The Conundrum of the German Electricity Market:
How Germany Ended Up With High Retail Electricity Prices
And What Can Be Done About It

By

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Abstract
The aim of this paper is to analyze the causes of high German retail electricity prices (the highest within the EU region and generally at least double those in the U.S.). The paper finds that the key culprit is the German government’s decision to dramatically increase the share of renewable electricity—primarily wind and solar—irrespective of the cost of this policy. With the highest share of renewables in electricity generation in the world—presently at 23 percent and expected to rise to 35 percent by 2020, 50 percent by 2030, and ultimately 80 percent by 2050—Germany has embarked unilaterally on a costly “green energy path.” This path has potential extremely adverse consequences for the German economy in terms of cost imposed on consumers and threat to long-term competitiveness of electricity-intensive and export-oriented industrial branches. The upward pressure on German electricity prices has been made much worse by oligopolistic structure of the German electricity sector, dominated by four vertically integrated utilities. While some sectors of the German electricity market are relatively competitive—particularly the generation and supply sectors—other sectors suffer from lack of competition and few incentives to cut costs. Yet, in spite of the high retail electricity prices, the health of most German utility companies has deteriorated dramatically since the onset of the 2008 global financial crisis. Consequently there are serious doubts that the electricity industry in its current shape will be able to generate sufficient profits to finance the upcoming massive investments necessary to improve the German transmission system, develop smart grid networks, and invest in industrial-scale electricity storage systems when these become economically viable.

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1 INTRODUCTION

1.1 Why Look at the German Electricity Market

There is much to be learned from Germany’s experience with electricity market policies and their impact on electricity pricing. The issues in connection with electricity pricing in Germany are much broader and varied than is typical of other major developed countries like the U.S. In the past two decades, German electricity policies have undergone several significant shifts, particularly focusing on the rapid increase in the use of renewable energy and the liberalization of the electricity market. Thus valuable lessons can potentially be learned from Germany’s electricity price setting policies over the past two decades.

There are several key parameters regarding the German economy, which make it an appropriate country through which to study the impact of electricity policies for developed economies. With a nominal GDP of around $3.4 trillion in 2012, Germany is the largest economy in Europe and the fourth largest economy in the world. Essential to this large economy are a number of electricity-intensive industrial sectors, which rely on electricity as a key production input. Accordingly, Germany is the largest consumer of electricity in Europe and the primary generator of its own electricity. This reliance on electricity makes the price of electricity a key factor in determining the competitiveness of the electricity-intensive industrial sectors. Germany’s electricity-intensive industrial sectors include: steel and metallurgy; chemicals and oil refining; transport engineering; heavy machinery; and electrical engineering. Cost competitiveness is critical for many of these sectors because Germany’s economic growth depends on its ability to export goods produced by the manufacturing sector. This export

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1 The World Bank, 2012
dependence is illustrated by the fact that slightly over a half of German GDP is made up of exports of goods and services.²

As a result of its successful long-term economic growth and consequently high level of GDP per capita, the German government has taken on the high-cost initiative of becoming the world’s most advanced renewable energy producer by legislating a series of expensive energy polices. It has done so with the desire to go “green” in its power generation as fast as possible. Starting with the 1990 feed-in-law or Stromeinspeisungsgesetz (StrEG), Germany attempted to encourage the production of electricity from renewable sources like wind and solar power. This feed-in law allowed generators of renewable electricity to supply the electricity to an obligated off-taker (i.e. a distribution system operator) at a guaranteed price for each kWh. This guaranteed price (i.e. feed-in tariff rate) is typically above the prevailing market price for electricity from conventional sources. Since then, such feed-in tariff policies have continued to exist with policies such as the 2000 Renewable Energy Sources Act, which set higher fixed tariff rates generators of renewable electricity for the next 20 years. As a result this policy focus on increasing the share of electricity generated from renewable sources of electricity, Germany has gone further to rely on wind power than any other major industrial country except Denmark (currently, 8.8 percent of electricity consumed in Germany is from wind power).

Most recently, in 2010, the German government published an outline of the Energiewende, its energy transition program toward renewable energies. This document states that, “By 2020, the federal government targets that renewable energy will meet at least 35 percent of total gross electricity consumption. In addition, the federal government is also committed to increasing the share of the electricity generated from renewable energy sources to

² The World Bank, 2012
50 percent of gross electricity consumption by 2030, 65 percent by 2040, and 80 percent by 2050.\(^3\) (IEA, 122). This decision to be at the forefront of reducing CO\(_2\) emissions makes Germany a great lens through which to look at the impact of different electricity polices on highly developed economies.

1.2 High Prices in the German Electricity Market

The most highly debated issue regarding the German electricity market today is why retail electricity prices are so high, while wholesale electricity prices are relatively low, compared to rest of the world.\(^4\) In fact, retail electricity prices have become so high that they were an issue hotly debated in the recent 2012 presidential and 2013 federal elections in Germany. This comes as no surprise when considering that the average retail electricity price for households in Germany is much higher than in the U.S. and the second highest, after Denmark, among the EU15 (see Figure 1). The high household electricity prices are of concern to policy makers and the public at large because they imply a reduction in living standards below the level which would have been reached otherwise.

To put these high household electricity prices in a proper perspective, consider a family residential electricity bill for the month of February 2014 in the State of Maryland. Maryland is one of the U.S. states with relatively more expensive electricity compared to states with major coal mines and coal-fired power plants. The family paid an average of 12.7 U.S. cents per kWh or EUR 0.092 per kWh. This is only one-third of what the average German household already paid for electricity in 2012 and about two-thirds what was paid by households in Greece, where electricity was cheapest among the EU15.

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\(^3\) IEA, 2013, p.122

\(^4\) IEA, 2013, p. 130
It is not only German households which suffer from high retail electricity prices. The average retail electricity price for industrial consumers is also high in Germany relative to other EU countries (see Figure 2 below). As mentioned above, Germany’s manufacturers are highly dependent on exports of their products. So if the price of electricity for these manufacturers is high relative to the price of electricity for their competitors in other countries, the manufacturers in Germany must deal with higher production cost. Inevitably, electricity-intensive industrial sectors in Germany become less competitive on a global scale. Ultimately, the decrease in competitiveness of German exports could have serious negative implications for its future GDP growth.

These issues beg the question, what is making retail electricity prices so high for household and industrial consumers in Germany? Is there an issue with German energy policies, the electricity market structure, or other market characteristics? This paper finds that there are two major factors affecting retail prices of electricity in Germany. The first is Germany’s political drive to lead the world in increasing the share of renewables in its electricity consumption. In order to do so, Germany has subsidized generators of renewable sources of electricity with feed-in tariffs. These feed-in tariffs have led to a surge in generation from renewables and a greater excess generation capacity, which have decreased wholesale prices of electricity. The surge in generation from renewables, however, has also led to higher associated distribution costs of balancing electricity supply and demand from decentralized and unreliable renewable sources of electricity. These higher distribution costs have subsequently outweighed the decreased wholesale prices and increased retail prices of electricity for consumers. Figure 3 illustrates the trend of increasing retail electricity prices in the face of in face of falling wholesale prices. The second major factor affecting retail prices of electricity is the relatively
uncompetitive structure of the German electricity market. The generation, distribution, and supply sectors of this market are dominated by four large vertically integrated utilities, namely E.ON, RWE, Vattenfall, and EnBW. Using their market dominance, these utilities have increased the profit margin within the distribution sector of the market by charging higher balancing and access charges for the distribution system than what is necessary given the costs of their services.

2 HOW THE GERMAN ELECTRICITY MARKET FUNCTIONS

2.1 Participants

In order to understand the key causes of why retail electricity prices in Germany are high, one must have a sound understanding of how its market functions. So before any in-depth discussion of prices, the structure of the market must be laid out. Figure 4 is a very basic illustration of how electricity moves among participants within the electricity grid. Participants in the German electricity market/grid include the following:

- Electricity generators
  - Although the statistics on the exact number of power plants and/or wind and solar farms in Germany are not readily available, Germany’s overall electricity generation capacity was estimated around 171.7 gigawatts and Germany’s total annual electricity generation was 602.4 terawatt hours in 2011.\(^5\)\(^6\) There are probably over 900 different generators; however, four utilities (E.ON, Vattenfall, Vat

\(^5\) Electricity generation capacity is the theoretical maximum quantity of electricity generated in a given moment. Total annual electricity generation is the actual quantity of electricity generated in a given year.

\(^6\) IEA, 2013, p. 133
RWE, and EnBW) owned about 73 percent of the overall generation capacity in 2011. Large power generators with major power plants typically supply their electricity to the transmission grid while small power generators (including wind and solar farms) supply their electricity directly to the distribution grid to which they are connected. These generators sell their electricity to the suppliers in the wholesale market.

- Transmission system operators naturally monopolistic regional transmission sector
  - 75 percent of all electricity produced in Germany runs through the transmission grid consisting of over 34,000km of extra-high and high voltage lines. Four naturally monopolistic regional transmission system operators (50Hertz, Ampiron, EnBW Transportnetze, and Tennet) own six geographically distinct sections of the transmission grid. Their primary job is to balance the electricity supply and demand in all of Germany throughout each day. The transmission grid takes electricity from connected large power plants and then supplies the electricity to the connected lower voltage distribution grid. The transmission grid also occasionally takes electricity from the distribution grid.

- Distribution system operators
  - The distribution system operators balance electricity supply and demand within their respective section of the distribution grid (i.e. network area). The distribution grid, consisting of over 1,620,000 km of medium and low voltage lines, takes electricity from the connected transmission grid and from connected smaller power plants. It then supplies the electricity to connected consumers and

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7 IEA, 2013, p. 137
8 OECD, 2004, p. 24
occasionally back to the transmission grid. Because of the rapid increase in the number of wind and solar farms in the past decade, more generation capacity is connected to the distribution grid than the transmission grid.\(^9\) Although there were around 869 naturally monopolistic regional distribution system operators in 2010,\(^{10}\) the four large German utility companies (E.ON, Vattenfall, RWE, and EnBW), which dominate electricity generation, also dominate the distribution grid.

- **Electricity suppliers**
  - In total, there are around 1,100 electricity suppliers in Germany.\(^{11}\) These suppliers act as brokers, buying electricity from generators in the wholesale market and then selling the electricity to consumers in the retail market. Once again competition exits, but to a limited extent. The four large utilities held 45 percent of the retail market share in 2011. The rest of the suppliers in the retail market were made up of around 900 municipal utilities,\(^{12}\) most of which also serve as distribution system operators.

- **Consumers**
  - There are two types of consumers who buy electricity from suppliers in the retail market: industrial consumers and household consumers. There were approximately 2.5 million industrial consumers and 44.4 million household consumers connected to the distribution grid in 2010.\(^{13}\) These consumers

\(^9\) IEA, 2013, p. 138  
\(^{10}\) IEA, 2013, p. 140  
\(^{11}\) IEA, 2013, p. 160  
\(^{12}\) IEA, 2013, p. 137  
\(^{13}\) IEA, 2013, p. 140
typically have the choice to buy their electricity from a large number of suppliers within their network area.

2.1.1 Electricity Generators

Compared to the transmission and distribution sectors of the German electricity market, the electricity generation sector is relatively competitive. There are many small generators or utilities, which are connected to the distribution network. However, the generation sector is primarily dominated by the four large utilities (E.ON, Vattenfall, RWE, and EnBW). Combined, these four utilities generated over 80 percent of electricity back in 2006.\textsuperscript{14} However, in recent years, the situation has changed dramatically. Because of factors such as the proliferation of electricity produced from renewable sources and the shutdown of eight nuclear power plants (owned by the four large utilities), the market share of these four utilities was reduced to 73 percent by 2011.\textsuperscript{15} The significant increase in competition among generators contributed to the steady fall in wholesale electricity prices since 2008. This trend has been particularly pronounced since mid-2011 (see Figure 5). However, it should be noted that although wholesale electricity prices have fallen since 2008, this has not resulted in a corresponding fall in retail electricity prices (see Figure 3). In fact, retail electricity prices have steadily risen during this period.

Increased competition was not the only factor that has led to the fall in wholesale electricity prices since 2008. The continued increase in generation capacities combined with very slow growth (and even an outright fall) in demand for electricity in recent years was a major factor contributing to the fall in wholesale electricity prices. The dramatic increase in the renewable generation capacity, for example, led to greater excess generation capacity overall,

\textsuperscript{14} Reisch et al., 2006, p. 409
\textsuperscript{15} IEA, 2013, p. 137
which caused the wholesale price of electricity to fall. In addition to this development, during the 2000s, both German and other European utilities overinvested in generation capacity from fossil fuels. This overinvestment led to an increase in generation capacity by 16 percent in Europe as a whole, which was unwarranted by economic conditions and growth prospects at the time. The post-2008 financial crisis and general economic downturn in Germany and the rest of Europe made things much worse, significantly reducing the demand for electricity.\textsuperscript{16}

On top of the increase in the supply of electricity, an external shock occurred in the form of the shale-gas development in the US, which caused US generators to rapidly switch to cheaper gas-fired generation. The switch pushed down the domestic demand for US coal and subsequently, US coal prices fell sharply. The falling US coal prices triggered a corresponding downward adjustment in European coal prices. Simultaneously, carbon emission permit prices collapsed under Europe’s emissions-trading scheme because too many permits were issued and the economic recession in Europe cut the demand for such permits.\textsuperscript{17} These two developments made it considerably more financially attractive to burn coal, step up coal-fired generation, and crowd out more expensive gas-fired plants in Germany. By some estimates, as much as 30 gigawatts of gas-fired generation capacity (including generation from brand new gas-fired plants) has been suspended in Europe following these two developments.\textsuperscript{18} Germany alone contributed to a large portion (roughly one-third) of this suspended capacity. Although effectively used gas-fired generation capacity decreased in Germany, this did not slow the increase in excess generation capacity overall. Instead, the decrease in gas-fired generation capacity was merely replaced by an increase in coal-fired generation capacity.

\textsuperscript{16} The Economist, 2013, p. 2
\textsuperscript{17} The Economist, 2013, p. 2
\textsuperscript{18} The Economist, 2013, p. 2
The impact of excess supply plus depressed demand for electricity has pushed utilities’ wholesale electricity prices in Germany down dramatically. Subsequently, the value of shares for the utility companies has plummeted. This is illustrated by the fall in European utilities share price (see Figure 6). The Economist magazine points out that:

Since September 2008, utilities have been the worst-performing sector in the Morgan Stanley index of global share price. In 2008, the top European utilities all had credit ratings of A or better. Now only five do.

The rot has gone furthest in Germany, where electricity from renewable sources has grown fastest. The country’s biggest utility, E.ON, has seen its share price fall by three-quarters from the peak and its income from conventional power generation (fossil fuels and nuclear) fall by more than a third since 2010. At the second largest utility, RWE, recurrent net income has also fallen by a third since 2010. As the company’s CFO laments, “Conventional power generation, quite frankly, as a business unit, is fighting for its economic survival.”...

Bloomberg’s New Energy Finance (BNEF), a data provider, reckons that 30-40 percent of RWE’s conventional power stations are losing money.\(^{19}\)

Given the current situation faced by the four major German utilities, any concern about the lack of competition in the generation sector of the electricity market would be misplaced. The current concern within the generation sector is the survival of these entities, their future role, and their ability to adjust to the dramatic change in market conditions.

2.1.2 Transmission System Operators

The transmission sector, along with the distribution sector, is the least competitive sector in the electricity market. In this naturally monopolistic regional transmission sector, 50Hertz, Ampiron, EnBW Transportnetze, and Tennet are the only four transmission system operators who balance electricity supply and demand within their six geographically distinct transmission grid areas (see Figure 7). Within each of these areas, only one of the four transmission system

\(^{19}\) The Economist, 2013, p. 1-2
operators provides its transmission services. These transmission system operators take any electricity not kept by distribution system operators (i.e. electricity generated by small power generators within the distribution grids) and any electricity produced by large power generators within their grid areas. Then they exchange the electricity amongst each other and send the electricity to distribution system operators that demand more electricity. The transmission system operators also have the ability to shut down large connected power plants supplying electricity to the transmission grid when too much electricity is generated in Germany in a given moment. Additionally, when there is too much/too little electricity supplied to the transmission grid, transmission grid operators also can export/import some electricity to/from neighboring countries (i.e. Austria, Belgium, the Czech Republic, France, Luxembourg, Poland, Netherlands, Sweden, and Switzerland). Although Germany has been a net exporter of electricity since 2003, its foreign trade of electricity is relatively negligible in relation to its total annual electricity generation. Its exports range between seven and ten percent and its trade surplus typically represents less than five percent of total annual electricity generation. In order for this electricity to travel long distances within and outside of the country, the transmission grid utilizes extra-high voltage lines (i.e. 220 kV to 380 kilovolts) and a few high voltage lines (110 kilovolts). These lines minimize transmission losses, which are inversely related to the line voltage.

The German company, EnBW Transportnetze is the only one of these transmission system operators, which is also a dominant regional generator of electricity (under the name EnBW). Although the other three large utilities used to dominate both the generation and transmission sectors, this ended in the early 2000s when the German government forced legal unbundling upon these vertically integrated companies (i.e. forced them to sell their transmission grids). Consequently, Amprion is controlled by a financial investor (Commerzbank), TenneT is
controlled by a Dutch transmission system operator, and 50Hertz is controlled by Belgian/Australian transmission system operators (see Table 1). EnBW is the only utility of the four large utilities that was not broken up by the German government and forced to sell its section of the transmission grid. This is because EnBW is the smallest of the four dominant utilities in each of the generation (i.e. generating less than 10% of the total electricity generated annual in Germany), distribution, and supply sectors. As a result, the German government viewed EnBW as the least able to abuse its monopoly position in the transmission grid and left it alone.

There are no taxes or levies for the services provided by the transmission system operators.\textsuperscript{20} However, the transmission system operators charge large power generators directly connected to the transmission grid for access to the grid. These operators are required to provide non-discriminatory third party access and can only deny access if they can prove that providing the access would be unfeasible or logistically unreasonable.\textsuperscript{21} In addition to access charges for generators, transmission system operators also charge consumers for their balancing services (i.e. for balancing supply of electricity with demand for electricity) in the form of a tariff on the final consumer bill. The Federal Decree on Network Access Fees in the German Energy Act of 2005 regulates how transmission system operators can calculate access charges and charges for balancing services. It has been fairly successful in preventing transmission system operators from charging excessively high prices. Consequently, Germany has relatively middle-ranking transmission charges compared to other EU member states.\textsuperscript{22} This federal decree also includes an incentive mechanism whereby the prices transmission system operators charge do not only

\begin{itemize}
  \item \textsuperscript{20} OECD, 2004, p. 24
  \item \textsuperscript{21} IEA, 2013, p. 152
  \item \textsuperscript{22} OECD, 2004, p. 37
\end{itemize}
depend on the cost base of their services. Instead the federal decree allows more efficient companies to receive higher returns.\textsuperscript{23} The transmission system operators thus make a profit in the electricity market from these access fees and tariffs rather than from buying and selling electricity.

2.1.3 Distribution System Operators

In the distribution sector within the German electricity market, the creation of a competitive market faces another challenge. The four large utilities, which already control the majority of the generation sector, are also dominant in the distribution sector. These four utility companies typically either own their own distribution companies or hold significant stakes and effective controlling interest in municipal distribution companies. So, although there were a total of 869 distribution system operators in 2010, many are completely or partially owned by the four large utility companies.\textsuperscript{24}

Similarly to the transmission system operators, the distribution system operators balance electricity supply and demand within their own section of the distribution grid (i.e. network area). These distribution system operators do not have the ability to shut down small power generators within their network areas. However, the distribution system operators still take electricity supplied by the transmission system operators and smaller power generators to which they are connected and supply it to consumers within their network area. If the supply of electricity generated exceeds the demand for electricity within their network area, distribution system operators can also supply the excess electricity to the connected transmission grid. Because the distribution grid primarily consists of medium (i.e. mostly 20 kilovolts) and low

\textsuperscript{23} IEA, 2013, p. 154
\textsuperscript{24} IEA, 2013, p. 140
(i.e. 400 volts) voltage lines, substations connecting the distribution grid to the higher voltage transmission grid step-down the voltage of the electricity supplied by the transmission grid. Conversely, when a network area has a greater supply of electricity than what is demanded by its consumers, the substations step-up the voltage of this excess electricity to allow the distribution system operators to supply the transmission system operators with the excess electricity.

Distribution system operators generally have the same sources of revenue as transmission system operators. Distribution system operators charge consumers and smaller power generators connected to their distribution grid for access and charge consumers for their balancing services (according to the Federal Decree on Network Access Fees). However, one difference is that in the case of around 800 distribution system operators with less than 100,000 customers, the regulatory authority of the state in which distribution system operators are located determines the network access fees. The federal decree, however, has not been successful in preventing distribution system operators from charging excessively high prices. This unsuccessful regulation stems from Germany’s unusually high maximum charges for access and balancing services in the distribution grid compared to other EU member states. Distribution system operators take advantage of these high maximum charges and their natural monopoly over distribution services in their section of their distribution grid and charge excessively for access and balancing services. Consequently, Germany has unusually high distribution charges compared to other EU member states.

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25 IEA, 2013, p. 152
26 OECD, 2004, p. 37
27 OECD, 2004, p. 37
2.1.4 Electricity Suppliers

On the supply side of the German electricity market, there are around 1,100 suppliers who buy electricity from generators in the wholesale market and sell the electricity to household and industrial consumers in the retail market. Many of the 1,100 suppliers also serve as distribution system operators in the distribution grid. Although the supply sector has many suppliers, similarly to the distribution sector, the four large utilities supply a very large share of total electricity supplied. Within the wholesale market, suppliers have two ways to buy electricity from generators: trading on the European Energy Exchange or over-the-counter contracts.

Germany has one power exchange called the EEX or the European Energy Exchange. The EEX has both day-head physical markets, where electricity is traded for the next day, and futures markets, where electricity is traded months or years in advance. Additionally, the EEX is divided into six bid areas, which correspond to the six areas in Germany controlled by the transmission system operators. Even though the EEX is divided into these bid areas, the bid areas have identical wholesale prices of electricity.\(^{28}\) In 2003, about ten percent of total electricity consumed in Germany was traded in the day-ahead market. This was seven times as much as the amount of electricity traded in the futures market.\(^{29}\) In years since 2003, there has been a noticeable increase in the day-ahead market volumes on the EEX as a result of a legal obligation under the 2000 Renewable Energy Sources Act for transmission system operators to market renewable sources of electricity on the EEX.\(^ {30}\)

\(^{28}\) OECD, 2004, p. 24  
\(^{29}\) OECD, 2004, p. 24  
\(^{30}\) IEA, 2013, p. 145
In contrast with this relatively transparent EEX market, over-the-counter contracts, particularly among the four large utilities, make up most of Germany’s wholesale market. For example, one of the utilities, E.ON, purchased 57 percent (i.e. 327.6 billion kilowatt hours) of the electricity it sold in the retail market through over-the-counter contracts in 2001. Of this, 17.5 billion kilowatt hours was purchased from power stations where it had an interest of 50 percent or less and another 168.3 billion kilowatt hours was purchased from other utilities where it had no interest.\(^{31}\) On the whole, 85-90 percent of total electricity consumed in Germany was sold in over-the-counter contracts. Unlike the EEX market, these contracts are based on bilateral relations, rather than an integrated market where all electricity is traded in an open market accessible to all actors. Moreover, because these over-the-counter contracts are done behind “closed doors,” price information is not disclosed.\(^{32}\) Prices of electricity under over-the-counter contracts are estimated to be higher than prices of electricity on the EEX. However, it recently has been found that these prices are converging, thus increasing market integration.\(^{33}\)

Once suppliers have purchased electricity from generators, the suppliers then sell their electricity to consumers in the retail market. Because many of the suppliers sell their electricity in more than one network area, consumers can choose from a large number of suppliers within their region. As a result, consumers are not tied to one regional supplier. Instead, over three quarters of all the network areas in Germany had over 50 suppliers in 2011.\(^{34}\) One of the aspects of the electricity market that make it so different from most other markets is that although suppliers purchase electricity from a particular electricity generator, the electricity they end up supplying to consumers may not be from that generator. For example, even though a supplier can

\(^{31}\) OECD, 2004, p. 25
\(^{32}\) Rees et al., 2010, p. 41
\(^{33}\) Growitsch et al. 2011, p. 9
\(^{34}\) IEA, 2013, P. 160
purchase all of its electricity from generators using renewable sources, it may not end up supplying any electricity from renewable sources to its customers. By purchasing electricity from renewable sources, the supplier is only paying the generators using those renewable sources and receiving its electricity from “random” generators (i.e. from an electricity pool) in return.

There is no relation between the source of electricity bought in the wholesale market and the source of electricity sold in the retail market because when a supplier purchases electricity from a generator, the generator’s electricity is put into a pool (i.e. the electricity grid). In this pool, the transmission and distribution system operators control which electricity is supplied to which consumers. These operators usually supply consumers with electricity that is generated nearest to their homes because this minimizes loses in electricity as it moves through the grid. So, the only guarantee that suppliers get when they purchase a certain amount of electricity from a generator is that the suppliers’ customers will receive that amount of electricity from the pool.

2.1.5 Consumers

Germany’s electricity consumers consisted of 2.5 million trade and industry consumers and 44.4 million household consumers in 2010.\textsuperscript{35} Trade and industry consumers use electricity as an intermediate good to provide goods and services. Household consumers, on the other hand, use electricity as a final good for their daily household activities. Although it was previously mentioned that consumers could choose from a large number of suppliers within their region, it is fairly infrequent for consumers to switch suppliers, especially in the case of household consumers. Only around four percent of household consumers and 35 percent of industrial consumers switched suppliers in 2002. Additionally, only 28 percent of household consumers

\textsuperscript{35} IEA, 2013, p. 140
and 65 percent of industrial consumers renegotiated their contracts with their traditional supplier in 2002. It is suggested that this low rate at which consumers switch their suppliers is a result of the high share of network charges and taxes (not determined by the suppliers) in the total cost of electricity in the retail market.\textsuperscript{36} As a result, variations in electricity prices among suppliers are not large enough for it to be worth consumer’s time and attention to switch their suppliers.

3 \textbf{CAUSES OF HIGH ELECTRICITY PRICES IN GERMANY}

3.1 Population Preferences

3.1.1 Historical Factors

In order to understand Germany’s political preferences with regards to electricity generation, it is worthwhile to step back and look at German history over the past four decades. Rupert Darwal makes a good summary of this history in his Wall Street Journal opinion article titled “Green Politics Made Europe Vulnerable to Putin:”

“Germany’s Greens first emerged as a political force at the end of the 1970s at a time of acute East-West tensions. In response to deployment of Soviet mid-range SS-20 missiles, NATO decided to station Pershing missiles in Germany. Massive, sometimes violent, demonstrations against nuclear power and nuclear missiles swept Germany… The protests turned the German left into the voice of radical environmentalism – a historical shift. Old Nazis and Neo-Nazis had been bearers of Germany’s culture of ecological politics, which had been marginalized with Hitler’s defeat. German environmentalism was anti-democratic and anti-capitalist…

In October 1980, Germany’s Green Party was formed to stand in parliamentary and state elections. Eighteen years later it entered government in a Red-Green coalition with the left-of-center SPD and in 2000 successfully pushed for the gradual phaseout of nuclear power. The Green’s biggest triumph came with Germany’s adoption of its Energiewende, the transition to renewable energy. The policy is a long-term bonanza for Gazprom [a Russian gas supplier]. It means that Germany will buy more and more Russian gas because it cannot depend on electricity from unreliable wind and solar to power its industries and keep the lights on.”\textsuperscript{37}

\textsuperscript{36} OECD, 2004, p. 26
Although Darwal is probably too harsh in his assessment, most of what he says is true. Germany’s Green Party has managed to lead Germany’s transition away from nuclear power generation and towards more unreliable electricity generation from wind and solar power. Needless to say, the major nuclear accidents in Chernobyl, Ukraine and Fukushima, Japan provided additional powerful ammunition to the anti-nuclear cause of the Greens and more or less provided final nails for the coffin of nuclear power in Germany.

3.1.2 Political Preferences

Since the 1990 feed-in law, the German government has made it its goal to shift Germany’s electricity production from carbon emitting sources like coal and gas-fired plants to renewable energy sources. This recent German political preference for renewable energy sources of electricity stems from public awareness of the importance of energy security and independence. After seeing how OPEC used oil as an economic weapon after 1972 and after seeing how the Russians have blackmailed Ukraine and other Eastern European countries with its natural gas exports in recent years, Germany has attempted to address some of its energy security issues.

Compared to Europe as a whole, Germany has a limited endowment of indigenous energy resources. Germany imports almost all of the oil, 80 percent of the natural gas, and 43 percent of the hard coal it consumes. It is even ultimately dependent on foreign suppliers for its nuclear fuel.\textsuperscript{38} It terms of indigenous fuels, the only fuel of significance easily mined and found widely throughout Germany is soft coal (lignite). Lignite is the lowest grade fuel containing large amounts of sulfur. With all of its hard coal virtually mined out, Germany has thus primarily

\textsuperscript{38} OECD, 2004, p. 8
relied on increasing the use of domestic renewable energies to increase the security of its electricity generation. As a result, Germany has positioned itself as one of the world leaders of the movement toward renewable energy use. In 2007, Germany agreed to the EU’s “20-20-20” targets which included a target to increase the renewable share of its electricity consumption to 20 percent. With its desire to go “green” as fast as possible, Germany predictably managed to reach this target already by 2011 (see Figure 8). After reaching this target, however, Germany did not stop. It extended this 2020 target by aiming to increase the share of its electricity consumption to 35 percent.

The political drive to increase the share of renewables in electricity consumption is not the only major shift that has taken place in the political arena in the last two decades. There has also been a love-hate relationship with nuclear power that has most recently turned towards hate. Both policy makers and the public at large have recently opposed electricity production from nuclear power plants. Following the recent Fukushima accident, the German government shut down eight of its seventeen nuclear power plants and promised to shut down the other nine by 2022. The sudden shutdown of the nuclear power plants put a significant strain on the German electricity transmission grid as it wrestled to balance electricity supply and demand. There were greater inconsistencies in the supply of electricity because the generating capacity of nuclear power plants in Germany was reduced from 20,399 megawatts of electrical output (i.e. 15 percent of installed capacity) to 12,003 megawatts of electrical output. Subsequently, wholesale electricity prices increased by approximately ten percent after the eight nuclear plants were shut down. It should, however, be noted that while this increase in wholesale prices may have had a

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39 World Nuclear Association, 2014, p. 1
40 Talbot, 2012, p. 52
slight impact by further increasing the already high retail electricity prices, wholesale electricity prices in Germany are still relatively low compared to the rest of in Europe.\textsuperscript{41}

3.2 Consequences of Political Preferences

3.2.1 Subsidization of Renewable Energy and Tariff Setting

In its attempt to increase the share of electricity produced from domestic renewable energies and strengthen the security of its electricity generation, Germany has resorted to subsidizing domestic wind and solar power generation. This generation ranges from a household installing one solar panel on the roof of its house to a business installing a wind farm with numerous wind turbines. Wind and solar power developments must be subsidized because although these renewable sources have negligible marginal costs (i.e. no fuels need to be purchased), they have very high fixed costs. The prices of solar panels have dramatically fallen in recent years thanks to large economies of scale in their production. However, solar panels and wind turbines are still relatively expensive in comparison to established technologies used in conventional generation (i.e. hydro, nuclear, thermal, and gas power) in terms of capital cost per unit generation capacity. As a result, if an individual or business invests in solar panels or wind turbines and were to sell the electricity generated at the prevailing market price (for conventional power), the returns these investors would get for their electricity would not be large enough to cover fixed cost within a reasonable investment horizon.

During the last two decades, Germany has primarily relied on feed-in tariffs to subsidize generators of renewable sources of electricity. The 1990 feed-in-law was the first law to establish feed-in tariffs for wind and solar power generators. Since then the 2000 Renewable Energy

\textsuperscript{41} IEA, 2013, p. 130
Sources Act has assured the use of feed-in tariffs for the next 20 years. These feed-in tariffs allow generators of renewable sources of electricity to supply the electricity to a distribution system operator who is obligated to buy it at a guaranteed price for each kWh. This guaranteed price is always above the market price for conventionally generated electricity because the tariff is set to cover the production costs of wind and solar power generation plus a reasonable regulated return on invested capital. This regulated return on invested capital helps investors in wind and solar power cover the high fixed costs of generation within a reasonable investment horizon.

Although increasing the share of electricity generation from renewable sources and strengthening energy security are both beneficial to the Germany economy, they come at a high cost in the form of generation subsidies. As shown in Figure 9 the overall cost of subsidies to renewable sources of electricity in Germany has surged from the EUR 4-6 billion range during 2007-8 to close to EUR 17 billion in 2012. Today, one of the most significant drivers of high electricity prices in Germany is the 2000 Renewable Energy Sources Act surcharge, which makes up 14 percent of the household electricity prices. The Renewable Energy Sources Act surcharge in 2013 was EUR 0.523 per kWh or 47 percent higher than it was in 2012. This is equal to an increase of almost EUR 60 in the average annual household electricity bill.\textsuperscript{42} It is the consumers, rather than the distribution system operators that carry the burden from the feed-in tariffs because the added price of the renewable electricity is passed on to consumers in the form of public service obligation charges.\textsuperscript{43} As a result, generators of renewable sources of electricity

\textsuperscript{42} IEA, 2013, p. 161
\textsuperscript{43} Kitzing et al., 2012, p. 194
received an estimated EUR 20 billion from consumers in 2012 for electricity that was only worth EUR three billion on the wholesale electricity market.\textsuperscript{44}

While consumers carry the financial burden of feed-in tariffs, they are not the only participant in the electricity market who is significantly negatively impacted by subsidies for electricity from renewable sources. These subsidies come at a great cost to electricity generators using conventional power as well. Under feed-in tariffs, renewable sources of electricity have grid priority, which means distribution system operators must take and use electricity from renewable sources before any other sources. This is important because in order for the transmission and distribution system operators to balance electricity supply and demand, these operators can refuse to take electricity from electricity generators producing conventional power when there is insufficient demand for electricity. With the growth in generating capacity of renewable sources of electricity and with the stagnant domestic demand for electricity, there has recently been a rising surplus of overall generation capacity. Therefore, generators producing conventionally generated power have been forced by grid operators to curtail their production correspondingly. Inevitably, with the surplus of generation capacity an additional fall in the wholesale price of electricity has also taken place. Because of these factors, some of the large German utility companies producing conventional power, such as RWE, have seen their net income fall by around a third. In fact, RWE has seen around 30 to 40 percent of its conventional power stations lose money.\textsuperscript{45}

Figure 10 is a highly stylized chart illustrating how feed-in tariffs for wind and solar power negatively impact both electricity consumers and electricity generators using conventional power. This chart represents what the supply and demand for base load electricity might look in

\textsuperscript{44} Schiermeier, 2013, p. 3
\textsuperscript{45} The Economist, 2013, p. 1-2
Germany today. Base load electricity is the minimum amount of electricity that is supplied over the course of a day during all hours. The supply curve for base load electricity consists of the aggregation of the marginal costs curves of each electricity generation segment. In total there are seven electricity production segments:

- **Hydropower generation MC**, which has the lowest marginal costs and is assumed to be essentially flat (accounts for five percent of power supply)
- **Nuclear generation MC**, which has the second lowest marginal cost and is also assumed to be essentially flat (accounts for 15 percent of power supply)
- **Thermal power generation MC** (including coal, biomass, and biogenic share of waste), which reflects the higher marginal cost of thermal generation than in the case of hydropower or nuclear power. The curve is upward sloping as increasingly less efficient thermal generation facilities are deployed (accounts for 56 percent of power supply)
- **Gas turbine MC**, which has the highest marginal cost because of the high cost of imported natural gas. It is also upward sloping as increasingly less efficient gas turbines are deployed (accounts for the ten percent of power supply)
- **MC of marginal gas turbines and other remaining marginal production facilities** (accounts for the remaining 14 percent of power supply)
- **Wind generation AC** (average cost; since marginal cost is negligible and since average cost determines the feed-in tariff rate affecting generators, suppliers, and consumers) is a multiple of the marginal costs of conventional power generation (above). It accounts for about nine percent of the remaining 14 percent of power supply under non-competitive market conditions (i.e. feed-in tariffs)
- **Solar generation AC** (average cost; since marginal cost is negligible and since average cost determines the feed-in tariff rate affecting generators, suppliers, and consumers) has the highest of all marginal costs. It accounts for about five percent of the remaining 14 percent of power supply under non-competitive market conditions

The demand curve for base load electricity is the usual downward-sloping demand curve and is fairly inelastic (i.e. demand does not dramatically change with changes in prices). Like in any market, the demand and supply curves together determine market prices and quantities supplied. However, in the non-competitive market conditions in Germany, feed-in tariffs for wind and solar power affect these prices and quantities. The feed-in tariffs disturb the wholesale market price for conventionally generated power and increase the blended end-user wholesale market price of all electricity for customers. In the chart, there are five different observable market prices:
• **Observed (distorted) wholesale price for conventionally generated power** (the first five segments of production), which can be found by drawing a vertical line at 86 percent of production (on the horizontal axis) and finding where this line intersects the supply curve. This point assumes that there are feed-in tariffs and thus renewable (i.e. unconventional) sources of electricity are in the market.

• **Hypothetical (undistorted) wholesale price for conventionally generated power**, which can be found at the point where the supply curve for conventional power intersects the aggregate demand curve. This point assumes that there are no feed-in tariffs and thus no renewable sources of electricity in the market.

• **Blended end-user wholesale price for electricity supplied to customers**, which reflects the observed wholesale price plus the effective “feed-in tariff subsidy” required to cover the additional cost of wind and solar power (added cost of renewable energy production plus profit for wind and solar power). This price does not include transmission costs, distribution costs, taxes, levies or any other tariffs.

• **Feed-in tariff rate for wind generation**, which is set by electricity regulators and based on average cost of wind power plus regulated return on capital.

• **Feed-in tariff rate for solar generation**, which is set by electricity regulators and based on average cost of solar power plus regulated return on capital.

The profits for each segment of conventionally generated electricity in Germany are determined by the observed wholesale price for conventionally generated power. These profits for each segment (i.e. hydro, nuclear, thermal, gas, and other marginal suppliers) are the area between the relevant marginal cost curve for each generation segment and the observed wholesale price for conventionally generated power. The profits for the unconventionally generated electricity in Germany, on the other hand, are determined by the feed-in tariff rates for wind and solar power. These profits for wind and solar power are the difference between their respective regulated feed-in tariff rate and their respective average cost.

Using the demand and supply curves, market prices, and generator profits, the chart illustrates how feed-in tariffs distort the electricity market. These distortions are reflected in the loss in producer surplus for conventional electricity generators, the loss in consumer surplus, and the reduction in the quantity of electricity demanded. The loss in consumer surplus is the area between the hypothetical wholesale price for conventionally generated power and the blended
end-user wholesale price for electricity supplied to customers. This area is bordered on the right by the demand curve for electricity. This area is a loss in consumer surplus because without feed-in tariffs, the blended end-user wholesale price for electricity would have been equal to the hypothetical wholesale price for conventional generated power (since no electricity from renewable sources would be generated).

The loss in producer surplus is the area between the observed wholesale price and the hypothetical wholesale price for conventionally generated power. This area is bordered on the right by the marginal cost curve of electricity generated in the remaining marginal production facilities. This area is a loss in producer surplus because without feed-in tariffs renewable sources of electricity would not have crowded out 14 percent of conventionally generated power. Thus, wholesale prices of electricity for conventionally generated power would not have fallen from the hypothetical wholesale price to the observed wholesale price of conventionally generated power.

Finally, the reduction in the quantity of electricity demanded in the electricity market is the horizontal distance between the point at which the hypothetical wholesale price for conventional power intersects the demand curve and the point at which the blended end-user wholesale price intersects the demand curve. This reduction in quantity demanded reflects the effect of the increased price of electricity resulting from the effective “feed-in tariff subsidy” required to cover the additional cost of wind and solar power.

3.2.2 Cross Subsidization of Electricity in Favor of Industrial Consumers

A comparison of Figures 1 and 2 on household and industrial electricity prices reveals that the real burden of high electricity price in Germany falls primarily on household consumers
(and the service sector of the economy) rather than on industrial consumers of electricity. For the three countries within the EU15 with the highest average household electricity prices in 2012, the ratio of average household consumer prices to average industrial consumers prices of electricity was 1.00 in Italy (i.e. both prices were essentially identical), 1.25 in Denmark, and a staggering 1.59 in Germany.

The large differential between household consumer and industrial prices of electricity in Germany cannot be explained alone by higher cost of electricity distribution to small consumers and related lack of economies of scale in delivery and distribution. Rather it is a result of a combination of differential taxation and surcharges for household and industrial consumers. The German government partially exempts industrial users of the feed-in tariff surcharge for renewable energy. The government established that large consumers of electricity who use more than ten gigawatt hours of electricity annually pay a reduced surcharge on 90 percent of the electricity they consume. For the other ten percent of electricity they consume, they pay the full surcharge. For electricity-intensive industrial sectors that consume over 100 gigawatt hours annually, the government established that these industries pay the lower surcharge on all (i.e. 100 percent) of their consumption.\textsuperscript{46} As a result, electricity-intensive industrial sectors that consume 18 percent of all electricity consumed in Germany are partially exempted of the surcharge. This means that those consuming the remaining 82 percent of electricity (i.e. household consumers and consumers in the service sector) end up carrying a greater burden of the surcharge. These consumers have to pay higher prices to allow electricity intensive industrial consumers to only pay the reduced surcharge.\textsuperscript{47}

\textsuperscript{46} Bjinse, 2013, p. 6
\textsuperscript{47} Bjinse, 2013, p. 5
The German government decided to exempt these electricity intensive industrial branches from the surcharge and put a greater burden of the surcharge on consumers because it wants these industries to remain internationally competitive. Given its heavy reliance on the export market, Germany does not want its electricity-intensive and export-oriented industries to have to deal with the economic disadvantage of additional electricity surcharge costs that other foreign industries may not have. So by partially exempting its industries, the German government has attempted to “level the playing field” for those industries and maintain their competitiveness vis-à-vis the rest of the world.

In addition to partially exempting electricity-intensive industrial branches of the feed-in tariff surcharge, the German government also exempts much of these industries’ electricity consumption of the eco-tax. After the government enacted the eco-tax in 1998, electricity consumption was for the first time subject to a tax. For the same reason of protecting its export-oriented industries, however, the German government decided that household consumers and consumers in the service sector should carry the burden of the eco-tax on all of their consumption, while electricity-intensive industries should not. Because the German government does not want the country’s companies to have to deal with the economic disadvantage of additional tax costs, it set an upper limit on the electricity tax for electricity-intensive industrial users with an annual consumption above 49 megawatt hours.48

3.2.3 Complex and High-Cost Transmission System

One of the key factors that determine the complexity and cost of electricity transmission in Germany is the reliance on decentralized generation of electricity. The already highly

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48 Eurelectric, 2011, p. 26
decentralized structure of electricity generation (i.e. relying on many small and widely dispersed electricity generators) is becoming increasingly complex with the growing number of wind turbines and solar panel installations. These installations dramatically increase the required length of low and medium-voltage power lines. More importantly, this increasingly decentralized structure is driving up transmission and distribution costs. Before the surge in renewable sources of electricity, conventional power generation plants were strategically placed relatively close to centers of demand. Coal-fired plants were located near coal mines and surrounding industrial areas (mostly in the north) and nuclear power plants were located near centers of demand in the south.

The case with renewable sources of electricity is not quite so straightforward, especially with regards to wind power. Wind power is generated mostly in the northern states. Table 2 shows that in four of these northern states (Saxony-Anhalt, Brandenburg, Schleswig-Holstein, and Mecklenburg-Vorpommern) wind power accounted for 46-48 percent of net electricity consumption in 2011. In one northern state (Lower Saxony), this share was slightly smaller at 25 percent. In contrast, in all remaining German states, except Thuringia (with a 12 percent share), wind power accounted for less than ten percent of net electricity consumption in 2011. The share of wind power in net electricity consumption was especially negligible in the southern states of Baden-Württemberg, Bavaria, Saarland, and Hesse. The map in Figure 11 shows just how uneven installed wind capacity is between Northern and Southern Germany.

This regional unevenness in the distribution of installed wind capacity within Germany puts stress on the German transmission system. Transmission system operators must transport electricity from the northern states (where most of the wind generation capacity is located and excess electricity is generated) to the southern states (where electricity demand exceeds supply),
such as the heavily industrialized state of Bavaria, which holds many of Germany’s electricity-intensive industries. Because the transmission system has greater difficulty balancing the supply and demand for electricity over longer distances between northern and southern states, transmission system operators are charging more for their balancing services. Because of this stress put on the transmission system by renewables, the German government has also embarked on the construction of new expensive high-voltage transmission lines connecting its northern and southern regions. Germany plans to build 1,900 km of high-voltage lines, but thus far it has only built 300km of these lines.\textsuperscript{49} This expensive grid expansion also comes at a cost to consumers. The expansion is paid through another regulated tariff that is paid by all consumers of electricity.\textsuperscript{50} This additional tariff thus further raises the retail price of electricity for both household and industrial consumers. It should however be noted that overall, the high cost high-voltage transmission is not that significant as an added cost to consumer electricity bills when compared to the other consequences of political preferences for renewable energy and other structural factors discussed later.

3.2.4 Added Cost of Balancing Unpredictable Supply of Renewable Energy

With Germany’s greater reliance on less conventional renewable sources of electricity, transmission system operators are not the only grid operators struggling to balance electricity supply and demand. The job of the distribution system operators in the electricity grid has also become increasingly complicated. The increase in the number of wind and solar farms in the past decade has meant that more generation capacity is connected to the distribution grid than the

\textsuperscript{49} Jeevan Vasagar, 2014, p. 2
\textsuperscript{50} IEA, 2013, 122
In order to balance the supply and demand of electricity within their section of the distribution grid, distribution system operators must maintain a level of electricity output that is close enough to the demand electricity, so as to avoid any grid failures (e.g. power outages or power overloads). The issue that distribution system operators deal with when handling significant shares of electricity produced from renewable sources is that the power produced by these renewable sources at any given moment is relatively unpredictable. Generators using conventional coal or gas-powered plants regulate how much coal or gas input they use in their plants. In contrast, generators using renewable sources do not regulate how many photons a solar panel captures or how many rotations a windmill makes in a particular moment. Even if the generators had the opportunity to cutback on the inputs for these renewable sources of electricity, they would not have any economic incentive to do so since the marginal costs of these renewable sources are negligible.

Consequently, under a German power system that increasingly relies on sources of electricity that are fundamentally unpredictable, balancing the supply and demand of those sources comes at a higher cost to distribution system operators. So, to maintain their profit margin, the operators then charge higher prices to their household and industrial consumers for their balancing services. It would be incredibly difficult to quantity the value of additional electricity market balancing services required to compensate for the unpredictability in the supply of electricity from renewable sources and so there is no German industry source that has attempted to do so. However, it is fair to say that the increasing balancing charges for customers connected to the distribution grid in Germany reflects a high cost of additional balancing services.

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51 IEA, 2013, p. 138
3.3 Structural Flaws of the German Electricity System

There have been several attempts by the German government to liberalize and increase competition in the German electricity market by forcing legal unbundling upon vertically integrated electricity companies. These vertically integrated companies took part in all or most of the sectors (i.e. generation, transmission, distribution, and supply) of the electricity market. In 1998, the government started by adopting the EU’s 1996 directive on electricity in the Federal Energy Industry Law. This 1998 Federal Industry Law forced these vertically integrated companies to separate accounting for their different production, transmission, and distribution activities. The German government soon intensified its efforts to liberalize the electricity market when it adopted another EU directive on electricity in 2003. This directive made the vertically integrated electricity companies split (i.e. in legal form, organization, and decision-making) into companies, which either take part in transmission and distribution activities or activities not related to transmission or distribution.\(^{52}\)

Additionally, under a 1998 amendment to the German energy law, the government made transmission and distribution companies guarantee non-discriminatory third party access. This meant that the transmission and distribution companies could no longer charge for services within their company more favorably than for services to other independent companies. The 2005 Energy Industry Act also helped prevent discriminatory access charges by publishing scales of charges for third-party access to transmission and distribution grids. However, it should be noted that Germany, compared to other EU member states, has unusually high maximum charges for access to the distribution grid.\(^{53}\)

\(^{52}\) OECD, 2004, p. 18
\(^{53}\) OECD, 2004, p. 37
In spite of the attempts made by the German government to liberalize the market, there remains an obvious lack of competition. The government only really succeeded in making the large vertically integrated companies sell their areas of the transmission grid to independent companies. Otherwise, in the face of liberalization, there have still been over 400 mergers, instances of cooperation or takeovers. Many of these mergers and takeovers have consisted of horizontal consolidation of large vertically integrated utilities and vertical consolidation of municipal electricity generators into the vertically integrated utilities.\(^{54}\) So even though there are many small generators, distribution system operators, and retailers, the four large utilities (E.ON, Vattenfall, REW, and EnBW), still dominate these sectors of the electricity market. The four large utilities generate over 70 percent of Germany electricity and capture a combined 45 percent of the retail market share.\(^{55}\)

One of the key indicators of the lack of competition in the electricity market is that, despite the liberalization efforts of the German government, there have not been any new significant entrants in the generation or supply sectors to date.\(^{56}\) This is surprising when considering that the generation and supply sectors are the only sectors of the electricity market that are not naturally monopolistic. The reason why there have been no new entrants in these sectors is that the low profit margins in the sectors are impeding new entrants. It has been estimated that that wholesale prices of electricity are approximately at short-run marginal production costs.\(^{57}\) Accordingly, Germany’s wholesale prices of electricity are relatively low compared to rest of Europe.\(^{58}\)

\(^{54}\) OECD, 2004, p. 17  
^{55}\) IEA, 2013, p. 137  
^{56}\) OECD, 2004, p. 22  
^{57}\) Brunekreeft, 2002, p. 214  
^{58}\) IEA, 2013, p. 130
The biggest cause of the low profit margins in the generation and supply sectors are the four large vertically integrated utilities, which dominate the generation, distribution, and supply sectors of the market. These large vertically integrated utilities do not mind suppressing the profit margin in the generation or supply sectors, so as long as they can compensate for these forgone profits with profits in the distribution sector. As a result, the utilities take advantage of their natural monopolistic position within their sections of the distribution grid to compensate for forgone profits in the relatively more open generation and supply sectors.

One way these vertically integrated utilities compensate for the foregone profits is by increasing access charges and charges for balancing energy in their sections of distribution grid. The distribution system operators do have an argument that the increasing reliance on unpredictable renewable sources of electricity is driving up the charges for balancing services (as mentioned above). However, it is likely that these operators are increasing these charges for balancing services by more than what was needed to compensate for the increased cost of balancing unpredictable sources of electricity. So, the operators are likely using renewable energy as a scapegoat for the rising charges for balancing energy.

Even though the distribution operators have a good reason to increase their charges for balancing services, they do not have much of a reason for charging high access charges. However, one study conducted for the European Commission showed unusually high distribution charges in Germany compared to other EU member states. This study found that in comparison to the EU average, customers connected to the low voltage distribution grid paid more for distribution access in Germany. Consequently, it is very likely that, in addition to the heavy

59 Brunekreeft, 2002, p. 211
60 Shahan, 2012, p. 1
61 OECD, 2004, p. 37
German reliance on renewable sources of electricity, the high cost of electricity distribution is a key culprit driving up retail electricity prices. This is particularly possible given that Germany has unusually high maximum charges for access and balancing services in the distribution grid compared to other EU member states.\(^{62}\)

4 Possible Solutions to Bring Down German Electricity Prices

Many industry specialists have given serious thought about what could be done to bring down end-user German electricity prices to more reasonable levels. Below is an evaluation of potential measures that may help address the problems related to German reliance on unpredictable renewable sources and structural flaws of the German electricity market.

These measures can be broadly classified into the following two types of solutions:

- **Policy Solutions**
  - institutional measures, mostly focusing on introducing more competition in the distribution sector of the German electricity market

- **Technological Solutions**
  - increasing the efficiency of wind and solar electricity generation
  - electricity storage methods, including
    - pumped storage hydropower plants
    - nitrogen-based fuel cells
    - using electrical cars for electricity storage purposes
    - industrial-scale electricity storage in large batteries
  - using a smart electricity grid to help matching of supply and demand for electricity

4.1 Institutional Measures

One of the biggest issues with the current German electricity market is Germany’s desire to increase the share of its electricity generated from renewable sources as fast as possible. This

\(^{62}\) OECD, 2004, p. 37
political preference has led to open ended subsidization of renewables, which does not take account of the excessive additional cost this imposes on consumers of electricity. The German government could bring the retail prices of electricity down significantly if it decreased the tariff rates set for renewable sources and slowed its transition toward renewables. Such a policy could bring down retail price because under feed-in tariffs, the added price of the renewable electricity is passed onto consumers. Recently the German government has taken a small step towards decreasing the tariff rates for renewables.

In mid-April of 2014, the German economics and energy minister, Sigmar Gabriel, announced several proposals to hold down the rise in German electricity prices, expressing the simple belief that costs matter. The essence of these proposals is to replace open-ended subsidies of renewable energy with a series of constraints. In particular, Gabriel proposed that:

1. Onshore wind generation capacity should expand by no more than 2.5 GW a year.
2. Photovoltaics should be subject to the same 2.5 GW annual capacity growth limit.
3. Offshore wind generation capacity should expand by a maximum of 6.5 GW by 2020.
4. The German government objective that renewable should have a 40% share in overall electricity supply by 2025 should remain in place, but the 11-year transition period should now take account of costs of reaching this goal.
5. Most importantly, from 2017 onwards, the renewable sector within the electricity market will be subject to competition and there will be no guaranteed prices.

Whether such policy shifts would be good for the renewable sector is highly debated. Economists in general would argue that subsidized businesses are always at risk of going under and thus decreasing dependence on subsidies and taxpayer support is better. The key issue is whether electricity generators using renewable sources can compete without

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63 Butler, 2014, p.1
64 Butler, 2014, p.1
65 Butler, 2014, p. 1
66 Butler, 2014, p. 1
subsidies, or at least with lower rates of support. According to Nick Butler of the *Financial Times*, the answer over time should be yes. The solar industry has already taken big steps toward decreasing the fixed costs and increasing the efficiency of solar power generation. The challenge in the coming years will be for wind industry to match this progress and decrease the fixed costs of wind generation.  

Curtailing the growth of onshore wind generation and even more so curtailing the growth of offshore wind generation (which is the most expensive form of renewable energy), makes a lot of sense for a government trying to decrease retail electricity prices. These two sources are currently the least economical form of renewable electricity. Onshore and offshore wind generation are a generation segment in which technological progress is relatively slow (if not minimal) and in which fixed costs are not falling. The restriction on the rise in photovoltaic generation capacities is also understandable given that solar power is still subsidized by consumers. Solar power has enjoyed dramatic fall in the cost and rise in the efficiency of solar panels, but it is possible that this process is soon coming to an end. Were the cost of solar panels continue to fall and efficiency of solar panels continue to increase, a reassessment of the restriction may be warranted.

The proposition that the renewable sector within the electricity market will be subject to competition and free of guaranteed prices by 2017 is the most ambitious attempt to reduce retail electricity prices. Minister Gabriel probably does not want to introduce a total shock to the renewables sector and introduce a completely free market without any transition from the subsidized market. Rather, it is likely that Minister Gabriel wants to

67 Butler, 2014, p. 1  
68 Hromadko, 2014, p. 1  
69 Harrabin, 2013, p. 2  
70 Hinckley, 2013, p. 5
introduce a yearly reduction in subsidies (factoring in developments in industry cost) on a multi-year basis. It may also be necessary to differentiate between vintages of wind and solar technologies as early investors incurred relatively high installation cost and late investors benefitted from falling equipment costs, particularly in the case of solar generation capacities.\textsuperscript{71} On the whole, it appears as though Germany is at a point where government officials are starting to take account of the high costs of their energy policies. They are starting to worry about the impact of their energy policies on electricity consumers and on the ability of electricity-intensive industrial branches to compete globally. This partial, but important, modification of past policies could be an important factor in helping Germany reduce retail electricity prices and preventing it from rendering its economy less competitive.

One of the other major issues with the current German electricity market is the inflated distribution cost (and profits) of the four major electricity distribution companies (E.ON, Vattenfall, REW, and EnBW). There is a general and probably justified suspicion that vertically integrated utilities (which generate electricity as well as distribute and supply it) deliberately depress the price of electricity paid to generators and suppliers and make up the low margin of their own electricity generation by extracting a large margin for electricity distribution over their sections of the distribution grid.\textsuperscript{72} By doing so, these vertically integrated utilities are taking advantage of their natural monopoly over their section of the distribution grid to create a barrier to entry to potentially new entrants in the generation and supply sectors of the electricity market. Based on these high distribution charges driven by the four large utilities, a simple proposition is

\textsuperscript{71} Schwartz, 2011, p. 1
\textsuperscript{72} Brunekreeft, 2002, p. 214
that, ceteris paribus, a more competitive electricity distribution environment would lead to more open generation and supply sectors and lower prices of electricity for consumers.

Like most governments in industrialized countries, the German government regulates distribution charges. However, the distribution of electricity is dominated by the four utilities which have significant political influence over government electricity policies and regulations. Under circumstances where the four utilities could not “get what they want,” the government could deal with the abuse of the natural monopolistic structure of the distribution system and the vertically integrated structure of the four utilities in two ways. The government could first regulate the prices that distribution system operators charge to consumer to the same degree that it already regulates the prices that transmission system operators charge. The government could do so by lowering the unusually high maximum charges for access and balancing services in the distribution grid. By doing so, the government would successfully prevent distribution system operators, from taking advantage of their naturally monopolistic position and charging excessively high prices. In turn, the decrease in distribution charges would permit a reduction in retail electricity prices.

The second action the government could take is to break up the four vertically integrated utilities. The government could force the four utilities to sell away their holdings in two of the three sectors (i.e. the generation, distribution, and supply sectors) in which they dominate. For example, the government could force E.ON to sell its holdings in the generation and supply sectors of the electricity market. Consequently, E.ON could no longer suppress the profit margin in the generation and supply sectors. It would also no longer have the same type of incentive to make up for the forgone profits in those sectors by increasing the profit margin in its distribution

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73 Hromadko, 2013, p. 1
sector. In turn, such government policies would make the generation and supply sectors more open and could potentially help decrease retail electricity prices.

Unfortunately, the reality in Germany today is that the four utilities still have significant political influence and they likely use this influence to prevent the government from enacting the policies described above. As a result, there is little that can be done with the four utilities’ abuse of dominance, except for tighter monitoring and regulation. Without a government resistant to lobbying and without a dramatic wave of new liberalizing policies, it does not look too hopeful that much progress can be made on this front in the short term. Therefore, it is unlikely that a significant reduction can be achieved in average distribution charges (per kilowatt hour) in Germany, even though this would have a corresponding effect in retail price of electricity paid by German consumers.

4.2 Technological Improvements Increasing Wind and Solar Efficiency

Another big issue in the German electricity market is the use of subsidies for wind and solar electricity generation, which dramatically drive up end-user costs of electricity. The necessity for these large subsidies for renewable sources of electricity stems from the fact that the returns investors get for their electricity from renewable sources under normal competitive market conditions are too small to cover the high fixed cost of wind and solar technologies within a reasonable investment horizon. Consequently, an obvious potential solution is to improve the efficiency of wind and solar power to achieve higher returns to capital.

In the case of wind turbines, no dramatic improvements in wind turbine design and efficiency have occurred in recent years (other than ability to turn at lower wind speed) and it is
unlikely any such improvements are on the horizon.\textsuperscript{74} In fact, as shown in Figure 12, the efficiency of wind turbines as measured by the ratio of output of electricity (in gigawatt hours) per unit of installed capacity (in megawatt) have been declining for the past two decades. This declining efficiency reflects both the lack of significant technological progress and the increasing need to rely on wind turbines at marginal (i.e. less windy) locations.

In the case of solar power, Figure 12 shows the opposite trend. There has been a steadily rising ratio of output of solar electricity per unit of installed capacity. This reflects the dramatic improvements in solar power technology in recent years. Along with this trend, the unit solar panel cost has fallen due to economies of scale in their production in countries such as China (the main production source). Although the fall in solar panel cost is unlikely to happen again, there is room for further improvements in the efficiency of solar panels.\textsuperscript{75} Some of the improvements that may be expected to occur in the near future include: an improved ability to generate electricity during cloudy days when sun is not out; and an ability to use building windows and roofing materials to generate electricity. The main consequence of these improvements will be to make solar power more economically viable. This greater economic viability could then permit a decrease in the level of subsidies needed to support solar power installations. But overall, the impact on average generation cost of electric power in Germany may only be pronounced in the long-term (i.e. over the next decade) since solar energy currently accounts for only one-fifth of total electricity production from renewables and renewables account for only around one-quarter of total electricity production in Germany.

Still, the more promising future of solar power relative to wind power in generating electricity in Germany is already reflected in recent trends in electricity production from the two

\textsuperscript{74} Harrabin, 2013, p. 2
\textsuperscript{75} Parkinson, 2014, p. 1
sources. During the last decade, the average annual growth of wind power electricity output in Germany was 9.7 percent, while the corresponding average annual growth of solar power electricity output was 57.7 percent. In 2003, output of solar power was 1.8 percent of output of wind power. By 2013, the output of solar power was 63 percent of the output of wind power.

4.3 Electricity Storage

Improvements in electricity storage are the key to dealing with the unpredictability of renewable sources of electricity. With a good electricity storage system, excess electricity that is produced by wind turbines and solar panels at a particular time of the day (i.e. when supply exceeds demand) can be stored and used when these renewable sources are not producing enough electricity (i.e. when demand exceeds supply). Such a system would decrease the cost of balancing electricity for distribution system operators and thus decrease the balancing service price they charge to consumers. It would also dramatically reduce the need for peak load electricity production (i.e. electricity production needed when electricity demand is highest).

4.3.1 Pumped Storage Hydropower Plants

The potential for building more pumped storage hydropower plants in Germany is very limited. Hydropower plays a minor role in German electricity generation, accounting for under five percent of overall electricity production in 2013. Pumped storage hydropower plants typically require the creation of two artificial lakes at significantly different altitudes (the bigger the difference in altitude, the higher the natural water pressure, and the greater the effectiveness of the facility). When additional electricity is needed, water from the higher lake is allowed to

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76 Carnegie, et al., 2013, p. 8
run down through a tunnel into a water turbine located next to the lower lake.\textsuperscript{77} This type of plant is used as a fast response facility (when electricity prices spike up) since it can produce electricity within seconds from the moment water is released from the upper lake. During times of excess electricity supply (when electricity is relatively cheap), electricity is used to pump water back from the lower lake to the upper lake. Unfortunately, the capital cost of this type of facility is extremely high and since most of German countryside is flat and unsuitable for the construction of these facilities, the potential for this technology is very limited.\textsuperscript{78}

4.3.2 Hydrogen-based Fuel Cells

A fuel cell is a device that converts the chemical energy from a fuel into electricity through a chemical reaction with oxygen or another oxidizing agent. The most commonly used fuel is hydrogen, but hydrocarbons like natural gas and alcohols like methanol are sometimes used. Fuel cells can produce electricity continuously for as long as these inputs are supplied. These fuel cells can be used on an industrial scale, like pumped storage hydro plants, to store electricity. During periods of low demand for power or excess supply of wind and/or solar power, electricity could be used to produce hydrogen from water through electrolysis.\textsuperscript{79} This hydrogen could then be stored for use in fuel cells to produce electricity during the periods of high demand for power or lack of supply of wind and/or solar power.

There are presently three major problems with this solution of industrial scale hydrogen-based fuel cells. The first is that the efficiency of fuel cells in producing electricity is still relatively low. The second problem is that the cost of fuel cells is currently relatively high as...}

\textsuperscript{77} Carnegie, et al., 2013, p. 22
\textsuperscript{78} Carnegie, et al., 2013, p. 22
\textsuperscript{79} National Renewable Energy Laboratory, 2014, p. 1
there has still not been any major technological breakthrough that would bring costs down.\textsuperscript{80} It is difficult to evaluate if and when the fuel cell technology will reach a point when it could be economical to use on an industrial scale for electricity storage. Companies such as Siemens in Germany have been working on the development of fuel cell technology for more than six decades now and the progress has been relatively slow. Lastly, the third problem with this solution is that hydrogen is a highly volatile and combustible gas, extremely prone to explosion. So, this solution could expect to see some political opposition from a safety standpoint.

4.3.3 Using Electric Cars for Electricity Storage

With rising gas and diesel fuel prices and thus with the expected rising share of electric vehicles on German roads, there is a potential for using electric cars for electricity storage purposes. The idea is that strong financial incentives (i.e. significantly lower electricity prices) could be given to owners of electric cars who recharge the batteries in their cars during periods of relatively low electricity demand (typically at night) and/or during periods of unusually high supply of wind or solar electricity.\textsuperscript{81} In order for this system to work, it would be necessary for the recharging devices to have screens which provide up-to-date information on spot electricity prices and which turn themselves on automatically during periods of low electricity demand. This technology actually already exists. However, the effectiveness of this solution completely depends on the penetration of electric cars in the overall German car market, which looks to be a very gradual process.\textsuperscript{82} The overall economic impact of this solution may not be as dramatic as

\textsuperscript{80} Electropaedia, 2008, p.2  
\textsuperscript{81} Halper, 2013, p. 1  
\textsuperscript{82} The Star Online, 2013, p.1
the impact of other storage methods, but this method would nevertheless have a significant impact if electric cars became popular in Germany over the next couple of decades.

4.3.4 Industrial-scale Electricity Storage in Large Batteries

If and when this technology is developed and becomes economically viable, it could drive down the price of electricity in a dramatic fashion. Using large batteries on an industrial-scale would reduce, if not eliminate, the need for relatively expensive “peak load” electricity (i.e. electricity produced when electricity demand is highest). This is because “base load” electricity (i.e. electricity produced when electricity demand is lowest) could be readily transformable into peak load electricity by releasing it from batteries when needed.83 This means that most non-renewable electricity would be generated in relatively cheap coal-fired or nuclear power plants running in base load mode. The use of gas turbines running on expensive imported natural gas would be either totally eliminated or significantly reduced. In effect, the demand curve for electricity at any given time of day will be flattened instead of exhibiting the typical daily pattern of spikes in electricity demand during work hours and early evenings.

In the case of unpredictable daily wind and solar power supply, it may gradually be possible to use this storage method for more than just offsetting daily fluctuations in renewable electricity supply. If electricity could be stored for more than a day, this would eliminate or at least dramatically reduce the need for back-up generation capacities on days when there is little wind and/or sun. Undoubtedly, the availability of economical industrial-scale electricity batteries would have a profound positive (cost-cutting) impact on the German electricity industry. The critical question is when such technology will be available. Most major technologists agree that

83 Anderson, 2013, p. 1
it is just a matter of time before a breakthrough occurs in the development of these large industrial-scale batteries.  

4.4 Using a Smart Grid to Better Balance Electricity Supply and Demand

There are only two major ways to better match supply and demand for electricity at any given point in time. The first way, as described above, is to improve the electricity storage system. The second way is to micromanage the supply and demand for electricity using up-to-date spot price information and a smart grid. In this latter case, up-to-date minute-by-minute spot demand information is already used to indicate to suppliers when more electricity is needed. However, it is demand side of the market where the potential benefits are greater. Demand can be managed to some degree to match the supply of electricity.

Under a smart grid, electricity meters located at any point of electricity consumption will signal the state of the electricity market and either encourage or discourage electricity consumption. These electric meters could be integrated with electricity consuming machinery (which can deal with interruption in electricity supply) in industry and a variety of appliances in households. The meters could then turn this machinery and these appliances on and off depending on the level the supply of electricity. For example, during periods of heavy/light demand for electricity, smart meters could turn off/on electric heating, electric water heating, and other major household appliances with flexible schedules (e.g. washing machines, dryers, dishwashers, etc.).

84 Anderson, 2013, p. 1
86 John, 2013, p. 3
Although the smart grid technology is already technologically viable, it is very expensive. Smart grids would come at a huge cost because of the necessity to install smart wiring and smart meters in the industry and household sectors. Another bigger problem is the huge risk of the development of a disruptive technology, like industrial-scale batteries, which would reduce the value of smart grid system and/or make it largely superfluous. Industrial-scale batteries could equally manage the balancing of supply and demand for electricity in a much simpler manner. Although these batteries are not yet economically viable, they appear to be ever closer to a major breakthrough.

5 LESSONS FROM GERMANY’S TRANSITION TOWARDS RENEWABLES

5.1 Solar Energy is Disruptive to the Old-Style Electricity Market

Because solar energy is produced during the day when demand for electricity is relatively high (the daily peak load period), it has driven down the peak load electricity wholesale prices in Germany. As the Economist points out, solar power generators have grid priority and so they take away a large portion of the peak demand during the day and consequently eliminate any price spikes that help conventional generators make all their money. This has led the price margin between peak load and base load electricity to fall by almost four-fifths.

To make the matters much worse for traditional German utilities, the sharply falling fixed cost of solar panels has had additional crowding out effects. The Economist notes that the cost of generating a megawatt hour of electricity using solar panels has decreased to EUR 150. This is above the prevailing wholesale price of electricity, but significantly below the feed-in tariff rate for electricity from solar power. As a result, solar generation will likely continue to increase even

87 John, 2013, p. 3
88 The Economist, 2013, p. 4
if the government cuts subsidies to solar power generators.\textsuperscript{89} It should also be noted that the four large utilities have been slow to invest in renewable energy, particularly in solar energy. Currently, they own only seven percent of renewable generating capacity in Germany, indicating that they “missed the boat.”\textsuperscript{90}

\subsection*{5.2 Problematic Future for Traditional German Utilities}

Technological change has by-passed traditional German utility companies. The traditional method of generation by these utilities has been to operate relative large and expensive nuclear or thermal power plants with a typical capacity between 1000-1500 megawatts. Each plant was located in the middle of a web of wires through which the utility distributes power. In contrast, the new developing decentralized method of generating power is quite different. Photovoltaic panels and wind turbines are arranged in, not a hub, but a net with spokes.\textsuperscript{91}

Consequently, traditional power generators are slowly being left with two roles in the electricity market. Their first role will be as generators of last resort, generating electricity for the grid if and when renewable sources of electricity do not produce enough electricity to meet demand.\textsuperscript{92} Their second role will be to invest in creating a smart grid or better electricity storage facilities. It is estimated that as much as one trillion euros will be needed to carry out these types of grid upgrades throughout Europe by 2020. Such an investment is a tall order to be handled by German companies, with a current market value around EUR 500 billion, which are currently

\begin{flushleft}
\textsuperscript{89} The Economist, 2013, p. 4
\textsuperscript{90} The Economist, 2013, p. 4
\textsuperscript{91} The Economist, 2013, p. 4
\textsuperscript{92} The Economist, 2013, p. 5
\end{flushleft}
cutting their capital spending.\textsuperscript{93} So far, the typical response of the traditional utility companies has been to shift out of power generation and move into “downstream activities,” such as power distribution and supply. However, this does not abate the fact that these utilities are suffering from massive losses. The \textit{Economist} points out that the market capitalization of traditional European utilities has fallen by more than EUR 500 billion in the past five years.\textsuperscript{94}

5.3 Lessons Relevant to the United States

The United States can learn a good deal from Germany about what to expect from future disruptive technologies in the electricity sector as well as what mistakes to avoid. The U.S. is facing the prospect of two disruptive technologies: solar generation, which has already arrived, and industrial-scale electricity storage. As was the case in Germany, solar energy will drive down peak load electricity prices, adversely affecting peak load prices for electricity generated mostly by conventional plants. Already, U.S. utilities face growing problems with the impact of installation of solar panels on residential homes. Households installing solar power either dramatically reduce their consumption of purchased electricity or even supply excess electricity into the grid during the day.\textsuperscript{95} At night, these homeowners either purchase relatively small amounts of electricity (compared to their consumption of electricity during the day) or none at all. These homeowners expect that utilities will simply oblige them by delivering marginal supplies of electricity as needed or taking the electricity they produce whenever conditions permit excess production over household needs. It is one thing when one or a few households do this, but it is another when this happens on a massive scale. Utilities lose substantial business if

\begin{itemize}
\item[\textsuperscript{93}] The Economist, 2013, p. 5
\item[\textsuperscript{94}] The Economist, 2013, p. 4
\item[\textsuperscript{95}] Howland, 2013, p. 4
\end{itemize}
they are only required to operate on a stand-by basis and provide either peak-load or balancing electricity as needed. Similarly to the German utilities, U.S. utilities will respond to this in the distribution sector of the electricity market by charging more for electricity balancing services.

As described earlier, industrial-scale electricity storage has the potential to be an extremely disruptive technology. Electricity storage will make it possible to rely solely on solar power in U.S. regions with regular and predictable sunlight. At the very least, it will become possible to store excess solar power produced during the day for the consumption of electricity at night. Thus, down the road, peak load electricity generators will be adversely affected by the shock of solar power generators taking away their daily peak load electricity market (by driving down prices as has been the case in Germany). Beyond the effect of such disruptive technologies in the electricity market, there are other lessons that the US can learn from the German experience in electricity market. The U.S. should be careful to avoid the German-type destruction of the value of its traditional utility sector. With the rising generating capacity of renewable sources of electricity, U.S. utility companies should be careful about investing in new nuclear, coal-fired, and gas-fired generation plants, particularly if these plants are intended for intermittent peak-load use. They need to realize that their traditional generation business will not be a growing business in the future. If they want to continue to grow, they will have to refocus their business on electricity distribution and supply. At the same time, the U.S. government should protect its consumers from excessive charges for distribution by making sure that distribution system operators are fairly charging their customers for their balancing services. Lastly, if the U.S. utility companies want to continue their role as a large generator, they will have to soon refocus on green energy, particularly wind and solar power. In doing so, they
should also be ready to face large investments in industrial-scale electricity storage and/or smart grids.
Figures and Tables

Figure 1: Household Electricity Prices for EU15 in 2012

Source: Eurostat

Figure 2: Industrial Electricity Prices for EU15 in 2012

Source: Eurostat
Figure 3: Development of Electricity Prices in Germany
Prices index based on 2005

Source: Federal Statistical Office, Destatis
Figure 4: Electricity Grid Structure

Source: MBizon
Figure 5:

Source: The Economist

Figure 6:

Source: The Economist
Figure 7: Post-2012 Regional Breakdown of the German Transmission Grid

![Figure 7: Post-2012 Regional Breakdown of the German Transmission Grid](image)

Source: Francis McLloyd

### Table 1: The Four Regional Transmission Grid Operators in Germany in the Post-2012 Period

<table>
<thead>
<tr>
<th>Current Corporate Name</th>
<th>Former Corporate Name</th>
<th>Current Owner</th>
<th>Overall Length of High Voltage Grid (in km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amprion GmbH</td>
<td>RWE Transportnetz</td>
<td>Commerz Real (74.9%), a wholly owned subsidiary of Commerzbank AG</td>
<td>Total: 11,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>380 kV: 5,300</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>220 kV: 5,700</td>
</tr>
<tr>
<td>EnBW Transportnetze GmbH</td>
<td>Transnet BW AG</td>
<td>EnBW Group (100%)</td>
<td>Total: 3200</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>380 kV: n.a.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>220 kV: n.a.</td>
</tr>
<tr>
<td>50Hertz Transmission GmbH</td>
<td>Vattenfall Europe Transmission</td>
<td>Wholly owned by Eurogrid GmbH, indirectly owned by the national transmission system operator of Belgium and an Australian-based Industry Fund Management</td>
<td>Total: 9,847</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>380 kV: 6,980</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>220 kV: 2,867</td>
</tr>
<tr>
<td>TenneT TSO GmbH</td>
<td>Transpower StomübertragungsGmbH, part of E.ON</td>
<td>TenneT B.V., the national transmission system operator of the Netherlands</td>
<td>Total: 10,805</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>380 kV: n.a.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>220 kV: n.a.</td>
</tr>
</tbody>
</table>

Source: Various websites of the transmission system operators
Figure 8: Growth in the Share of Renewables in Gross Electricity Consumption in Germany, 1990-2013

Source: Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety

Figure 9: Subsidies Renewables and Solar PV Installation Cost in Germany

Source: The Economist
Figure 10: Stylized Aggregate Supply and Demand for Electricity in Germany

Table 2: Distribution of Wind Turbines and Wind Power Share of Net Electricity Consumption Within German States in 2011

<table>
<thead>
<tr>
<th>German State</th>
<th>Number of Wind Turbines</th>
<th>Installed Generation Capacity (MW)</th>
<th>Share in Net Electricity Consumption (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saxony-Anhalt</td>
<td>2,352</td>
<td>3,642.31</td>
<td>48.11</td>
</tr>
<tr>
<td>Brandenburg</td>
<td>3,053</td>
<td>4,600.51</td>
<td>47.65</td>
</tr>
<tr>
<td>Schleswig-Holstein</td>
<td>2,705</td>
<td>3,271.19</td>
<td>46.46</td>
</tr>
<tr>
<td>Mecklenburg-Vorpommern</td>
<td>1,385</td>
<td>1,627.30</td>
<td>46.09</td>
</tr>
<tr>
<td>Lower Saxony</td>
<td>5,501</td>
<td>7,039.42</td>
<td>24.95</td>
</tr>
<tr>
<td>Thueringia</td>
<td>601</td>
<td>801.33</td>
<td>12</td>
</tr>
<tr>
<td>Rhineland-Palatinate</td>
<td>1,177</td>
<td>1,662.63</td>
<td>9.4</td>
</tr>
<tr>
<td>Saxony</td>
<td>838</td>
<td>975.82</td>
<td>8</td>
</tr>
<tr>
<td>Bremen</td>
<td>73</td>
<td>140.86</td>
<td>4.7</td>
</tr>
<tr>
<td>North-Rhine-Westphalia</td>
<td>2,881</td>
<td>3,070.86</td>
<td>3.9</td>
</tr>
<tr>
<td>Hesse</td>
<td>665</td>
<td>687.11</td>
<td>2.8</td>
</tr>
<tr>
<td>Saarland</td>
<td>89</td>
<td>127</td>
<td>2.5</td>
</tr>
<tr>
<td>Bavaria</td>
<td>486</td>
<td>683.6</td>
<td>1.3</td>
</tr>
<tr>
<td>Braden-Württemberg</td>
<td>378</td>
<td>486.38</td>
<td>0.9</td>
</tr>
<tr>
<td>Hamburg</td>
<td>60</td>
<td>53.4</td>
<td>0.7</td>
</tr>
<tr>
<td>Berlin</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Offshore-North Sea</td>
<td>31</td>
<td>155</td>
<td></td>
</tr>
<tr>
<td>Offshore-Baltic Sea</td>
<td>21</td>
<td>48.3</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>22,297</strong></td>
<td><strong>29,075.02</strong></td>
<td><strong>9.9</strong></td>
</tr>
</tbody>
</table>

Source: Jens Peter Molly, Germany Wind Energy Institute
Figure 11: Distribution of Wind Turbines in Germany (2011)
Installierte Leistung (MW) = Installed capacity (MW)

Source: European Environment Agency
Figure 12: Trends in Ratio of Output to Renewables Generation Capacity in Germany, 1990-2013

Source: Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety
REFERENCES


