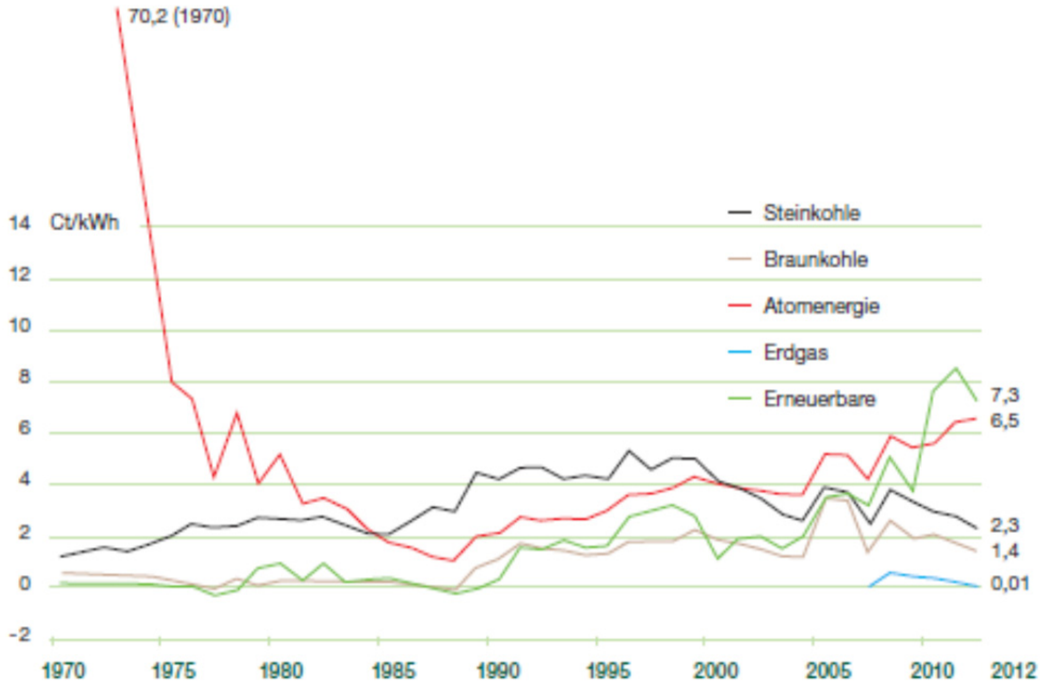
term investments in complementary infrastructure to support further development of renewable energy in Germany will be non-trivial, but will also likely be small when compared to the costs of supporting the introduction of renewables. Network investments will also have the effect of reducing some of the other renewables integration costs currently incurred (such as re-dispatch and curtailment).

VII. Renewable and solar PV support in Perspective

A final area of investigation concerns the rationale and magnitude for renewable (and solar PV) support in the context of similar support for conventional power generation. As mentioned above, support for renewable energy including in particular solar PV is in part motivated by the desire to cure market failures associated with the early stages of development of certain technologies. Often, such support is also provided with the desire to create or maintain certain industries with associated employment and larger economic benefits. Such concerns are independent of the desire to compensate for the environmental externalities such as greenhouse gas emissions. Therefore, many countries including Germany (and the United States) have been providing some form of support for various forms of energy production. Estimates of the magnitude of such support depend significantly on what forms of support are included. Consequently, they should be used with care. Figure 18 below shows one such estimate for historic support for various fuels used in power generation in Germany, on a cents/kWh basis.

Figure 18 shows that the average support for renewable energy ("Erneuerbare" – the green line on the chart) has only recently surpassed the average support for nuclear and hard coal support (Atomenergie – the red line, and Steinkohle – the black line). While average support for solar PV is currently closer to 30 €cents/kWh (see Figure 12 above), it is important to note that this current average support represents higher support in earlier years and that the support for new solar PV is dropping rapidly and expected to be below closer to 12 €cents/kWh. It is also important to note that the high support per kWh is not unique to solar PV, but rather that at the beginning of the nuclear industry per unit support for nuclear energy was even higher. Both are consistent with the idea that high initial support may be necessary to kick-start a learning process that triggers scale- and learning related cost decreases over time, i.e. a combination of market pull and technology push instruments.

Figure 18: Historic Non-market support for various fuels in Germany

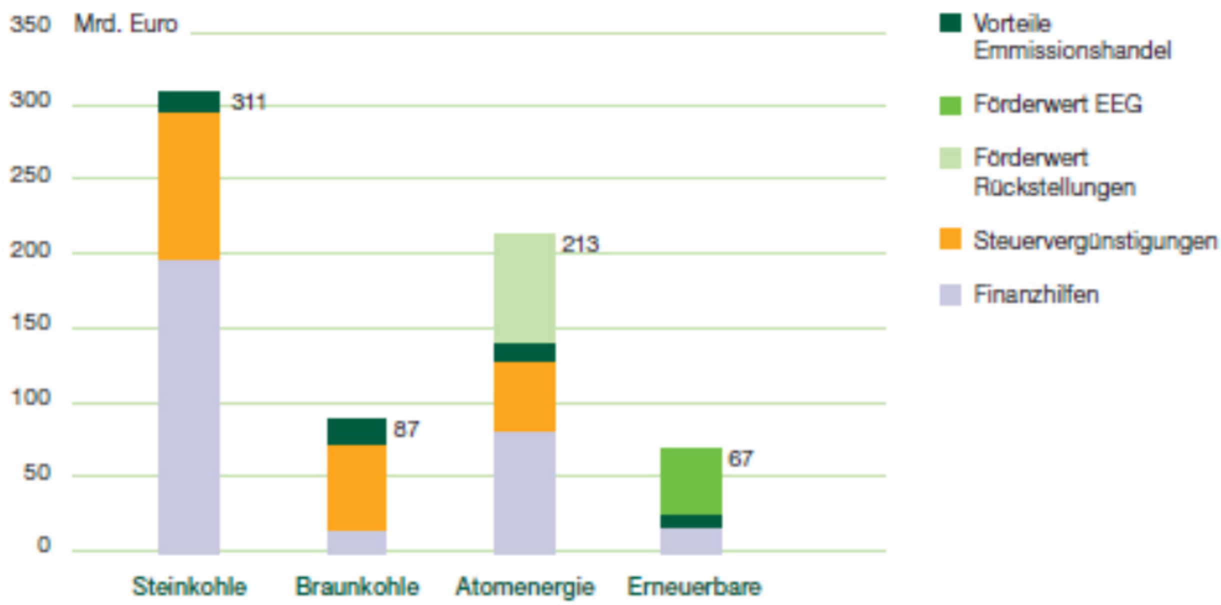


Source: Reproduced from Figure 4, Forum Ökologisch-Soziale Marktwirtschaft e.V., Was Strom Wirklich kostet, August 2012.

If support for a technology is designed to represent an investment into bringing a technology to market, then cumulative support for any given technology are a useful means of comparison. Figure 19 below therefore shows cumulative support for various electricity production related fuels since 1970.

Figure 19 shows that total support for hard coal (Steinkohle, first column from the left) in Germany surpasses 300 billion Euros in real terms. Support for nuclear energy (Atomenergie, second column from the right) surpasses 200 billion Euros. While some of the support does not directly relate to electricity production (since coal can also be used for heating), the figures show that the 67 billion Euros spent on renewable support (Erneuerbare, fourth column from the left) through 2012 are significantly below the amounts historically spent for other sources of energy.

Figure 19: Cumulative support for various fuels in Germany (real) between 1970 and 2012



Source: Reproduced from Figure 2, Forum Ökologisch-Soziale Marktwirtschaft e.V., Was Strom wirklich kostet, August 2012.

Projections suggest that the current levels of support of approximately $20 billion per year for renewables will be needed for several more years to come (even though, as discussed above, payments are leveling off and will likely begin to fall), so that the total support for renewables needed to shift Germany's electricity sector away from fossil (and nuclear) fuel may well be comparable to the support given to fossil in nuclear fuels historically.[56] However, it also shows that the support for renewables will likely be comparable to the support given for other fuels and hence should not be singled out as unaffordable.

VIII. Conclusions

For the past 15 years or so, Germany has embarked on an ambitious set of policies to transform its electricity (and broader energy) sector. The nuclear accidents in Japan led to an acceleration

56 These support payments for fossil and nuclear generation do not include various externality costs as well as future obligations such as ultimate disposal of spent nuclear fuel.

of the efforts, which have produced some of the fastest increases in renewable power generation in the world. With almost a third of globally installed solar PV capacity, Germany has now reached levels of renewable energy production leading to significant interactions with the rest of the electricity system. The approach of rapidly ramping up renewable energy production through a system of technology specific FITs guaranteed for 20 years and collected from most (but not all) end-use customer through a renewables levy has led to increases in electricity prices that in turn have resulted in concerns about their affordability and effect on Germany's competitive position in the world. It has also led to concerns that existing market rules and structures will need to be adjusted to ensure reliable electricity supply in the future.

This report took a closer look at the impact of Germany's program of support for renewable energy and in particular solar PV. The main conclusion is that by and large the German path has been remarkably successful, given the goal – shared by a great majority of the population – of "de-fossilizing" Germany's electricity sector. While the costs of electricity to most end use customers have indeed increased, it is important to note that the size of the renewables levy by itself is an incomplete (and likely exaggerated) measure of the cost of the program to consumers. It is also important to note that exemptions for trade-sensitive and energy-intensive industries contribute to higher rates for non-exempt consumers, but also ensure that exempt industries do not suffer a competitive disadvantage internationally. The exemptions have meant that electricity costs for large industrial users in trade-sensitive industries are generally in line or even below those faced by European competitors and thus likely have at least contributed to the fact that until now German industry's competitive position remains quite strong.

Germany has certainly contributed to the creation of a global solar PV industry and resulting costs of solar PV that have declined dramatically and begin to approach the costs of power generation from new fossil power sources in at least some countries (including Germany, where natural gas prices are high). With hindsight it is likely that the rapid expansion of solar PV capacity from 2009 to 2011 under the existing FIT program has settled German consumers with costs that are higher than what might have been possible had FITs been adjusted downwards earlier and more rapidly. However, these costs have been incurred and given the legal reforms already passed and currently underway, it is likely that the incremental cost of further increasing Germany's solar PV capacity to its planned target level of 52 GW – from already achieved 35 GW - will be quite minor, given how far the FITs (and the cost of solar PV) have decreased.

It is clear that the introduction of renewable energy including solar PV has had a fundamental impact on the German wholesale electricity market. In particular, it has led to a significant loss of profit margins for traditional fossil generation and corresponding losses to their owners. As a result, there is some legitimate concern, given the increase in re-dispatching activities, that if too many of money-losing fossil generators retire, electric reliability may be affected. Short term measures now in place are intended to ensure that plants needed for system reliability cannot retire and that their owners are appropriately compensated.[57]

Given the fact that renewable energy has reached sizable market penetration and maturity, the focus of Germany's policy is therefore appropriately shifting towards the creation of a regulatory environment that allows even higher penetration of renewable energy in line with intermediate and longer term targets, a task that requires adjustments both of renewable energy sources and the rest of the electric system to ensure continued supply of electricity at the high levels of reliability historically (and currently) enjoyed by German consumers.

One lesson for the United States is therefore that complementary regulatory frameworks should be put in place – where they are lacking – to ensure that all elements of the electricity market face appropriate incentives and are compensated for the value they provide to the system. Apart from capacity mechanisms, appropriate pricing and procurement of ancillary services and demand response are likely key features of future electricity systems currently under-developed in Germany (and to some extent and in some regions also in the United States).

It can certainly not be concluded that Germany is now (finally) abandoning a flawed system of FITs to support renewable energy system. There is significant evidence that FIT based systems, which provide the revenue certainty needed to attract low-cost financing for renewable energy, allow for lower cost renewable energy procurement than most of the alternatives used in the United States, in particular certificate based systems using Renewable Energy Certificates (RECs).[58] Therefore, if, as is the case in Germany, democratic support for a transition away from

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57 Whether or not the current mechanism does appropriately compensate the owners of such plants prevented from retiring is being disputed by at least some of the owners of such plants.

58 See COMMISSION STAFF WORKING DOCUMENT, Review of European and national financing of renewable energy in accordance with Article 23(7) of Directive 2009/28/EC, SEC(2011) 131 final; page 6

conventional and towards renewable energy is strong, the use of well-designed FITs is likely superior to alternative regulatory support mechanisms, especially during the early phases of renewable technology development. At a share of renewable energy in excess of 20% and after more than a decade of support, prices for power from new renewable projects are now close enough to the cost of new conventional generation that a transition towards a more market-based approach seems justified.

In hindsight, the period 2009-2012 is likely the one where the German FIT system was not well enough designed to avoid overshooting the solar PV targets (and hence avoiding the associated costs of committing to relatively high FIT payments at the time). The primary lesson there is that since unlike conventional power sources solar PV development can be extremely dynamic, a system of FITs to support solar PV development must be able to adjust quickly (and perhaps automatically) to observed levels of installation. Subsequent reforms to Germany's renewable energy law have largely rectified this, with future FIT levels being revised often and in response to clearly defined build-out corridors, but it would have been preferable for these adjustments to have been automatic and part of the program from the start.

Germany's renewable energy and solar PV support programs have led to Germany increasing the share of solar PV and wind in its energy mix significantly, putting the country on a path towards a broadly supported transition towards an electricity system primarily powered by renewable energy. This transition involved new technologies, and as was the case for previous (and now conventional) forms of energy, the development of these technologies required public support – the levels of which are in line with cumulative levels previously provided to other forms of energy. The total level of support has remained low enough that Germany's economy has continued to perform well – in part due to the (partial) exemption of certain industries, which, while unpopular, is likely a reasonable measure to assure that German companies in energy – intensive and trade-exposed sectors do not suffer an unfair disadvantage. As the recent Ukraine crisis has shown, the transition has also helped reduce the exposure of Germany to potentially volatile input prices to the traditional power system, a benefit that has largely remained unquantified, but could prove significant in the future.

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