Chapter 10
Germany's Transition Toward an Energy System Based on Renewable Resources: An Overview

Philip Mayrhofer and Benedikt Römer

The transition toward an energy system based on renewable resources is a transnational challenge that requires coordinated policies among governments. As a consequence, it is one of the European Union's (EU's) major objectives to bring forward directives that lead to an efficient internal market for electricity. This market is supposed to ensure security of power supply and consumer benefits based on increasing competition between energy utilities. Germany plays an important role in this development because of its geographic location at the center of Europe, its economic capacity, and its political influence. The German government has expressed in different position papers, initiatives, and legislative measures that there is a strong political will to be a forerunner in the global transition to a system based on renewable energy sources. A Smart Grid infrastructure is an integral part of this future energy system. And even though, for example, smart meter roll-out is more advanced in other countries (e.g. Italy and Sweden), Germany is being observed with regard to an integrated, long-term approach to Smart Grids.

In the following chapter, we provide an overview of the current state in Germany's transition of its energy system. For this purpose, we proceed in two steps. First, we describe the German electricity market. We focus on the generation and consumption of electricity as well as the mechanisms by which electricity is traded. Since the power sector has a long history of state control and influence, the regulatory framework in which the transition happens is also depicted. Here we introduce the directives on EU level that lead to the unbundling of the value chain as well as legislation that incentivizes the production of electricity from renewable resources. Information and communication technology (ICT) is the basis for the implementation of the next generation electricity infrastructure. As a consequence, we close this section on regulatory aspects with an excursus on the current state of broadband penetration in Germany and what objectives are pursued by public programs.

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Germany's transition toward a next generation electricity infrastructure, i.e. a Smart Grid, is the focus of the second part of this chapter. Here we outline the necessity of a Smart Grid in Germany based on the previous description of the energy market. After that we describe the beacon project "E-Energy: Smart Grids made in Germany." It is an example for the public support that the German industry and academic institutions receive in their efforts to develop the energy system of the future. Three years into the pilot projects, it is possible to derive first results. Furthermore, the program has sparked several educational initiatives that ensure that graduates from Germany's universities come well prepared to tackle the challenges of the global transition to a Smart Grid-based energy system with electricity from renewable resources.

Transition to Renewable Energy Sources: A Brief Introduction to Germany's Energy Market

In the following, we give an overview of the German power market by describing the supply side as well as the demand side of electricity. Furthermore, we describe how electricity is traded and how prices for end-consumers are composed. We also introduce some of the legal and regulatory framework which governs the electricity sector and influences its transformation toward a renewable energy system.

Power Supply—Germany's Electricity Generation

In 1992, Germany generated a total of 538.2 TWh of electricity. The German power supply was mainly based on fossil fuels and nuclear energy: fossil fuels accounted for 63.7 %, with coal providing the biggest part of the power generation (55.1 %). The remaining 36.3 % were mainly provided using nuclear energy (30 %), followed by oil and gas (8 %) and hydro power (4 %). Figure 10.1 shows that other forms of renewable energies than hydro power had no significant role in power generation (AGEB 2012).

Since 1992, the structure of power generation has massively changed in Germany. Renewable energies have been promoted by the federal government (see below for a description). This led to an unprecedented growth of all forms of renewable energies. The share of renewable power generation (see Fig. 10.2) increased within 20 years from 3.6 % in 1992 to 19.9 % in 2011 (AGEB 2012).

In 2011, Germany generated a total of 614.5 TWh of electricity; 76.3 TWh or 14.2 % more than that in 1992. Even though fossil fuels and nuclear energy still play an important role in the German power supply, their contribution decreased both in absolute and relative numbers (see Fig. 10.3). Fossil fuels accounted for 58.3 % in

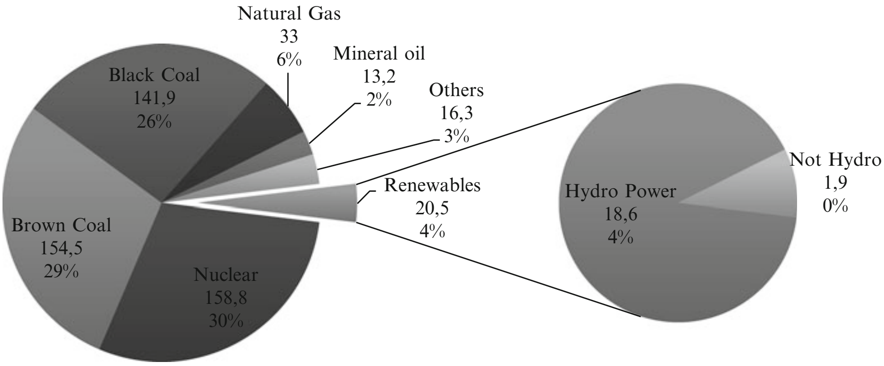

Fig. 10.1 Gross power generation in Germany in 1992 in TWh (Based on AGEB 2012)

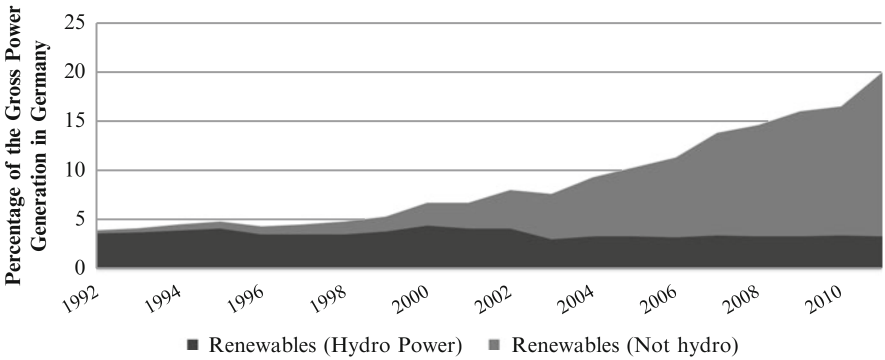

Fig. 10.2 Growth of renewables in Germany since 1992 (Based on AGEB 2012)

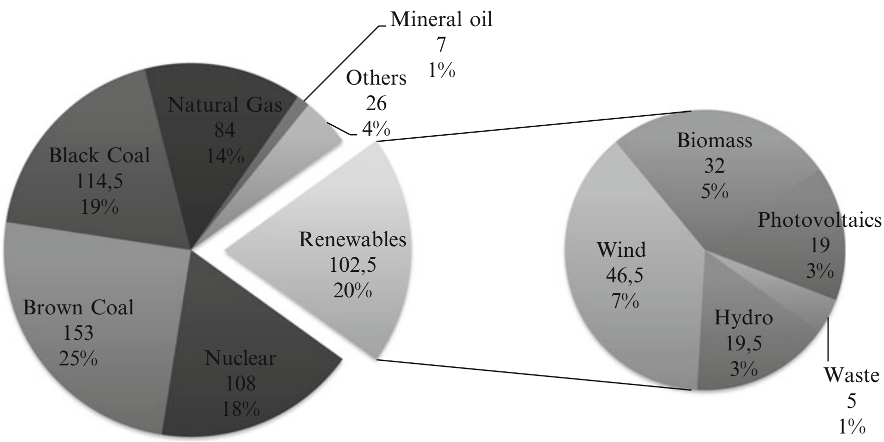

Fig. 10.3 Gross power generation in Germany in 2011 in TWh (Based on AGEB 2012)

2011, with coal still providing the biggest part of the power generation (43.5 %). The use of nuclear energy shrunk to 108 TWh or 18 % of the power supply and thus accounts now for less than renewable energies. Within the renewable energies, the generation from hydro remained approximately the same in absolute values, accounting today for only 16 % of all renewables. Wind power has the biggest share in renewable electricity generation with 38.1 %, followed by biomass (26.3 %). Photovoltaics account for 16 % of the renewables, but showing the steepest growth in recent years. The remaining part is generated by biological waste combustion (AGEB 2012).

Besides the distribution of power generation by energy source, it is important to consider the fact that power generation is not equally distributed over diverse regions in Germany. This is especially true for the renewable energy sources of wind and photovoltaics. In general, most of the photovoltaic electricity is generated in the South, whereas the biggest amount of wind energy plants is situated in the North. This imbalance will even grow further over the coming years due to an increasing use of offshore wind power plants in the North Sea and the Baltic Sea.

The goals of Germany's federal government can serve as indicators for future developments: by 2020, the contribution of renewable energies to Germany's power consumption is planned to reach at least 35 %, growing further to meet the goal of at least 80 % in 2050 (BMWiBMU 2010). Even more important in the short term is the German nuclear phase-out which has been decided after the Fukushima catastrophe in 2011. By 2022, all nuclear power plants are legally forced to shut down (BMU 2011). Thus, around 18 % of the current production has to be replaced within the next 10 years.

Power Demand—Germany's Electricity Consumption

In 2011, Germany had a gross power consumption of 608.5 TWh. This means that it generated slightly more than its consumption, which led to higher power exports (56 TWh) than imports (50 TWh) (AGEB 2012). For the last 9 years, net power exports have been positive. Germany's final electricity consumption per capita lies 11 % over the average of the European Union (Eurostat 2011).

A reason for the relatively high electricity consumption in Germany may be its large industry sector (see Fig. 10.4). It accounts for 42.4 % of the total electricity consumption. Households account for 27.3 % and Services for 27.1 % of the electricity consumption. The remaining 3.2 % are consumed by transportation, that is, mainly rail traffic (AGEB 2011). As electric mobility is planned to play a bigger role in Germany (the federal government has set the goal of one million electric cars by 2020), this last part is likely to grow within the coming years (Bundesregierung 2010).

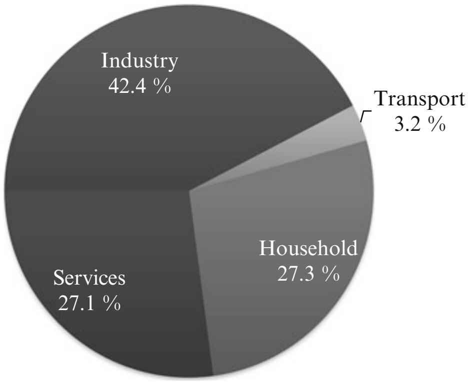

Fig. 10.4 Overview of power consumption in Germany (Based on AGEB 2011)

Electricity Trading and Markets in Germany

Electricity is traded differently in wholesale and retail markets. In the first part, we will describe wholesale electricity trading in Germany before looking at retail trading.

Germany has a liberalized electricity market (see discussion below), which means that electricity customers can freely choose their provider and they can choose from a wide variety of products with diverse pricing conditions and durations. These products are simplified described in the following. All products are either traded over the power exchange (European Energy Exchange, EEX) or in bilateral deals (over-the-counter). Electricity is traded short term on the spot market or middle to long term on the futures and options market.

On the spot market, single-hour contracts and block contracts are traded day ahead. Block contracts are divided into baseload and peakload. Baseload blocks run 24 h of day, whereas peakload signifies a block of certain hours that are characterized by, on average, a high demand for electricity (8 A.M. to 8 P.M. weekdays).

Futures and options are traded to hedge against price risks. These products are standardized regarding their contract volume (electric work), load (base/peak/off-peak), delivery period, and securities. Delivery places are the control areas of the four German transmission system operators (Panos 2009).

These products are used for wholesale trading. Electricity prices are usually given in €/MWh and the average price in recent years lies around 50 €/MWh. However, there are significant price fluctuations, with the yearly average for the peak/off-peak price spread lying between 10.93 and 27.34 €/MWh (e.g. in years 2004–2009) (Genoese et al. 2010a, b). In the past, the price floor was 0 €/MWh. However, since power generation from renewables that are difficult to control and predict (solar and wind) has reached high installed volumes (see electricity generation section), new extreme situations sometimes lead to negative electricity prices. Such situations have occurred in times with either a low system load (usually in times of holiday) with having at the same time at least an average wind feed-in or in times of high wind generation and only moderate system load. On October 4, 2009 (German unification day, thus a bank holiday), the spot market price went even down to minus 500.2 €/MWh (Genoese et al. 2010a, b).

Flexible and very fluctuating prices are usual in the wholesale market, whereas a view on the retail market provides a completely different picture. Nearly all households in Germany still have a conventional electricity meter, which measures the electric load and is read out manually once a year. This is the reason why private households still have fixed-price contracts. An average three-person sample household pays in around 25 €-cent/kWh. However, around 46 % of this price accounts for taxes (23 %) and further duties (23 %), BDEW (2011) which result mainly from apportionments from public programs to support the production of renewable (see next section). This shows that due to the liberalized market, households are free to choose their electricity provider. However, even though a variety of products and tariffs are offered (e.g. differentiated by the ratio of renewable used to generate the electricity), only few vary by time or load as the lack of smart meters does not allow for these. With upcoming smart metering technology, this situation may change (Flath et al. 2012).

Regulatory Framework

The following section aims at complementing the earlier overview of the German electricity market by an introduction to Germany's regulatory framework. We first focus on the legal framework of the liberalization and deregulation of the European and German electricity sector. Second, we describe the legal basis for incentivizing the generation of electricity from renewable energy sources. In addition, we provide a brief overview of the state of as well as public objectives for broadband penetration in Germany. The latter is of importance for the implementation of a "Smart Grid infrastructure," which will be discussed in the second part of this chapter.

Liberalization: "Unbundling" of the Incumbent Monopolists

One of the European Union's priority objectives is the creation of an internal market for energy, namely for electricity and gas (EU 2012). In order to achieve this, a set of directives have been issued that aim at introducing common rules for the sector and that establish service obligations and consumer rights. An important requirement was to introduce competition to the national, monopolistic industries.

Just as almost everywhere in Europe and the world, the electricity sector in Germany until the late 1990s was a non-competitive market. It consisted of vertically integrated geographic monopolies: the primary components of the electricity supply chain—generation, transmission, distribution, and retail supply—were integrated within individual electric utilities. While generation and transmission was controlled by few, state-owned utility companies, distribution and retail supply was primarily organized in smaller, regional, and local public suppliers (predominantly the so-called Stadtwerke).

In the course of liberalization, legislators had to consider the natural monopolies that exist on the level of the transmission and distribution networks for electricity. Long-haul transportation (Transmission System Operation) and distribution of electricity on the "last mile" (Distribution System Operation) is based on an infrastructure for which it is more cost-effective to not have several power lines maintained in parallel. As a consequence, the former monopolistic incumbents were forced to disintegrate or "unbundle" their operations. In several steps, these large, regional utilities (today: RWE, E.ON, Vattenfall, und EnBW) had to separate the transportation and distribution business on account, functional, legal, and finally ownership level from their electricity production and retail units. The latter steps of the value chain were then opened to new entrants who were able to produce electricity or to build new consumer-facing retail brands. Thus, the incumbents encountered competition on these steps. The legal framework in the European Union (EU) and the respective implementation in Germany is described in the following.

The legal framework for the implementation and regulation of a competitive internal market for energy in the European Union (EU) is provided on EU level by the respective directives for electricity (1996) and gas (1998). In 2003, these directives were augmented by a so-called acceleration directive that abolished many discretionary options by introduced binding requirements for competitive markets in all member states. In Germany, the EU directives were implemented in national legislation in the form of the "Energiewirtschaftsgesetz" (EnWG) in 1998 and adapted in July 2005 (BMWi 2005).

The main governing entity regarding the adherence to the directives and German legislation is the Federal Network Agency, headquartered in Bonn (BNetzA 2012).[1] In addition, there exist regulatory authorities on regional level which are responsible for utilities with less than 100,000 consumers in their network and which networks reside in only one state.[2] The Federal Network Agency's task is to ensure the liberalization and deregulation process of the electricity, gas, telecommunications, postal, and railway infrastructure markets. For the purpose of implementing the aims of regulation, the Agency has effective procedures and instruments at its disposal. These include rights of information and investigation as well as the right to impose graded sanctions. In the electricity market, its objective is to guarantee non-discriminatory network access and efficient network usage charges. Here activities include among others: (1) the authorization and setting of network charges for electricity, (2) monitoring the unbundling of the incumbent utilities, (3) the improvement of conditions of access to the power network, and (4) monitoring of abusive practices.

One of the most important elements of ensuring competition in the energy markets refers to the access to the transmission and distribution network. Only a non-discriminating access to these networks provides new entrants in the renewable energy sector with the basis for operation. The EU directive of 1996 allowed its member states to decide between a negotiated and a regulated access to the electricity networks. Here, Germany took a different route than all other EU member states by

[1] The Federal Network Agency (in German: Bundesnetzagentur für Elektrizität, Gas, Telekommunikation, Post und Eisenbahn (BNetzA)) is a separate higher federal authority within the scope of business of the German Federal Ministry of Economics and Technology (BMWi).

[2] For example, the Bavarian Regulatory Authority is responsible for these smaller utilities within the state of Bavaria. See Bavarian Regulatory Authority (2012).

being the only state to opt for a negotiated access. The installment of the EnWG in 1998 at first allowed the network operating utilities to self-monitor the industry and to allow third parties access to the network. With the EU's accelerating directive in 2003, this option was taken away and Germany now also has installed a system of regulated network access which is enforced by the Federal Network Agency.

The regulated operators of the transmission networks need to be compensated for allowing third parties' access to their networks. Since 2009, these network access charges are defined ex ante for a period of five years by the Federal Network Agency. This incentive regulation system[3] calculates a revenue cap for network operators and is based on cost data which the operators regularly have to submit. Individual cost structures are compared to other operators and efficiency goals are implemented. The objective of the revenue caps is to incentivize operators to implement cost cutting programs based on technological innovations or more efficient use of resources. Also lower network access charges ultimately lead to lower consumer prices of electricity. However, this form of regulation bares the risk of underinvestment in infrastructure. As a consequence, the Federal Network Agency is also regulating network quality and is able to impose fines in case that network reliability decreases.

Incentivizing the Generation of Electricity from Renewable Energy Sources

Germany has a long history of incentivizing the integration of renewable energy sources in the energy system. Already in 1991, a notably brief act[4] established that producers of power from renewable sources were offered a certain percentage of the residential electricity price.[5] Furthermore, utilities were obligated to grant access to the electricity grid in the regions in which the power was produced. In the following years, electricity from renewable energy sources grew steadily.

In order to put that development on broader basis and to comply with EU directives, the law underwent major restructuring in the year 2000. The Renewable Energy Sources Act[6] specified the legal framework in which feed-in tariffs were enforced. Its guiding principles were guaranteed grid access, purchase guarantees for a period of 20 years, and purchase prices that are methodologically based on the cost of generation and decline annually based on expected cost reductions.[7] Jacobsson and Lauber (2006) provide a detailed analysis of the policy and point out

[3] The legal basis is based on the Anreizregulierungsverordnung (ARegV 2012).

[4] The first Electricity Feed Act ("Stromeinspeisungsgesetz") consisted only of three paragraphs. See the references for a link to an archived version (in German).

[5] For solar and wind power the percentage was set at 90 %, for other sources such as biomass and hydro 75 % of the residential price had to be paid.

[6] Also known as the "Act on Granting Priority to Renewable Energy Sources." In German, it is called the "ErneuerbareEnergien Gesetz (EEG)." A link to the English translation of the law that passed the German Bundestag on February 25, 2000, can be found in the references. See EEG (2000).

[7] See de Jager and Rathmann (2008) for an international comparison and details on the characteristics of the German implementation of feed-in tariffs.

the remarkable impact of the law with regard to the diffusion of different renewable energy technologies. In the following, Germany became an example and role model for the establishment of feed-in tariffs which are now implemented in more than 50 states (European Commission 2008). Germany's history as a reliable legal environment in this field contributes to a favorable assessment by the international investment community. Together with Australia, China, and France, Germany is considered having a low risk profile for climate change investments (Deutsche Bank 2006).

The Renewable Energy Sources Act has been adapted to technological change and international treaties in different iterations. The most recent amendment went into effect on January 1, 2012.[8] It continues to incentivize the production of energy from renewable resources, but stresses the need to become more cost-efficient. It also emphasizes the need of additional market and network integration which becomes more crucial with an increasing share of dynamic power sources in the system. Finally, it includes the precise targets for renewable energy sources which have been formulated in 2010 in a major guideline for Germany's energy policy: renewable energy sources shall contribute at least 35 % to the energy consumption by 2020; furthermore, their contribution shall increase to 50 % in 2030, 65 % in 2040, and 80 % in 2050.

Besides these public programs and regulation regarding competition and production of electricity in the energy market, another aspect requires attention. In order to enable the interaction between various actors as well as dynamically changing producers and consumers of electricity, an information and communication technology (ICT) infrastructure needs to be build that mirrors the overall electricity system. In this context, broadband penetration plays an important role and is described in the following section.

Broadband Penetration in Germany: Current Status and Public Objectives

In its position paper on Germany's ICT strategy "Digital Germany 2015" (BMWi 2010), the government has recognized the importance of broadband networks for the transition toward a Smart Grid. This future power system relies on the exchange of information regarding the supply from dynamically changing power sources as well as on information from the distributed power consumers. The information is exchanged via ICT which is based on data networks. As a consequence, a facilitating component of the transition to a renewable power system is the level of broadband availability. In this section, we describe the current status of broadband penetration in Germany as well as public objectives in this field.

The German government has long put an emphasis on providing nationwide access to broadband networks (BMWi 2009). Fig. 10.5 shows the current state of broadband

[8] A link to the amendment of 2011 can be found in the references (EEG 2011). Previous amendments were enacted in 2004 and 2009.

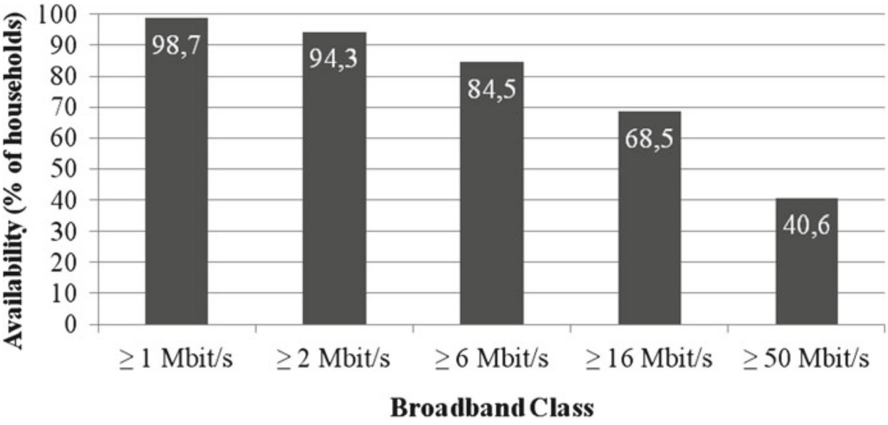

Fig. 10.5 Broadband availability in Germany (BMWi Breitbandatlas 2011)

penetration in Germany (as of 2011).[9] Currently, 26 million German households (i.e. more than 68 % of households) use high-speed broadband connections with more than 16 Mbit/s. These are provided by different fixed-line (DSL, cable) or wireless technologies (3G GSM, Wifi, LTE, satellite, etc.). Relatively fast connections of at least 1 Mbit/s are available for almost all households in Germany. This means that currently around 600,000 households are not connected to high-speed Internet networks.

For the near-term future, the German government set ambitious targets. By 2014, connections with more than 50 Mbit/s shall be available for at least 75 % of German households. Important pillars of the government's strategy to reach these targets are formulated in its document on broadband strategy (BMWi 2009). These include a series of measures in the fields of capitalizing on synergies in the construction of infrastructure, the guarantee of supportive frequency policies, a commitment to growth and innovation-geared regulation, and appropriate financial support.[10]

Transition to Smart Grid Infrastructure—The Case of Germany

The first part of this chapter focused on the power market, the ongoing growth of renewable energies in Germany, and connected direct implications. In the second part, it is described how this change leads to the need for an even wider transformation of the German infrastructure and how the German political support around this transition is organized.

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[9] The data are based on the most recent report (in 2011) by the Federal Ministry of Economics and Technology (BMWi). The so-called "Breitbandatlas" provides a regular monitor of the current state of broadband penetration in Germany and its regions.

[10] Detailed information is available at a dedicated website: www.zukunft-breitband.de/ (last accessed: May 1, 2012).

Necessity for a Smart Grid

In the past, electricity in Germany was mainly generated in conventional coal, gas, or nuclear power plants (Nitsch 2008). Due to the controllability of these power plants, it was possible to react to the fluctuating demand by adjusting generated power and thus to balance demand and supply (Steger et al. 2009). Storing electricity was only needed to a small extent. Thus, today, all German pumped hydro plants, as the most important storage technology, provide in total the power of 7 MW and a capacity of 0.04 TWh (SRU 2010), compared to 614.5 TWh of yearly total generation of electricity. As described in the introduction to the German power market, generation from renewable energy sources, especially wind and solar, is growing rapidly and is predicted to reach large shares of German power production. The feed-in characteristics of wind and solar energy differ significantly from those of conventional power plants. On the one hand, generation of renewables is depended on environmental factors, thus, unsteady and often peaks in different times than demand. On the other hand, power of wind and solar energy is not controllable. The conventional approach of adjusting supply to demand increasingly loses its effectiveness. This can lead to decreasing security of supply. Possible outcomes range from malfunctioning devices to blackouts in the worst case (Bünger et al. 2009). To tackle this challenge, diverse concepts are in development. Besides the requirement to expand the existing electricity grid (by more than 3600 km for the high voltage grid alone) (dena 2010) and the capacity of electricity storage by a multiple (Economist 2011), the approach of a Smart Grid is seen as particularly promising. Smart Grid refers to an electricity grid, which is enhanced by ICT and thus enables to adjust demand to fluctuating supply in near to real time (E-Energy 2012).

Political Support for a Smart Grid Infrastructure: E-Energy—Smart Grids Made in Germany

Smart Grid is a novel context. It is seen as an important way to integrate renewable energies and various countries apply different approaches to foster research on an implementation of Smart Grid technologies. This section focuses on the German approach. As Smart Grid is a topic touching many different industries, public programs can facilitate large scale pilot projects, which are important to involve and connect key players. In addition, such programs enhance public visibility of the topic and bring it to a broader audience, including researchers and entrepreneurs. This provides a powerful leverage to the initial investment. In the following pages, the German initiative E-Energy is introduced and its goals, progress, and first results described.

The three major goals of German energy policy are economic efficiency, security of supply, and compliance with environmental standards. These are especially challenging

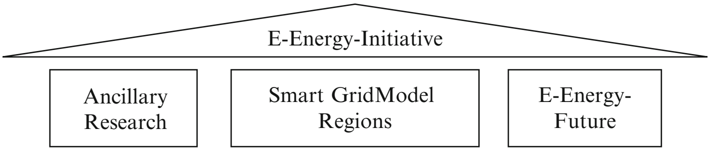

Fig. 10.6 Overview of German research initiative E-Energy

as Germany faces the situation of growing demand, scarcity of raw materials, and climate change at the same time. Consequently, Germany's main objective is to ensure reliable supply of electricity at reasonable cost for the society. However, its energy policy also aims at supporting innovation and economic growth. For this Germany is forming a spearheading role in research, development, and implementation of technologies for a Smart Grid. With an increased international competitiveness in this key industry, Germany, as an export nation, expects to generate positive effects on national employment and ultimately overall economic wealth. The occasionally used expression "internet of energy" for the concept of a Smart Grid expresses the hope for an even stronger impetus for new entrepreneurial activities and a strong positive impact on the economy (BMWiBMU 2012).

The Funding Program

The above described public policy goals are facilitated with the research initiative "EEnergy—ICTbased energy system of the future." This initiative is a "beacon project" of the Federal Ministry of Economics and Technology (BMWi) in interministerial partnership with the Federal Ministry of the Environment, Nature Conservation and Reactor Safety (BMU). Its goal is to support research that focuses on the reduction of electricity consumption by using energy more efficiently. At the same time, it focuses on the integration of renewable energies in the future electricity grid. This challenge shall be tackled with the help of innovative ICT systems. The initiative E-Energy consists of three pillars: Smart Grid model regions, as the core of the program, ancillary research, and a part named E-Energy Future (see Fig. 10.6).

The first pillar consists of six *model regions*, which are operated by partners from industry and academia since 2008 and after winning a public competition. In these regions, ICT systems for the support of the energy sector are developed and tested. These projects include research on smart metering, demand side management, storage devices, IT security and data protection, and decentralized electricity generation. They are also connected to research projects on electric mobility which have launched subsequently. Besides these model regions, which are focused on the technical application, the *ancillary research* team works on accompanying questions: how can effective global architectures be designed, how are business models of Smart Grid stakeholders changing, how should the legal and regulatory framework look like, and how can open questions about data protection, security, and standardization be solved? The third pillar consists of two projects developing *future scenarios*, new business ideas, and education. Overall finance for this initiative amounts to around EUR 140 million, with a contribution of EUR 40 million by BMWi, EUR 20 million by BMU, and the remainder by the participating industry (E-Energy 2012).

Preliminary Results

Although the E-Energy initiative is running until the beginning of 2013, parts of the preliminary findings are described in the following.

In the commercial sector, up to 20 % possible energy savings are realized by the use of ICT; for households, there is less potential (5–10 %). Load shifting potential in the private sector is estimated at around 10 %—mainly through heat pumps and air conditioners. In the commercial sector, load shifting potential is seen to be significantly higher. First tests showed that grid stabilization can be supported by ICT control of generation and localized purchase of reactive power. Furthermore, ICT supports the integration of decentralized, small producers and decreases the need for extensive grid expansion. In order to facilitate such systems, sensors are needed which measure grid characteristics as well as production and consumption at the grid margin. Security of supply can be enhanced through improved forecasting and decentralized cellular approaches. By the use of new ICT systems, an improved balance of supply and demand can be achieved for distribution grids at balance group level, while transportation of wind power surpluses remains a difficult problem for the transmission grid. Besides these stabilization enhancements, technology developed in the model regions can help market participants to optimize business operations. It could be shown that time-variable rates for electricity implemented in the projects induce initial changes in consumer behavior, while sustainable changes have to be supported by automated systems. The integration of an increasing number of smaller production units may lead to completely new market functions, such as flexibility operators, that ensure non-discriminatory market access for small suppliers and aggregate energy outputs or flexibilities to marketable units for electricity trading or grid operation (BMWiBMU 2012).

Program Spillovers in Education

To be able to meet the new challenges, changes in the educational facilities are also needed. More than in the past, ICT system developers will have to address the rapidly changing energy market. Their greatest challenges will be secure data management systems and service platforms in compliance with data protection provisions. New occupational profiles will also emerge at the interface between energy and information technologies. Of particular importance here is therefore mainstreaming the issue in the scientific and training community.

In the project promoted by the Federal Economics Ministry, Mediabased Learning and Collaboration Services for Electromobility (MEMO), experts develop material for multimedia basic and advanced training of craftsmen based on the grid integration of electric vehicles. The experience gained can be transferred to other fields in energy supply (MEMO 2012). Integrated in the E-Energy initiative, the Center for Digital Technology & Management (CDTM) of the Ludwig-Maximilians-University, Munich, and the Technical University of Munich brings students from various backgrounds together to work in interdisciplinary teams on problems and questions in the field of Smart Grid. The aim is to provide students with technical know-how about future smart energy systems as well as necessary methodological tools (such as scenario analysis, business planning, or user need studies). This knowledge is applied in several projects and qualifies them to shape and support the transition to a future Smart Grid. As part of this project, researchers together with students have developed far-reaching future scenarios, business concepts, and working prototypes. Some of the results have also been transferred to practice by graduates who subsequently founded companies in the field (CDTM 2012).

Summary

This article provides an overview of the current state in Germany's transition of its energy system to a renewable energy system. It is structured into two parts. First, Germany's changing electricity market with growing influence of renewables is described. Here the focus lies on generation and consumption of electricity as well as trading mechanisms and the regulatory framework. Second, Germany's efforts to implement a Smart Grid—an ICT-supported electricity system for an integration of renewables—are described. The focus lies on the necessity of a Smart Grid in Germany and public support for the industry and academia in the form of the research project E-Energy. In addition, first results of the E-Energy project and program spillovers in education are depicted.

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