Making renewable electricity a reality

Policies and challenges when transforming Germany’s electricity system

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Abstract

Germany is to undertake a speedy phase-out of nuclear energy and at the same time move into the age of renewable energy. The policy basis for the transformation of the electricity system is the Renewable Energy Sources Act (EEG). The aim of this report is to investigate the transformation of the German electricity system: popularly called the Energiewende. The report will introduce and analyze the Renewable Energy Sources Act as a policy instrument, and how the electricity grid needs to be developed in order to handle the increasing shares of electricity from renewable sources. The history, main regulations, and the success of the EEG will be investigated. Furthermore, the ways in which the EEG needs to be revised will be given attention. The imperfections of today’s electricity grid when implementing a dominating share of renewable electricity, and ways in which Information and Communication Technology can be used in solving those imperfections will be analyzed. The basis for this thesis is a literature study. Since this is a current topic changing frequently, up-to-date research is used as the main reference. The EEG is based on a feed-in tariff system. The main concern when implementing a dominating share of renewable electricity is the fluctuation over time. It is difficult to know how much power will be produced and when. The future challenge of the electricity grid is to keep meeting demand and supply in a secure way. To succeed with the transformation, the EEG not only needs to be revised but a solution to the system stability is also necessary. The EEG is considered a successful policy instrument but what it is missing today is incentives for balancing demand and supply, energy efficiency, and technology innovation. In order to deal with fluctuating sources, the main focus when upgrading the grid should be to improve the forecasting issues. The success of making RES a significant part in electricity generation could become strong proof for the global community that an electricity system based on renewable energy sources is possible.
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Acronyms and Abbreviations

BMU - The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

DNO - Distribution Network Operator

DSM - Demand side management

EEG - Renewable Energy Sources Act (In German: Erneuerbare-Energien-Gesetz)

FIT - Feed-in Tariffs

ICT - Information and Communication Technologies

PV - Photovoltaic

R&D - Research and Development

RES - Renewable Energy Sources

TSO - Transmission System Operator
1. Introduction

1.1 Background

In its cabinet decisions from June 2011 concerning the transformation of Germany’s energy system, the German government confirmed an extensive reorientation of its energy policy. It is to undertake a speedy phase-out of nuclear energy and at the same time move into the age of renewable energy. The basis for these decisions is to cease the usage of nuclear power no later than at the end of 2022, dynamically expand renewable energies in all sectors, rapidly expand and modernize the electricity grids and improve energy efficiency with the aid of modern technology. With these decisions the German government intend to ensure that the energy supply remains reliable, Germany’s position as an industrial location is strengthened, and the sustainability and climate objectives are rigorously implemented. Figure 1.1 shows sub targets and the final goal for the transformation of Germany’s electricity system. Note that the goals for electricity and energy are differing. The policy basis for the transformation of the electricity system is the Renewable Energy Sources Act (EEG) (BMU, 2012).

![Figure 1.1; sub targets and final target set by the German government for renewable-based shares of electricity and energy use. (BMU, 2012)]

Germany has set itself up for a grand experiment, an experiment that could have repercussions all over Europe, which depends heavily on German economic strength. Germany must build and use renewable energy technologies at unprecedented scales and at enormous but uncertain cost, while reducing energy use. All of this must be done without undercutting industry, which relies heavily on reasonably priced, reliable power. (Talbot, 2012) But if this transformation succeeds Germany has the prospect of becoming a pioneer among industrialized countries, with a highly efficient energy system based on renewable energies. They will be able to set an example for an economically successful and sustainable transformation. (BMU, 2012) The percentage of renewable energy sources in electricity generation has risen from 6.8 percent in 2000 to 20.3
percent in 2011 thanks to the EEG (BMU, 2012). Although the EEG has proven to be very effective in increasing the level of renewable energy sources in electricity generation the transformation of the electricity system will be a great challenge. To succeed with the transformation, the EEG not only needs to be revised but a solution to the system stability is also necessary. One attractive solution is using information and communication technologies (ICT) to create a “smart grid.” There is no consensus on the definition of a smart grid, but what it comes down to is changing the way people think about the generation, delivery and use of electricity. Smart grid is essentially aimed to modernize our twentieth century grid for a twenty-first century society. (Borlase et al., 2012) In its National Renewable Energy Action Plan (2010) the German Federal Government states that the smart grid will make a key contribution in the future to the integration of electricity from renewable energies.

1.2 Aim

The aim of this report is to investigate the transformation of the German electricity system: popularly called the Energiewende. The report will introduce and analyze the Renewable Energy Sources Act as a policy instrument and how the electricity grid needs to be developed in order to handle the increasing shares of electricity from renewable sources. The focus will be on what Germany needs to do in order to succeed with the transformation. This is done using the following research questions:

- What is the history behind the EEG?
- What are the main regulations in the EEG?
- What parts of the EEG are successful and in what way?
- What parts of the EEG need to be revised?
- What are the main imperfections on today’s electricity grid when implementing a dominating share of electricity from renewable energy sources?
- How can Information and Communication Technology (ICT) be implemented as part of the transformation of Germany’s electricity system?

1.3 Delimitations

The report will only concern electricity. Goals and action plans for energy will not be mentioned unless relevant for the electricity sector. Policies other countries use will not be accounted for unless necessary when improving Germany’s policy. There are other solutions to system stability besides smart grid but they will not be analyzed in this report.

1.4 Disposition

Chapter 2 describes the method behind the thesis. Chapter 3 provides a background for the German electricity system and for how German energy
policies have been created. Chapter 4 describes the main regulations of the Renewable Energy Sources Act and the achievements of the act so far. Chapter 5 analyzes the changes demanded on the electricity grid and the EEG in order to succeed with the transformation. Chapter 6 and 7 cover discussion and conclusion.
2. Method

The basis for this thesis is a literature study. Literature has primarily been gathered from Linkoping University’s library, and to a lesser extent, the Newman Library of Baruch College NY and Kyung Hee University’s library. Since this is a current topic changing frequently, up-to-date research is needed as the main reference. Therefore a limited amount of books have been used and instead most of the literature gathered consists of scientific papers. Publications from the German Federal Government and its ministries have also been used.

When selecting appropriate scientific papers, the focus has been on finding information about Germany’s energy system, in particular the electricity market and grid, but to get a broader background for why Germany’s energy policy is framed the way it is, some papers also cover the electricity system and energy policies of the European Union. Among the selected articles, a balance was maintained between the background of the EEG, how the EEG should be developed, and issues with the electricity grid when introducing renewable energy sources. Many articles bring up the issue of climate change and lowering CO₂-emissions. This is not part of the thesis’ problem formulation and articles covering that issue have not been selected.

Since this is a political issue, publications from the German Federal Government and its ministries have been considered important. When selecting those publications, important factors have been when the documents were published and if they contain updated numbers on the development of renewable electricity. Before starting the research for scientific papers newspaper articles were revised, in order to get a sense of how the public is dealing with the transformation of the German electricity system. Those articles have only been used as references to show the public attention Germany got after its decision to eliminate its nuclear power use.

Both critical and positive articles have been used to get as balanced a picture as possible. Some of the papers are associated with popular science, while others are scientific. The reason for choosing papers from both areas is the level of public attention this transformation receives and that it affects all levels of society, from households, to giant industrial companies, and to the government. Publications from the area of popular science tend to be more political and also express current opinions in society. The scientific papers focus more on the technological side of the problem and not so much on how the public is experiencing the transformation.
3. Germany’s Electricity System

3.1 The German Electricity System

The electricity system of today is built for traditional energy sources, such as nuclear power, oil and coal. Traditional, condensing power plants provide secure energy in the sense that they can be turned on and off when needed, and the supply can always be adjusted to the demand.

![Diagram of electricity system](image)

*Figure 3.1: basic structure of a traditional electricity system (Wissner, 2011; Borlase et al., 2012)*

An electricity system is generally constructed as shown in Figure 3.1. From the generating power plant, the electricity is transferred to high-voltage transmission lines that transfer the electricity over long distances. The German transmission system consists of four major transmission companies, or transmission system operators (TSOs), that are responsible for the transmission and for reserve power on the high-voltage level in their respective area. From the transmission lines, the electricity is transmitted to a distribution substation where a transformer steps the voltage level down. After the substation, the electricity is transferred onto a distribution network that consists of smaller, local transformers that further step down the voltage level to suitable levels for consumers. (Wissner, 2011; Borlase et al., 2012) Just four companies own 85 percent of the German power generation capacity. Furthermore, the two largest companies own 60 percent of the capacity. Since the actual power output of many renewable energy (RE) installations is not known in real-time and cannot be balanced with real-time demand, the sum total of EEG power generation is predicted monthly. The TSOs transform the actual fluctuating power generation into a band of constant power, which equals the predicted generation, and transfer that constant power to electricity retailers. This is known as “vertical balancing of electricity.” The TSOs have to provide the constant power based on the monthly predictions and need to purchase or deliver additional power for this purpose. Deviations from the predictions are considered in establishing future monthly forecasts. (Langniß et al., 2009)
To match generation and demand, the grid operators rely on reserve power to equalize all net deviations in the short-run. Today, the system of reserve power is divided into three parts: primary, secondary, and tertiary reserve power. The primary reserve power reacts automatically within seconds to frequency deviations caused by increased or decreased power capacity. It gets its steering information directly from the main frequency. A central network control station activates the secondary reserve power within minutes and its purpose is to relieve the primary reserve power from potential new disturbances. Tertiary reserve power replaces secondary reserve power. It is not activated automatically but instead requested via a phone call. (Wissner, 2011)

Stability in the electricity system requires that electricity supply matches demand at all times, not just on average. When supply is not equal to demand, the observed level of system frequency will deviate from the established set-point value, which is 50+/-0.2 Hz. Deviations from this target can compromise the stability of the transmission system. System frequency falls when demand exceeds supply and rises when demand is lower than supply. Maintaining system frequency at the desired value is greatly facilitated by having accurate load forecasts. When load forecasts are inaccurate, generators can unexpectedly go offline. When actual electricity flows are not equal to expected flows, system frequency is kept within the operational limits by deploying balancing power. (Forbes, 2012)

The German grid is strained as never before. The decision to close the nuclear plants (See chapter 3.3.2) has increased reliance on coal-fired power plants as balancing power (Talbot, 2012). Balancing power is dispatched up when the
system is short of generating resources and down when there is excess supply. Primary and secondary control power is almost always activated. The system operator is obliged to maintain balance between power generation and demand. (Forbes, 2012)

An electricity meter builds a natural link between customers and suppliers. The measured data is the basis for the customers’ bills, which is often the only conscious moment of contact they have with their power supplier. Mechanical meters are still the most common, but digital, intelligent meters (also called smart meters) are already available on the market. (Wissner, 2011)

3.2 Supply and Use of Energy and Electricity

Figure 3.3 and 3.4 show gross electricity generation per source and final energy use in Germany in 2011.

![Gross electricity generation, %](image1)

![Final energy use, TWh](image2)
3.3 The Development of German Policies for Renewable Energy

Germany has 22 years of experience with a legally regulated system of fixed minimum payments for renewable-generated electricity.

<table>
<thead>
<tr>
<th>START (-END)</th>
<th>CONTENT</th>
<th>BY WHO</th>
<th>MAIN PURPOSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980’s</td>
<td>Research and development (R&amp;D)</td>
<td>Federal Ministry of Research and Technology</td>
<td>Research covering technologies for renewable energy sources.</td>
</tr>
<tr>
<td>1989-1995</td>
<td>Market stimulation program</td>
<td></td>
<td>Installation of 250 MW of wind power. Guaranteed a fixed payment per kWh of electricity produced, together with investment incentives for private operators such as farmers.</td>
</tr>
<tr>
<td>1990-2000</td>
<td>Electricity Feed-In Act</td>
<td>German Bundestag</td>
<td>Created foundations for funding of renewable energy sources. Based on the principle that feed-in tariffs (FITs) should cover the investor’s costs of producing renewable energy, and it obligated public utilities to purchase electricity from renewable sources.</td>
</tr>
</tbody>
</table>

Table 3.1: The development of promotion programs for renewable electricity in Germany (Ragwitz and Huber, 2005; Büsgen and Dürrschmidt, 2009; BMU, 2012; Mabee et al., 2011; Pfeiffer, 2012)

As seen in Table 3.1, the Electricity Feed-In Act introduced the system of feed-in tariffs (FITs). In the FIT system, the basic principle is that any national generator of renewable electricity can sell its electricity at a fixed tariff for a specified time under specified conditions depending on location, technology etc. (Fouquet, 2013). The Electricity Feed-In Act covered hydropower, wind power, solar power, landfill gas, biogas and fuels obtained from agricultural and forestry products, residues or waste. The supply companies paid 80 percent of the average electricity price chargeable to end-users as a feed-in tariff. This meant that the FITs were based on the electricity price. Whenever the electricity price changed so did the FIT. Smaller suppliers are the main generators of electricity from renewable sources, and there had been many obstacles to their access to the power grid. The Electricity Feed-In Act solved this problem by including guaranteed purchase and the payment of fixed FITs. This made wind farms an attractive proposition and numerous wind farms were established in Germany. (Pfeiffer, 2012)
The Electricity Feed-In Act had an asymmetric impact on the utilities operating the grid. One example is wind turbines. The wind turbines that benefited most under the Electricity Feed-in Act are concentrated in Northern Germany. Thus, grid operators in the North were at a slight competitive disadvantage, which caused a problem when the electricity market was liberalized. Another problem caused by the market liberalization was falling electricity prices, which led to lower feed-in prices for electricity from RES. This started to undermine their economic basis, particularly that of the wind turbines that had been installed in the previous years. As a consequence of these problems a debate arose about the future of the Electricity Feed-In Act. (Ragwitz and Huber, 2005)

3.3.1 The European Union Shaping German Energy Policies

Germany is an important member of the EU, both in regard to its energy use and its geographical location in the center of Europe’s electricity grids. Germany is by far the largest energy user within the EU, accounting for almost 19 percent of the gross energy use and 20 percent of net imports. Germany generates 19 percent of the electricity. (Röhrkasten and Westphal, 2012) Figure 3.5 shows the electricity generation by source in Germany, in its neighboring countries, and in the European Union as a whole.

German energy policy has been shaped by EU policies, which collectively addresses energy security, as seen in Table 3.2. The Treaty of Lisbon from 2009 is the first treaty that contains an energy chapter. Energy solidarity is thus a part of the EU’s primary law, marking a step toward ‘Europeanizing’ energy security. The particular energy mix of a member state is an issue of national sovereignty though. The EU is committed to creating an internal market for gas and electricity. (Röhrkasten and Westphal, 2012)
<table>
<thead>
<tr>
<th>START</th>
<th>BY WHO</th>
<th>NAME</th>
<th>CONTENT</th>
<th>END</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>EU</td>
<td>Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market</td>
<td>Set overall target for 21 percent renewable electricity production. Individual target for each member state.</td>
<td>2010</td>
</tr>
<tr>
<td>March 2007</td>
<td>EU</td>
<td>Course for development of an integrated European Climate and Energy policy</td>
<td>Introduced the 20/20/20 targets, which is binding targets for renewable energies and climate protection; 20 percent share of renewable energies in overall EU energy use, 20 percent reduction of greenhouse gas emission, 20 percent improvement in energy efficiency.</td>
<td>2020</td>
</tr>
<tr>
<td>August 2007</td>
<td>German Federal Cabinet</td>
<td>Integrated Energy and Climate Program</td>
<td>Based on policy decisions established by the EU and included the forthcoming revision of the EEG.</td>
<td></td>
</tr>
</tbody>
</table>

Table 3.2: Decisions taken by the EU and Germany based on the European Unions environmental policies. The EU approach to energy policy builds on policy fields of shared competencies; environmental and climate policy combined with competition and internal market policies. (Röhrkasten and Westphal, 2012; Büsgen and Dürrschmidt, 2009; Fouquet, 2013; EU, 2001)

The 20/20/20 targets are for the EU as a whole. The member states are required to meet different individual targets depending on their national framework conditions, such as the current share of renewables or economic capacities. The Directive 2009/28/EC sets a binding national target. To sketch out the timeframe and measures with which they intend to reach the target, the member states have to develop National Renewable Energy Action Plans. (Fouquet, 2013; Büsgen and Dürrschmidt, 2009; EU, 2001) The EU does not demand a certain policy instrument, so the member states are free to choose the one they see fit. However, two communications on the expansion of renewable energies in the electricity sector from the European Commission published in 2005 and 2008 state that a well-adopted feed-in tariff policy, like the one in Germany and many other member states, is generally the most efficient and most effective support schemes for promoting renewable generated electricity. (Büsgen and Dürrschmidt, 2009) To promote renewable energy, Sweden, Poland and Romania use the quota system, the UK and Italy use a combination of feed-in tariffs (FITs) and quotas, and the rest of the member states use FITs. (BMU,
Figure 3.6 shows the different binding national target values and the development until 2010 for Germany and its neighboring countries.

According to its National Renewable Action Plan Germany expects to generate 38 percent of its electricity from RES by 2030. This can be compared with the goal of at least 35 percent by 2030 mentioned earlier. The EEG (and its FIT program) can be seen as a tactical policy used to achieve the strategic goal laid out in the Directive 2009/28/EC. (Mabee et al., 2011)

As seen in Figure 3.7 Germany has exceeded their 2010 target of 12.5 percent renewable electricity, achieving 16.9 percent by that date. Far from every member state managed to reach their individual target but since some member states managed to exceed their targets, the EU as a whole almost reached the
overall target of 21 percent. Compare Figure 3.6 and 3.7 and note that the targets for electricity and energy are differing.

### 3.3.2 Effect of Fukushima on Germany’s Energy Policy

![Figure 3.8: an overview of the relatively rapid development of decisions leading to the shutdown of Germany’s nuclear power plants. Before the Fukushima disaster the nuclear power plants were seen as a bridge to a low-carbon electricity system. (Lechtenböhmer and Luhmann, 2013; Talbot, 2012)](chart)

One of the challenging goals of the Energiewende, cutting overall greenhouse-gas emissions by 40 percent from 1990 levels by 2020, and 80 percent by 2050, was made easier by the fact that Germany already generated almost 20 percent of its electricity from nuclear power, which is basically carbon-free (Talbot, 2012). Figure 3.8 shows the rapid development of German energy policy following the Fukushima disaster. The decision to shut down the nuclear power plants made Germany even more dependent on the implementation of renewable energy sources (RES) (Lechtenböhmer and Luhmann, 2013). The phase-out has been regulated in clear and legally binding form in a step-by-step plan set out in an amendment to the Atomic Energy Act (BMU, 2012). Further improvements of the EEG are necessary to succeed in the phase-out of nuclear power and to reach the goals set up for 2020, 2030, 2040 and 2050 (Lechtenböhmer and Luhmann, 2013). Besides putting more pressure on the success of the transformation over to RES in electricity generation, the decision to shut down the nuclear power plants created headlines in newspapers all over the world, giving the EEG and Germany’s energy policy unprecedented attention (Dempsey, 2011; The Economist, 2011; BBC News, 2011). The change in the politics for nuclear power means the shortcomings and further developments of the EEG and the electricity grid are even more important in order for Germany to succeed with the transformation.
4. The Renewable Energy Sources Act (EEG)

4.1 Main Regulations in The EEG

The EEG is a feed-in tariff (FIT) system that obliges distribution network operators (DNOs) to connect renewable energy sources (RES)-driven power plants, to purchase RES electricity and to pay a fixed remuneration in cent per kWh to the plant operator (Langniß et al., 2009). The aim of the EEG is to preserve in law the priority of RES in electricity generation by means of an obligation to take and pay for RES electricity (Pfeiffer, 2010). The goals of the EEG include decreasing costs of renewable electricity supply to the national economy and promoting further development of renewable technologies (Mabee et al., 2011). With the EEG, two important and innovative features were implemented: degression of tariffs and stepped nature of tariffs (Ragwitz and Huber, 2005). As seen in Table 3.1 the EEG has so far been revised three times. Development of the EEG is important to adapt the policy to changes in the market and the growing share of RES. (Büsgen and Dürrschmidt, 2009; BMU, 2012) The main functions of the EEG are mentioned below. See Table 4.1 for an overview of the two most important economic structures of the EEG: FITs and degression rate.

4.1.1 Feed-In Tariffs and Degression Rate

The total amount of feed-in compensations, i.e. the amount of remunerations the DNOs pay to the plant operators, will be distributed evenly among all high voltage grid operators and equally among all electricity consumers (Ragwitz and Huber, 2005). The level of remuneration, or FIT, is differentiated by technology, plant capacity and other characteristics. Remuneration is based on the following formula: 

\[ P_{ni} = P_{n}(1-d)^{v-T+k} \]

where:

- \( P \) = specific remuneration per kWh
- \( T \) = the base year when the EEG was established
- \( v \) = the year of start of operation
- \( i \) = the technology category
- \( k \) = the additional premiums for innovative technologies
- \( d \) = the degression rate

(Langniß, et al., 2009)

FITs are one of the most widely used incentive rate structures for stimulating the development of renewable electricity and for creating conditions that reduce risk and improve investment security (Mabee et al., 2011). The EEG covers power generated from hydroelectric plants, landfill and biogas, wind turbines, photovoltaic (PV) cells, biomass, geothermal resources and methane from abandoned mines (Pfeiffer, 2010). The guaranteed payments from the tariffs provide investors with the security and confidence they need to invest the large sums of money required to construct and maintain renewable energy facilities. It is structured so as to provide an equal opportunity for projects of varying sizes.

FITs encourage technological learning. Engineers are persuaded to develop more efficient technologies to increase the amount of electricity generated and the rate of profit return from the initial investment. (Mabee et al., 2011) Low technical
efficiencies of PV modules and the unfavorable location of Germany, i.e. the relatively low rate of solar insolation, are among a multitude of reasons for solar electricity's lack of competitiveness. Due to the lack of competitiveness a high support is necessary for establishing a market foothold. (Frondel et al., 2010)

The EEG implements the tariff degression model to account for generation technologies becoming less expensive to produce, install, and operate (Mabee et al., 2011). The degression rate is technology-specific to reflect technological progress and cost reductions due to learning effects. The reason the degression rate is set in advance is to guide plant manufacturers on the expectation on cost reductions. (Langniß et al., 2009) The high initial rate rewards early investments while anticipation of declining rates encourages more rapid development of increasingly efficient technology. The degression model answers the problem of investors waiting for cheaper technologies, processes, and economies of scale. They know that the quicker they act the higher rate they will receive. The fact that prices paid for renewable electricity will go down in a smooth fashion is reassuring to investors. (Mabee et al., 2011)

<table>
<thead>
<tr>
<th>Feed-in Tariff</th>
<th>Degression rate</th>
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<tbody>
<tr>
<td><strong>General</strong></td>
<td></td>
</tr>
<tr>
<td>• Technology-specific and adapted after project size.</td>
<td>• Decreases the tariff rate by a fixed percentage every year. The degression rate begins at one percent per year and is set in advance.</td>
</tr>
<tr>
<td>• Guaranteed rate at a set period of time.</td>
<td>• The rate is technology-specific and takes technological development into account.</td>
</tr>
<tr>
<td>• Not limited to the quantity installed.</td>
<td>• New connections in later years are offered at a lower price level.</td>
</tr>
<tr>
<td>• Public authorities set an effective price.</td>
<td>• Price remains constant for 20 years.</td>
</tr>
<tr>
<td>• Feed-in prices are fixed for 20 years (no longer linked to electricity retail prices).</td>
<td>• Reactivated or modernized old facilities count as new facilities if the cost of renewal amounts to at least 50 percent of the cost of new facilities.</td>
</tr>
<tr>
<td><strong>PV</strong></td>
<td></td>
</tr>
<tr>
<td>• Receives the largest support out of all the RES.</td>
<td>• Higher rate than other RES.</td>
</tr>
<tr>
<td>• Fixed FIT for 20 years.</td>
<td></td>
</tr>
<tr>
<td><strong>Wind</strong></td>
<td></td>
</tr>
<tr>
<td>• Lower FIT than PV.</td>
<td>• Higher rate than other RES.</td>
</tr>
<tr>
<td>• Guaranteed FIT during 20 years. For the first five years the FIT is fixed, but for the next 15 years the tariff might be less depending on the efficiency of the individual wind turbine. If the electricity output turns out to be low the FIT might be fixed for 20 years.</td>
<td></td>
</tr>
<tr>
<td><strong>Others</strong></td>
<td></td>
</tr>
<tr>
<td>• Lower FIT than PV.</td>
<td></td>
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*Table 4.1: the main functions of the FITs and degression rate. Also explaining the differences between different technologies. (Mabee et al., 2011; Fouquet, 2013; Ragwitz and Huber, 2005; Frondel et al., 2010; Langniß et al., 2009)*


4.1.2 Electricity Prices

The costs of the FIT payments are passed onto the consumer in the form of the EEG surcharge. 13 percent of the total electricity price increase between 2002 and 2006 was due to the EEG. Increasing production, transport, and distribution costs were the larger part of the increase though, accounting for around 75 percent of the total price increases. The special equalization scheme is the part of the EEG that relieves most of the burden of the EEG on electricity-intensive companies. Their surcharges are limited to 0.05 cents per kWh. (Büsgen and Dürrschmidt, 2009) According to the Federal Network Agency, the companies enjoying the reduced surcharge currently consume approximately 18 percent of electricity in Germany but pay only 0.3 percent of the total amount collected by the surcharge. The burden of paying for the EEG falls disproportionately on the remaining consumers, especially households and small to medium-sized companies. Instead of allocating the costs more fairly, the government has been further reducing the threshold that companies are required to meet to qualify for being exempt from paying the costs of the EEG. The exemptions for energy-intensive industries are justified mainly by reasons of international competitiveness. (Weber et al., 2012)

As electricity production from renewable energies is currently still more expensive than electricity generation from the existing conventional power plants, the continuing expansion of RES will initially lead to a further increase in the differential cost of the EEG and hence, the surcharge payable by consumers (Büsgen and Dürrschmidt, 2009).

4.1.3 Priority Grid Access

![Diagram](image)

Figure 4.1: how the electricity and the payments for the FITs are distributed through the electricity system. Hollow arrows show electricity and the full arrows show payments. Grid operators represent both distribution network operators and transmission system operators. (Langniß et al., 2009)

The EEG mandates priority access for RES to the grid (Langniß et al., 2009). See Figure 4.1 for information on how electricity and payments move through the system. All renewable energy projects that are entitled to the tariff are also granted priority to connect to the grid (Mabee et al., 2011). But the EEG also provides flexibility to the different actors involved in the system. Plant operators and networks operators may, under a mutual agreement, deviate from priority access which means that plant operators abstain from generating power at certain times. This is done to avoid overstress on the electricity grids but it is not used as a systematic strategy to match generation to demand. RES plant operators are also allowed to market RES electricity outside of the EEG framework but so far this has not been economically advantageous since the EEG remuneration is higher than the average prices on the power exchange. (Langniß et al., 2009)
In the first amendment, the demand for more evenly distributed purchase of electricity was an incentive to reach more geographically distributed generation. The increase in degression rates in the second amendment was due to the rapidly declining price of solar panels and wind turbine components. (Mabee et al., 2011; Ragwitz and Huber, 2005) The adjustments and improvements made to the payment rates were due to current market and cost trends with a view towards achieving the goal of generating at least 35 percent of Germany’s electricity supply from RES by 2020 (Pfeiffer, 2010). The flexibility premium and optional market premium in the third amendment were introduced as an incentive to promote demand market oriented operation of installations for the use of RES. The increased support for research and development (R&D) was implemented to support the development of innovative solutions. (BMU, 2012)

In view of the dynamic expansion of RES electricity, regular monitoring of the EEG is necessary. The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) is required to submit a progress report on the EEG to the Bundestag every four years. (Büsgen and Dürrschmidt, 2009) The government also has to monitor the progress of the transition. In 2011, the German government approved the monitoring process called “Energy for the Future.” In this process the German government will present a monitoring report once a year and a progress report every three years in order to review the implementation of the EEG on the transformation of Germany’s electricity system. Corrective measures will be taken if required. (BMU, 2012)

### 4.2 The Effects of The EEG on The Electricity System

### 4.2.1 Increase in Renewable Energy Sources Since The Implementation of The EEG

In progressing from the Electricity Feed-In Act to the EEG, Germany has seen a significant growth in its renewable generation capacity over a relatively short period of time (Mabee et al., 2011). Figure 4.2 shows how the renewable energy (RE) shares of electricity generation have grown since 1990. The growth is almost linear, without any sudden increases. The growth of RE in the 1990’s is insignificant compared to the growth since the EEG was implemented. It is easy
to see that the EEG has been a more effective policy than the Electricity Feed-In Act.

By 2011 the greatest contributions came from wind energy, hydropower and solar power. Figure 4.3 shows how the capacity was distributed over different sources. From 2000 until 2011, electricity generation from wind and photovoltaic (PV) has increased the most. Hydropower is almost the same.

By 2011, renewable energy sources (RES) also triggered investments totaling 22.9 billion Euro while 318,600 people were employed in the renewable energies sector (BMU, 2012). Germany now has more installed wind power capacity than any other country worldwide and claims at least half the market in PVs. Due to the EEG, wind power has surpassed hydropower as the main RES, covering around 40 percent of all RES electricity. (Langniß et al, 2009)
4.2.2 Effects on The Electricity Prices Since The Implementation of The EEG

Price increases are largely attributable to the costs of the EEG, since 2000, electricity prices in Germany have risen consistently (Weber et al., 2012). The EEG will have long-lasting consequences on the electricity price because of the fact that each newly established plant is granted a 20-year period of fixed FITs, irrespective of future market conditions. Even if the subsidization scheme ended this year, electricity consumers would still be burdened with charges until 2014. (Frondel et al., 2010) Germany has already incurred significant costs. Each monthly electric bill carries a renewable-energy surcharge of about 15 percent. Wholesale electricity prices have jumped approximately 10 percent since the eight nuclear plants were shut in 2011. (Talbot, 2012)

Both Frondel and Talbot fail to compare the influence of the EEG on the electricity price with increase in prices for conventional power. The costs of electricity generation, transport and distribution in that sector have risen by 5.43 cent per kWh since 2000. That price is equal to 45 percent of the total price increase. See Figure 4.4 for a complete overview of the electricity price and its different components. As derived from the figure, the increase of the EEG surcharge corresponds to 28 percent of the total increase in electricity price.

Besides being the central driver for recent electricity price increases, the future changes in cost for fossil fuel also plays a decisive role. A successful transformation of the electricity system initially demands costs greater than those in a business-as-usual scenario, but the costs for the transformation are considered to be much higher if stagnant or even falling fossil fuel prices are assumed. There is great unpredictability for assumptions on future fossil fuel prices, but no matter if the prices will decrease, remain stagnant, or increase, the prices for renewable electricity have been falling and are expected to continue to fall in the future. There is also no discussion about limits to an easily available supply when it comes to electricity from RES. (Weber et al., 2011)
So far, renewable energy is not power being generated at the lowest possible price since there is no marked-based system where consumers have access to multiple suppliers within a system that uses FITs. It might be argued, however, that the goal of a successful FIT system is to incent generation using a variety of renewable electricity options, not to drive the generation of electricity from RES at the lowest possible cost. (Mabee et al., 2011)

4.2.3 Use and Selection of Renewable Energy Technologies Since The Implementation of The EEG

In the last few years the dynamic inefficiency (i.e. the inability to, on a short-term, adapt to changes in economic conditions) of the EEG in adjusting its support levels to accommodate a rapidly changing market has been revealed. The cost of PV modules falling rapidly while fees change slowly enabled investors to enjoy very attractive rates of return, which have channeled a great deal of money into PV development in Germany. (Weber et al., 2012) The net cost of subsidizing PV will increase tremendously unless FITs are not diminished accordingly in the coming years, with a skyrocketing demand in Germany as a consequence. The cost of subsidizing PV is significantly higher than for wind power, but the amount of solar electricity produced is considerably less than the amount of electricity produced by wind converters. (Frondel et al., 2010)
5. Requirements on Future Energy Policy and The Future Electricity System

In this chapter, problems and suggestions for improvements of the policy and the electricity grid will be discussed.

5.1 The EEG

The first part concerns the policy.

5.1.1 Problems with The EEG

Today’s policy instrument contains shortcomings and problems regarding prices and technology. These are discussed below.

5.1.1.1 Electricity Prices

A considerable proportion of the surcharge-increase shown in Figure 4.4 is due to growing industry exemptions. A shrinking number of consumers carry the burden of paying for growing support for renewable energies. As mentioned in chapter 4.1.2 the costs are disproportionately distributed between certain industry companies and the rest of the electricity consumers. (Weber et al., 2012) According to the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) (2012) electricity generated from RES and paid for under the EEG is still, on average, more expensive than electricity from fossil or nuclear sources. In 2011, approximately 600 companies were exempted from the surcharge. As a result, the EEG costs paid by all other electricity customers are currently around 20 percent higher. Weber et al. (2012) argues that the EEG levy should not be considered an adequate indicator of the costs of restructuring the electricity system, since a shrinking number of consumers carry the burden of paying for growing support for renewable energies due to the special equalization scheme. The criteria for qualifying for the reduced surcharge include electricity consumption and the share of a company’s electricity costs as part of its gross value added. A measure attempting to quantify exposure to international competition, however, is not included in these criteria even though, as mentioned earlier, international competitiveness is the main reason for the exemptions made for industrial companies. Current criteria to qualify for exemption not only disregard a true measure of international competitiveness, but also create perverse incentives that might lead to an increase in overall electricity consumption, thereby encouraging less efficiency, not more. Companies that just barely clear the consumption threshold for exemption are encouraged not to invest in energy efficiency improvements. Companies close to the threshold are even encouraged to increase their electricity consumption in order to qualify for the exemption. (Weber et al., 2012)

Wholesale electricity prices have fallen between 10-20 percent during 2011-2012. One of the primary causes of lower wholesale prices is the merit-order effect. Sources with lower marginal costs of production, such as fuel or operation and maintenance costs, are always able to outcompete generation technologies
with higher marginal costs. The sources with lower marginal costs are the first to be brought online to meet demand. The source with the highest marginal cost is the last in the merit order and sets the price all generation sources receive. Since, for example, wind and solar energy producers have marginal costs that are close to zero, a growing supply of electricity from renewable energy sources reduces wholesale electricity prices, as conventional plants with the highest marginal cost are pushed out of the market and replaced by plants with lower marginal costs. This leads to a new, lower electricity price. (Weber et al., 2012) According to the BMU (2012) the electricity price reduction effect of EEG-assisted electricity generation amounted to around 0.9 cents per kWh in 2011. Whether, and to what extent, these effects will be reflected in the electricity prices paid by final consumers depends largely on the electricity supplier’s procurement and market behavior. The main beneficiaries of the merit-order effect will probably be the electricity-intensive companies exempted from the surcharge. Since they are special-contract consumers buying electricity directly on the exchange, they tend to gain the most benefit from falling wholesale electricity prices. (Pfeiffer, 2010)

Another criticism of the EEG and electricity prices regards cost savings achieved by grid operators as a result of the decentralized feed-in not being passed onto the end-users. The problem of operators choosing not to pass on the benefits of feed-in tariffs (FITs) has not yet been resolved to the satisfaction of consumers. Consumers are paying grid-access charges that do not correspond to costs incurred by operators. (Pfeiffer, 2010)

5.1.1.2 Renewable Energy Technologies

To some degree, the EEG has become the victim of its own success. It succeeded in attracting investments in photovoltaic (PV) and adding capacity to the market. However, the additions in PV capacity have far exceeded government targets. The unprecedented capacity additions meant increasing payments for the FITs, which contributed to increasing the costs of the EEG. Additional tariff reductions were not enough to cool the overheated investment climate. Investments increased even more in the time between when the tariff cuts were announced and when they were implemented, since investors wanted to take advantage of the higher tariffs before they were reduced. (Weber et al., 2012) The main disadvantages of the EEG lay primarily in the lack of flexibility and dynamism in the system of FITs. The varying FITs, which are calculated on the current cost price of the relevant technology, result in support being extended to technology that generates high costs but contributes little to the achievement of development targets. At the present, PV gives rise to the highest capital costs per MW of capacity and has the highest share of investment in production capacity of any renewable energy source (RES). (Pfeiffer, 2010)

Fondel et al. (2010) questions the effects of the degression rate. The degression rate was introduced to create incentives to cut costs and innovate, but instead it does just the opposite by encouraging the immediate implementation of existing technology. Doing so helps investors to secure today’s favorable subsidies for the next 20 years at an unvaried level, free from the imperative of modernizing with the latest technology. By increasing the FIT levels in the amended versions of the EEG, the cost-diminishing impacts of the degressive system were destroyed.
The EEG is not encouraging innovation so much as it makes existing technologies profitable. Technological efficiencies of solar cells are far below their theoretical potential. Although the average commercial module efficiency has increased considerably over the years, the best laboratory cells are still much higher. From an economic perspective, this suggests that one should have abstained from strongly subsidizing the market penetration of relatively immature PV technologies and rather, research and development (R&D) funding should have been increased first. (Frondel et al., 2010; Talbot, 2012) To give some perspective, the cost of the EEG and the amount invested in R&D can be compared. The total cost paid under the EEG in 2011 amounted to 12.1 billion Euros. The same year, around 245 million Euros were invested in different research projects. (BMU, 2012)

5.1.2 Improving The EEG

5.1.2.1 Electricity Prices

There are different views on the influence on electricity prices from the EEG. While some claim the cost of the transformation caused by the EEG is far too high, others argue it is not high compared to other influences on electricity prices. Still others question if the goal is to actually drive the generation of electricity from RES at the lowest possible cost (Pfeiffer, 2010; Wand and Leuthold, 2011; Büsgen and Dürrschmidt, 2009; Langniß et al., 2009; Mabee et al., 2011; Weber et al., 2012; Frondel, 2010). Either way, there is consensus that there are inequalities in electricity prices between industries and households, and to a lesser extent between households and grid operators. Weber et al. (2012) argues that as concerns over rising household electricity rates grow, the extent of industry exemptions becomes harder to justify. They suggest that energy-intensive industries not exposed to international competition should pay a greater share of the EEG costs.

According to Weber, et al. (2012) the life-cycle costs of RES in electricity generation are nearing those of new conventional power plants and further costs reductions are expected if capacity can be maintained. Financing the EEG will initially require additional investments but these investments are likely to become net savings in the future. However, careful management in order to reduce initial costs and maximize long-term benefits through effective and efficient policy design is crucial. While a majority of the literature critiques the increasing electricity prices but still agrees on the success of the EEG, Frondel et al. (2010) argue that the EEG is a massively expensive policy and that other policy instruments that harness market incentives or correct market failures would be a better way to go. They also argue that funding for R&D should be a much higher priority.

5.1.2.2 Renewable Energy Technologies

Pfeiffer (2010) warns that in view of the ambitious development aims, particular care must ultimately be taken to avoid undermining cost effectiveness and the competitive principle in the power industry. When RES accounts for 35 percent of power supplies and are fed into the grid on a priority basis as well as attracting payments set by the government, it will be time to re-examine the rules. Pfeiffer (2012) also argues that until the price of solar power has fallen, it
is advisable to restructure FITs to favor other energy sources, such as biomass and off-shore wind power, in order to achieve the development targets at less expense. Weber et al. (2012) suggests that greater cost efficiency for large infrastructure projects, such as offshore wind farms, can be ensured by combining FITs with competitive offers, in which project developers bid for the level of support they need to build a wind park in a predefined location. Frondel et al. (2010), on the other hand, suggests that a uniform subsidy per kWh of electricity from renewables, which would harness market forces to determine which types of renewables could best compete with conventional energy sources. Frondel et al. (2010) believes that the incentives of the EEG today stifle innovation by granting a differentiated system of subsidies that compensates each energy technology according to its lack of competitiveness. That allowed PV to be the most subsidized renewable energy in the unleveled playing field created, although it is the most expensive, and hence, the biggest winner. That would be avoided if a uniform subsidy were offered.

The issue with fluctuating sources and how a balancing mechanism is supported in the EEG is a recurring topic in the literature. As seen in Figure 4.3, fluctuating sources account for the majority of the power attributed to the EEG. The power supply needs to be matched to the power demand and a mechanism is needed to allow cost recovery for this service. The current policy structure needs to be reformed to manage the challenges of an electricity system that relies on growing shares of renewable power. The renewable technologies are now a central pillar of the electricity market. Adding further generation capacity can no longer be the sole aim of renewable energy support policies. The aim must also be to optimize the renewable energy mix and to make supply more responsive to demand, which is confirmed by both Langniß et al. (2009) and Lechtenböhmer and Luhmann (2013).

Büsgen and Dürrschmidt (2009) argue that measures to promote the use of storage technologies and system integration, such as use of virtual power plants, load management and energy storage systems, and greater incentives for repowering are needed. Langniß et al. (2009) and Büsgen and Dürrschmidt (2009) believe that appropriate parameters and incentives must be created to improve grid management in order to balance supply and demand, as well as technical optimization, expansion of grid systems to make power plants more flexible and easily regulated.

5.1.2.3 Market Competition

As mentioned earlier, only four companies own most of the power generation capacity in Germany, which is a clear indicator of a market with limited competition (Langniß et al., 2009). It is essential to examine RES in the light of the criterion of commercial viability. In the long run, providers of green energy must be enabled to stand on their own feet in the energy market. Both Pfeiffer (2010) and Langniß et al. (2009) gives suggestions on further improvements of the EEG that will give renewables the necessary impetus towards acquiring the ability to compete with fossil fuels. Pfeiffer (2010) suggest that further development of the market premium already included in the EEG will establish renewables as a strong competitor in the electricity market. The premium will create more additional incentives for operators of plants for the generation of electricity from renewables to sell their electricity directly on the energy
exchange. This will create more competition in the energy markets. According to Langniß et al. (2009) incentives are needed that improve system and commercial integration of renewable power into the electricity supply system. Those incentives would concern all actors along the value-added chain, from power plant operators to end-users, and would allow for more efficient integration and result in lower costs to final consumers. The EEG has been noted for encouraging more competition and costing less than alternative policies. Along these lines adapting the EEG to encourage commercial integration should encourage more competition and result in operators of renewable energy plants being prepared and capable to market their generation independently or through third parties to the power markets.

5.2 The Electricity System

This part covers the shortcomings of today's electricity grid and the improvements needed.

5.2.1 Imperfections in Today’s Electricity Grid

All energy sources have specific characteristics. For renewable energy sources (RES), the most significant characteristics are the fluctuation over time of some sources such as wind and solar power, and the availability of sites with good resources. Wind resources, for example, differ widely both locally and regionally. (Langniß et al., 2009) One main concern when implementing fluctuating renewable sources are the minimization of forecast errors, so that imbalance costs for plant owners can be reduced (Simão et al., 2012). It is difficult to know how much power will be produced and when. The future challenge of the electricity grid is to keep meeting demand and supply in a secure way. In order to do this, the electricity grid needs to be more flexible. Balancing power and the capability to store electricity are also needed to be able to meet demand in times when production from RES is not sufficient. (Wissner, 2011) Vertical balancing, when the transmissions system operators (TSOs) transform fluctuating power into constant power, is the balancing mechanism used today, has been criticized for creating additional costs and for not matching the real power demand patterns. The EEG requires an immediate commercial transfer of the RES electricity quantities to electricity retailers. However, this has not been feasible in practice since the actual power output of many RES installations is not known in real-time and therefore cannot be balanced with real-time demand. (Langniß et al., 2009) Currently, the EEG does not provide any incentive to generators, grid operators, or power suppliers when it comes to matching generation and distribution of RE with the actual power demand, both in the short and long-term, or when it comes to RES reliability of power supply. (Langniß et al., 2009; Büsgen and Dürrschmidt, 2009) Retailers face uncertainty and risk because the final calculation of the transformation of fluctuating power to constant power is made a year and a half after power generation whereas retailers often purchase a year or more before delivery. Thus, retailers do not know how much EEG power they are forced to purchase, leaving them at risk about quantities to purchase on conventional power. This also mean they do not know the burden from the EEG beforehand. A specific balancing mechanism between TSOs is needed to ensure that the amount of RES electricity remunerated annually according to the EEG, as well as the resulting burdens, are equally distributed.
To adapt renewable energies appropriately and to minimize overall costs, power generators, grid operators, and power suppliers all need to be involved, since an optimization of the entire supply system is needed. (Langniß et al., 2009) Availability of secure, reliable networks to transport energy supplies, energy management, and balancing intelligence are important elements when implementing more RES. Demand side management (DSM) is increasingly important, but the rules for DSM are presently lacking. Upgrades of the grid are needed to allow the possibility of backflow (two-way transmission) and increasing the flexibility of the network. (Fouquet, 2013) Grid infrastructure is, and must be, continually updated, adapted and built specifically for an energy mix that includes increasing shares of RES and corresponding technologies. It is important to avoid overstressing existing power grids, and as of today, EEG does not provide any incentives in that respect. (Langniß et al., 2009)

Lechtenböhmer and Luhmann (2013) mention 4 main technical and regulatory challenges, besides the management challenge of implementing the transformation of the electricity system:

- How to continue a steady and efficient expansion of RES without increasing the need for balancing power to impractical levels
- How to provide balancing capacities from several origins, not only from conventional power plants, to assure frequency stability and to bridge possible capacity gaps in times of insufficient RES supply
- How to achieve targeted electricity savings
- How to increase the capacities of the transportation grids and enable intelligent use of distribution networks (smart grids) in order to manage the targeted expansion of RES

Meeting these four challenges is the core regulatory target in Germany. The third challenge, however, is not being discussed in a regulatory context yet, even if demand side management is under consideration. Electricity savings and efficient use are important when implementing RES. Today that is not part of the EEG.

The growing share of RES in electricity generation has led to decentralization in the production of electricity. As described in the previous section, the original power flow direction runs from higher to lower voltage levels, but the feed-in of many smaller, distributed sites can lead to power flow reversion. The high volatility in the feed-in of wind and solar power can lead to situations where it is no longer possible to efficiently control the grid. For example, overload leads to load rejections, which in turn can result in entire power plants coming to a complete stop. In these situations the grid has to deal with conditions it was not built for and it is difficult to have reasonable steering without the help of information and communication technologies (ICT). The distribution grid must be upgraded in order to better handle varying, and partially reversed, electricity flows. The grid capability must be upgraded to make it an enabler of the desired change instead of a potential bottleneck. (Lechtenböhmer and Luhmann, 2013; Wissner, 2011)
Other than the direct costs covered by the EEG, i.e., payments for feed-in tariffs (FITs), indirect costs arising from grid development, need for balancing power and measures to offset fluctuations in the power supply from RES will be added to the bill of carrying out the transformation. (Pfeiffer, 2010)

5.2.2 Improving The Electricity Grid

Figure 5.1 shows how, compared to figure 3.1, the electricity grid of the future can be designed.

![Figure 5.1: possible structure of an electricity system based on renewable energy sources and combined with information and communication technology.](image)

Production from renewable energy sources (RES) is usually distributed, and hence more suitable for the flexible electricity grid we want to see in the future (see Figure 5.1). Fouquet (2013) describes an energy source as distributed when it provides energy close to the point of consumption, either as a stand-alone power source or one that is connected directly to the distribution grid. Distributed energy sources include distributed generation, storage of electrical energy, and demand response. In most cases the generator is connected to the electrical grid.

There is a strong consensus in the literature that the electricity grid of the future needs to be more flexible and that information and communication technologies (ICT) will have a leading part in achieving that. Wissner (2011) writes that implementing ICT will lead to processes that are run automatically and information flows between single sectors that are efficient and wieldy. As mentioned earlier by Langniß et al. (2009), an integrated optimization of power flow over all stages of the value chain is only possible if all participants and system components are able to communicate with each other. Wissner (2011) also describes a future power system where the different players interact with each other continuously and in all directions.

Each part of the structure described in Figure 5.1 can be improved in order to achieve the desirable change of the electricity grid. The following sections describe the most important changes. Focus lies on the importance of ICT.
5.2.2.1 Power Generation

The option ICT offers for electricity generation is a better prediction of expected power generation. Although the ability to predict power generation is high today, ICT offers a better communication between grid operators and the fluctuating plants that will lead to a better prediction. Better communication is important to be able to deal with an increasing share of decentralized power sources with a fluctuating feed-in, which is confirmed by Wissner (2011) and Forbes et al. (2012).

In order to create better communication between a great amount of small power plants, a virtual power plant can be created by using ICT. A virtual power plant is a pool of small generation units that, combined, achieve the characteristics of a big plant. Communication needs to be cross-linked in between the single power plants and a central control unit is needed. Measuring devices that give information about supply, use, grid status, and possibly also meteorological data will be used. (Wissner, 2011) Using virtual power plants will provide higher flexibility in generation. Two of the main imperfections of today’s grid, dealing with fluctuating feed-in and unpredicted deviations as mentioned in the previous section, can be cleared within the pool of power plants. The EEG so far does not provide an incentive for building virtual power plants since there is a fixed FIT regardless of the current grid status.

5.2.2.2 Power Transmission

Changes on the transmission system are not a focus in the literature. It is worth noting however, that Lechtenböhmer and Luhmann (2013) mention that in the existing EEG, regional differences are not taken into account as grid operators provide regional balancing. Regional balancing consists of two parts: transporting electricity from the vast northern sources to consumers located mainly in the south and using ‘smart’ regional balancing to avoid inefficient demands on the grid when a decentralized generation increases. A report from the Federal Network Agency suggests that the four transmission system operator (TSO) regions should be split into regional ‘cells’. These cells would provide and optimize their internal balance and communicate with the general systems grid distributor in times of remaining or intentional deficiencies or surpluses. (Lechtenböhmer and Luhmann, 2013)

5.2.2.3 Reserve/Balancing Power

This is an area that is mentioned several times in the literature. As mentioned in previous sections, one of the main problems with RES is the fluctuating feed-in. Pfeiffer (2010) argues that storage technology is one way of meeting differences in generation and consumption. Examples of electricity storage technologies are batteries, compressed-air reservoirs, pumped storage systems, and hydrogen systems. Talbot (2012) agrees that storage technologies need to be deployed at a larger scale but that today’s storage technologies are too expensive and the amount possible to store is not sufficient. Until large-scale, cheap storage is available, gas power plants, which can start up quickly and efficiently, will be the most practical way to cope with balancing fluctuating feed-in. Talbot (2012) also
mentions offshore wind power as a balancing power. It is Germany’s steadiest source of wind but the wind farms need to be installed far from the coast, which standard transmission lines are not adapted for, and the electricity, once at the coast, also needs to be transported all the way from the coast to the south of Germany, where most of the electricity-intensive companies are located.

5.2.2.4 Power Distribution

Distribution grid operators need to know about the actual grid load and be able to reshape it if it endangers grid stability. To provide grid operators with the information they need, demand side management (DSM) and demand response programs are crucial information and communication (ICT) applications. The main way of upgrading the distribution grid is to make the grid ‘smart’ by applying intelligent components, such as smart meters, and monitoring flows. Wissner (2011) describes two different strategies to implement demand response programs: price-based and incentive-based. Price-based programs make the electricity more expensive when there is a shortage and cheaper when there is easy availability. Consumers are expected to shift at least some of their demand from peak load to base load times, flattening the load curve. Incentive-based programs give the right to the grid operator to cut certain amounts of load. This can, depending on the design of the program, imply direct load control where suppliers or grid operators can directly access customers’ appliances or machines at short notice and drop load thereby. In Germany, such measures are mainly offered to major customers, not usually including households or small businesses. Both price and incentive-based programs need ICT to direct their measures. For price-based programs, smart meters are an essential element since they are able to communicate bi-directionally. One development for incentive-based programs is computer chips. They can be implemented in household devices to cut the devices off the grid when system stability is jeopardized. The chips notice frequency deviations and act automatically. As mentioned in the previous section, the possibility to communicate between both the supplier and consumer will be an important part of the future’s electricity grid.

5.2.2.5 Power Consumers

Today, domestic electricity customers are a passive group. It is important that consumers become active players through integrating into a comprehensive energy system based on ICT. Fouquet (2013) emphasizes that clear consumption reduction targets could be created and triggered through DSM. This would create a shift from today’s kWh selling attitude to an energy service orientation. Utilities have to shift from being pure producers of kW to becoming service providers. Regulators and lawmakers need to not only seek to increase the amount of energy supplied by renewable energy sources, but also create a clear vision to drastically reduce household energy use.

In a paper covering the ‘smart grid’ and ‘smart market,’ the Federal Network Agency abandoned the unilateral notion that the only possible suppliers of electricity are the traditional electricity producers. The agency instead introduced a new third party standing between consumers and producers, a so-
called ‘prosumer.’ As a prosumer, electricity-consuming agents supply their respective balancing capacities according to their capabilities of demand management or decentralized production. Large consumers may do this on their own while for smaller consumers, such as households, a specialized agent could control it. (Lechtenböhmer and Luhmann, 2013) Röhrkasten and Westphal (2012) also mention the change of consumers into ‘prosumers’ to play a more active role to balance demand and supply.

While Fouquet, Lechtenböhmer and Luhmann and Westphal are only emphasizing the importance of the consumers to become active players, Wissner goes one step further and describes a solution to make it reality. As described earlier, the mechanical meters mostly used today only provide a one-way communication. Consumers do not have any opportunity to see how much electricity they use and through that, minimize their usage. According to Wissner (2012) smart meters can use virtually all available transmission technologies (Internet, GPS, etc.) and allow information flow in two directions. By linking the smart meter to a computer, it will be possible to provide individual power use patterns to customers, and the customer can then evaluate the data, allowing him to use electricity more efficiently. This can be combined with the price-based programs mentioned earlier. Increased energy efficiency can be achieved by letting the customer see in real-time how much electricity he uses and combine that with the customer’s knowledge of a lower price during times of low load. Smart meters are able to store different tariffs that indicate high load or low load. It is also possible to implement new technology into smart meters so that customers know exactly which device consumes how much power at what time. In the long run this will make customers more aware of their electricity demand which will give them an incentive to buy more efficient electric appliances, which will lower the grid load in general.
6. Discussion

When looking at the first sub target of the EEG, 35 percent renewable electricity by 2020, and the current expansion of renewable energy sources (RES), it seems highly likely Germany will reach their first target by 2020, and also the succeeding ones leading to 80 percent renewable electricity by 2050. The likelihood of Germany managing to shut down their nuclear power plants by 2022 is also high. The success of the EEG so far is undisputable, at least when focusing on the expansion of RES. The greatest challenge now is not the expansion itself, but to handle the expansion so that the electricity grid can handle it and so consumers do not have to pay an unreasonable price.

The cost of paying for the EEG is not evenly distributed today. Consumers – mainly households – are not only paying an unfairly high electricity price because of the exemption for industries, but also because the falling wholesale prices tend to benefit industries more than consumers. The savings from decentralized feed-in are not passed onto consumers either. In order to succeed with the transformation, the whole society should be participating in paying for it. When such a big part of the industry is exempted from paying the surcharge, it raises the question of the aim of the transformation. How can Germany make a full commitment towards a future electricity generation based on RES when such an immense part of its economy is not participating? The main reason for the exemption for electricity-intensive industries is international competitiveness, but competitiveness is not part of the criteria to actually be exempted. The criteria to be exempted today are the company’s electricity consumption and the share of the company’s electricity costs as part of its gross value added. If international competitiveness truly is the main reason, it should also be a criterion and companies that do not compete on the international market should not be exempted. Since Germany is the first country undergoing such a monumental transformation of the electricity system, raising the prices of electricity for an industry heavily dependent on it can have devastating consequences. Some kind of exemption is most likely needed, but as it exists today, it misleads rather than improves.

What the EEG is missing today is incentives for balancing demand and supply, energy efficiency, and technology innovation. All these are important to make sure the expansion of RES is undertaken properly. The present EEG focuses too much on the amount of RES implemented and too little on the problems that come with it. As Lechtenböhmer and Luhmann (2013) mentions, there are four main technical challenges, among them how to implement RES without raising the need for balancing power to infeasible levels and the need of having decentralized balancing power. Virtual power plants are a viable option to solve both those challenges. The virtual power plant would balance power within itself and become a decentralized balancing power outwards, moving away from the need for conventional power plants. Forecast errors could also be dealt with within the virtual power plant. Since it would consist of several power plants put together, the pressure of the performance of the individual plant becomes less important.

The priority access RES have to the grid is an important part of the EEG, but insufficient forecasts lead to uncertainty for retailers over how much electricity
from RES they actually buy. Germany needs to focus more on upgrading the grid in order to improve the forecast issues. Upgrading the grid is not a question concerning only Germany. The German electricity grid is integrated with the European grid. This leads to the question of Germany’s relationship with the EU. What kind of obligations does Germany have to the EU when undertaking this transformation? The European policies say that the particular energy mix of the member states is a question of national sovereignty, but does the transformation over to renewable electricity require too vast upgrades of the grid to only concern Germany?

A main issue mentioned in the literature is the one of technological innovation. A rapidly changing market embracing the feed-in tariffs and heavily subsidized solar power, and a policy that lacks the dynamic efficiency necessary to change the tariffs fast enough might lead to technological innovation being neglected. The aim of the EEG to expand the share of RES instead led to too much focus on one kind of technology. A uniform subsidy might be a better way to go, at least until the efficiency of PV cells has been improved.

As Weber et.al (2012) and Talbot (2012) write, the current policy instrument is not focusing enough on energy efficiency and reducing energy use. It must be made a higher priority. Reduced electricity demand would make the transformation cheaper, easier, and faster. An interesting issue related to this is how to steer demand with information and communication technologies (ICT) as mentioned in the price-based and incentive-based programs. Both of these programs offer a risky way of dealing with energy efficiency. If suppliers or grid operators get the control to shut off appliances with short notice, how will that affect the customer? As mentioned, the present passive customer will turn into a prosumer. To let grid operators shut off appliances will take the power away from the customer. In today’s society, the power of consumers is in general heavily emphasized. Taking the power away from the customers to steer their electricity use themselves is taking a step back from the development of consumer power. Price-based programs on the other hand give the power to the consumers. The consumer will be able to see how much electricity he uses, how much it costs at different times of the day, and it will be clear how he can use electricity more efficiently. There might be a risk that this will not lead to a sufficient decrease in electricity use, and in that sense incentive-based programs would probably be a better option. The price-based program is most likely the one that is most easily implemented. Consumers know they have power and, by making them part of the transformation, Germany will have a greater chance of succeeding.

An issue of interest is if this kind of transformation is possible in other countries. As of now, the rest of the world is standing aside watching to see if Germany will succeed or fail. If Germany succeeds, the pressure on other developed countries to implement similar changes will become much higher. For developing countries, economic growth is still very important, and a majority of those countries are heavily populated. Germany is a big country with vast amounts of land with room for, for example, on-shore wind farms or solar power plants. There is a great risk that a transition over to RES for a developing country would be too expensive and that the electricity supply would not be sufficient due to lack of land. So, even if Germany succeeds, what about the rest of the world?
What possibilities do developing countries have to do the same transformation, and what responsibilities do developed countries have? As of today Germany has reached a point where technical issues are larger than the policy issue of increasing the amount of RES in electricity generation. More research is needed to make ICT and virtual power plants a reality. Outside of Germany more resources are needed to get the implementation of RES started. So far global agreements, such as the Kyoto protocol, have failed to result in essential actions. For the global community to be able to fight climate change and other urgent environmental issues, more countries need to take the responsibility Germany is taking today.
7. Conclusions

• Germany has so far succeeded in the expansion of RES. The EEG is considered a successful policy instrument but what it is missing today is incentives for balancing demand and supply, energy efficiency, and technology innovation.

• The main issue is thus how to move on from where Germany stands today. Upgrading the electricity grid to match a future demand and supply of RES and controlling the expansion and the policy instrument so that the cost of the transformation does not become uncontrollable will be the next challenges for Germany.

• In order to succeed with the Energiewende, the whole society should be participating in paying for it. The electricity intensive industries need to assume a larger part of the surcharges.

• The main focus when upgrading the grid should be to improve the forecasting issues. Using virtual power plants can also be of use when improving forecasts, but more research is needed to make ICT and virtual power plants a reality.

• Energy efficiency and electricity use are other issues that need to be given higher priority. When comparing price-based and incentive-based programs, there might be a risk that the price-based program won’t lead to a sufficient decrease in electricity use. In that sense, incentive-based programs would probably be a better option.

• Overall, Germany will most likely succeed with the transformation of the electricity system. They are well on their way already and by meeting challenges in the same way they have in the past, the sub targets and final target will be reached. The success of making RES a significant part in electricity generation could become strong proof for the global community that an electricity system based on RES is possible.
8. References


