UNIVERSITEIT TWENTE.

Twente Centre for Studies in Technology and Sustainable Development

Energy Transition in Germany until 2040

What are Germany's energy options to compensate for the nuclear phase-out in 2022?

by

Dorian Luh

Bachelor Thesis

Executed from 22.04.2014 to 04.07.2014

Supervisor: Dr. Maarten J. Arentsen

External member: Dr. Ir. F. J. Dijksterhuis

In 2010 the federal government enacted an energy concept

for the upcoming decades in Germany.

For a long time it was foreseeable that the energy mix has to change

if Germany wants to achieve its ambitious aims.

Especially the postulated CO_2 reduction brings huge defiances with it.

To accomplish the goals, the shift tends towards

sustainable energy carriers and natural gas.

Table of Content

List of abbreviation

BMWi – Federal Ministry of Economic Affairs and Energy

BTCE – Billion tons coal equivalent

COE – Consumption of electricity

EC – European Commission

EEG – Erneuerbare-Energien-Gesetz (freely translated: Renewable-Energy-Law)

EU – European Union

GDP – Gross domestic product

IEA – International Energy Agency

KgCE – Kilogram coal equivalent

MTCE – Million tons coal equivalent

PEC – Primary energy consumption

TCE – Tons coal equivalent

TCU – Tons coal unit

TWh – Terrawatt-Hours

1. Introduction

The current discussion on the electricity-tariff-development makes it clear: The energy transition has far-reaching effects in Germany. In June 2011, the German government determined the abandoning of nuclear energy until 2022. Unchanged to this alteration are the demands by the government for a safe, economic and environmental energy supply for Germany.

Germany is especially governing the development in sustainable energies. They are supposed to counteract the missing nuclear energy by 2022 and to replace more and more of the energy carrier coal, which has a high CO_2 emission. The rising problem concerning the usage of just sustainable energies, such as wind and solar, is the fluctuating energy production due to weather conditions. Furthermore storage technologies are being developed, but do not provide an economic realizable solution so far.

Nonetheless, the future development in sustainable energies plays a major role on the energy market. To provide a long-term stable solution it needs a strong partner, who fits the demands by the German government. A promising partner is low CO_2 emissive natural gas. It is necessary to compensate the high fluctuation rate in Germany by sustainable energy carriers.

The German electricity market consists of an oligopoly, which is dominated by 4 companies – RWE, E.ON, EnBW and Vattenfall – who are responsible for 90% of the power generation [1]. Up to now 120,000 people are working in the electricity industrial sector in Germany. As the German Federal Government Department for economy and technology states, energy has to be safe, clean and especially affordable. Therefore the Federal Government provided 3.5 billion Euros for the advancement and research in the field of modern energy technologies from 2011 until 2014 [2].

The phase-out of nuclear energy will leave a lack of 19 GW, which has to be compensated for by renewable energies and conventional power plants.

The time needed for building a new conventional power plant from planning until it can go onto the grid takes around 10 years. Therefore the analysis will take place until 2040.

In my Bachelor thesis I will research Germany's energy options for the nuclear phase out in 2022. The foreseen transition in the next decades to a mix of renewables and potential conventional power plant partners has to fulfill several German political targets:

- security of supply

- economic feasibility

- climate protection

Furthermore Germany has to be seen in a European context to understand the electricity relations and influences from an EU perspective view. Doing so, I will clarify and emphasize the key factors in energy transition.

2. External Preconditions for Germany

My Bachelor Thesis is based on the following framework requirements and determining factors for the evolving economic changes in Germany:

2.1 Gross Domestic Product

The average increase of the gross domestic product (GDP) was at 0.9% in 2012. In the intermediate term a gain of 1.5% is prognosticated, which will slowly evolve back below 1% by the end of the forecasting horizon. It totaled to 2.468 billion Euros in 2012. This trend is closely related to the German population, which will be treated in the next sub chapter. The related table with the corresponding numbers is shown in figure 1 [3].

2.2 Population

In the predicted period the population in Germany will drop from 82 million to 77 million inhabitants. The life expectancy rises, while the birth rate drops drastically. This drop will be partially compensated by immigration. By 2040 the residents below an age of 18 will decline to 11 million (see figure 2).

Gross domestic product

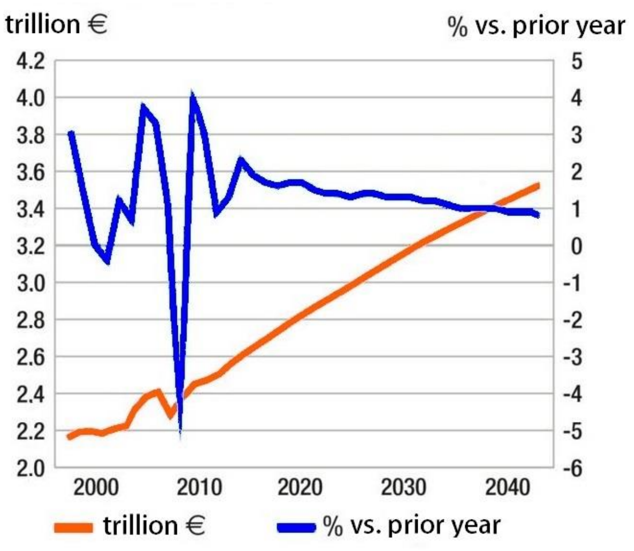


Figure 1

Population

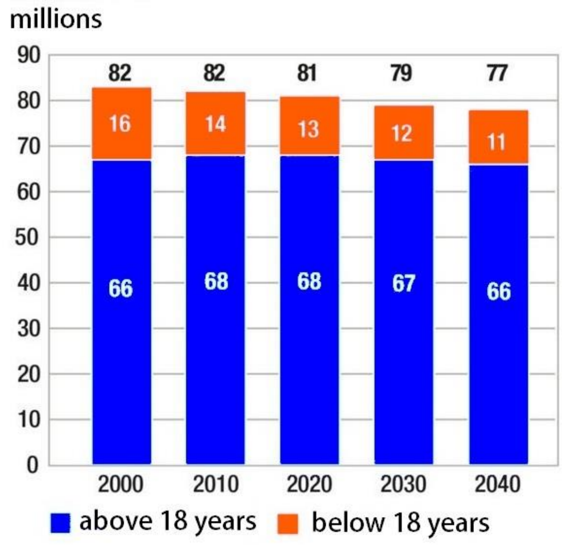


Figure 2

2.3 Primary Energy Consumption

According to economic literature Germany will be needing less energy in the future. It is stated that from 2012 until 2040 the primary energy consumption[1] (PEC) will reduce by one quarter. The raised awareness regarding the handling, more efficient technologies and a slower economic growth will provide a high retrenchment. The share of different energy carriers for the energy mix will change drastically. In the following, the total PEC and the sustainable energy PEC for Germany will be prognosticated until 2040.

The share of natural gas for the PEC rises from 101 million TCU[2] in 2012 to 116 million tons at the end of the prognosticated era. In 2030 natural gas will replace mineral oil as energy carrier number 1. It is not only sufficiently enough available and flexible usable, but also the fossil energy carrier with the lowest CO_2 content. This is the biggest concern for coal, which counteracts the accomplishment of the climate protection until 2040, leading to a rapid decrease. Its share lowers from 113 to 48 million TCU.

Primary Energy Consumption Total

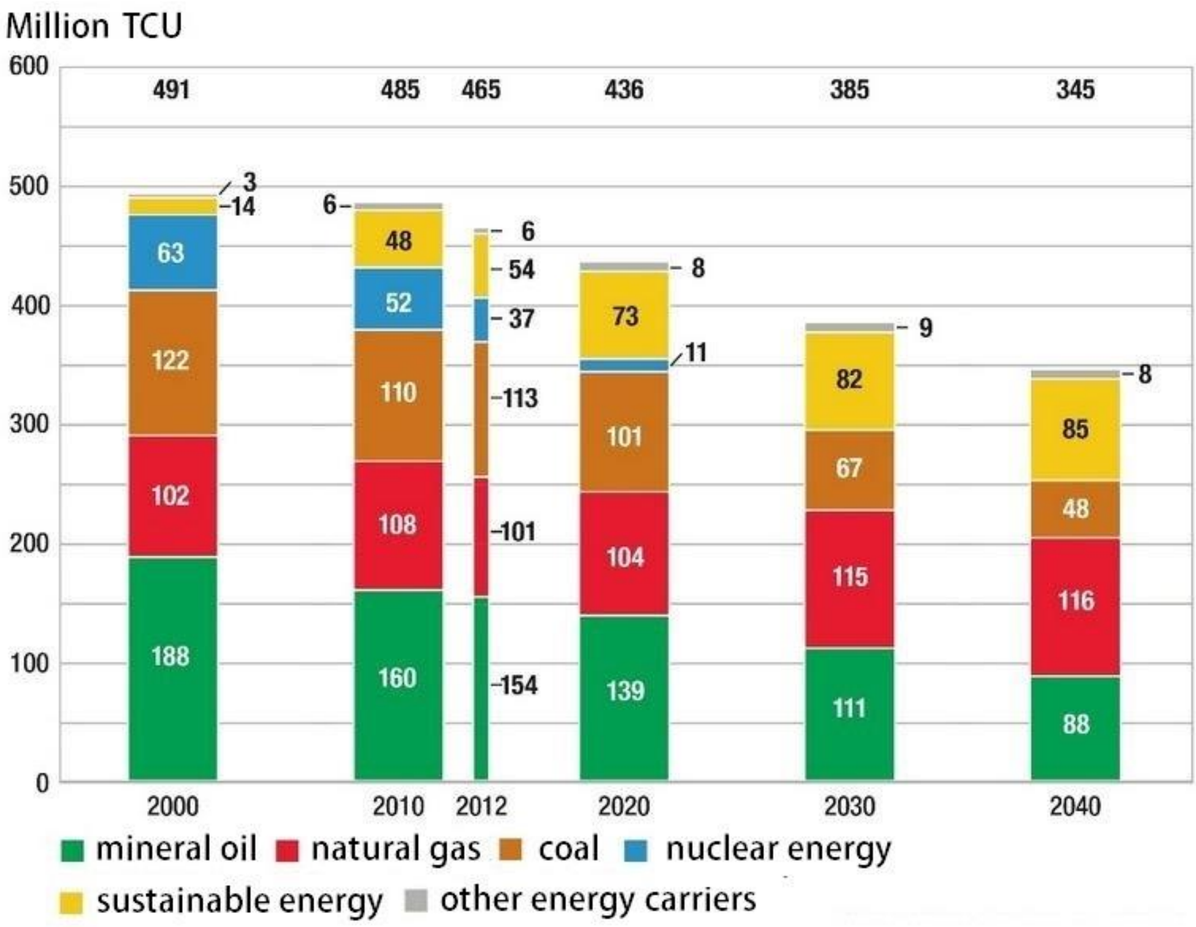


Figure 3

[1] Primary energy consumption (PEC) labels the available energy in natural energy carriers (e.g. mineral oil), which are not transformed or processed yet (e.g. gasoline or diesel). PEC is measured in stone coal units (TCU) in middle Europe. 1kg TCU equates to the amount of energy, which is freed by burning 1kg of stone coal.

[2] 1 TCU = 700 kg crude oil = 890 Nm^3 natural gas = 29.31 GJ = 8.14 MWh

Also the mineral oil is declining, but still has a portion of 88 million TCU, which corresponds to one quarter of the whole PEC. From 2023 onwards nuclear energy will vanish from the energy mix. The highest gain has the sustainable energy sector. With inclining market penetration its growth will become slower from 2020 on, but until 2040 it will have increased by about 60% (85 TCU/54 TCU) compared to 2012 (see figure 3).

When just considering the PEC for sustainable energies (see figure 4), biomass will have the highest share in 2040. In total this weather independent energy carrier will have a gain of 40%. Due to problems with the sustainability of biogas production its rise is more moderate. The contribution of wind energy almost triples, and has a share of 4-5% on the total PEC. Photovoltaic and solar heat will grow by 85%, but will just share a contribution of 2% to the total at the end of the forecasting horizon. Furthermore will water power, geothermal energy and heat pumps added up just gain 1%, and are therefore of lower importance.

Primary Energy Consumption Renewable Energies

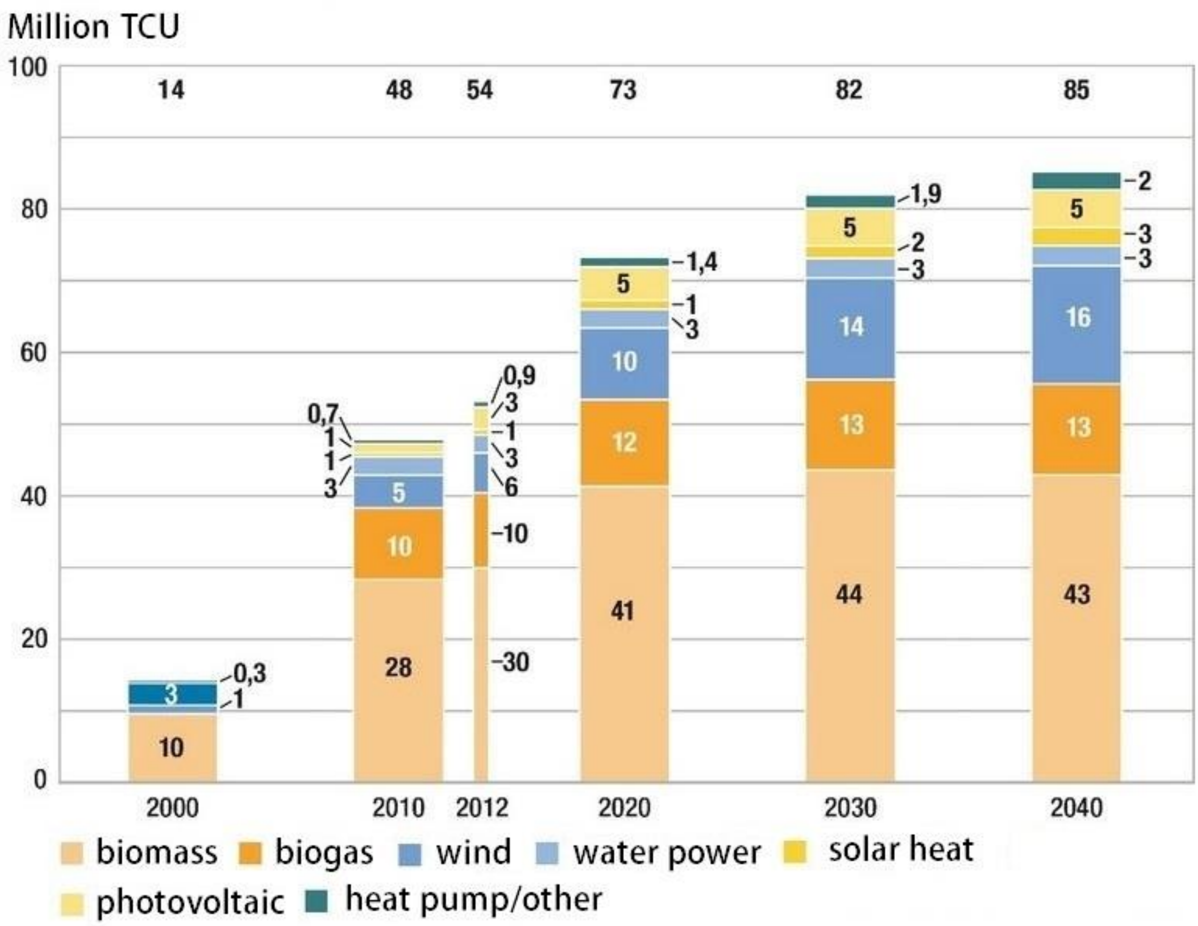


Figure 4

2.4 Energy Efficiency

The energy efficiency[3] in Germany is rising. Figure 5 shows two important reference parameters. In the year 2000 almost 2.3 TCU were necessary to generate a GDP of 10.000€, whereas in 2040 just 0.98 TCU will be required to accomplish the same result. The German per head usage on primary energy will drop in the time range from nearly 6.00 TCU to less than 4.50 TCU.

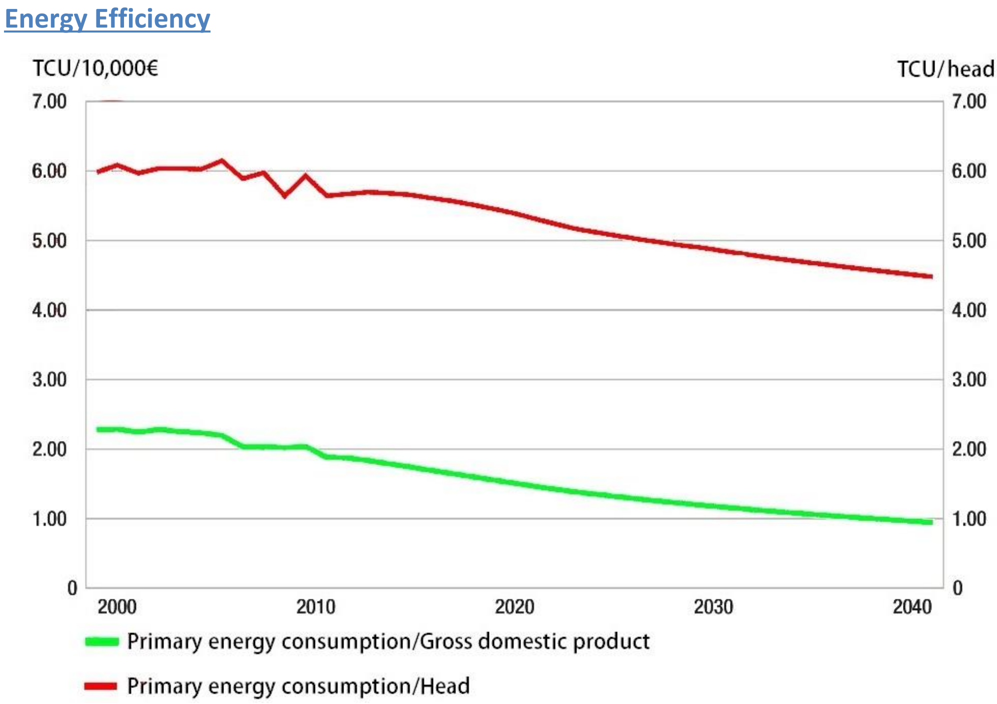


Figure 5

[3] Energy efficiency means to reduce the energy, which is required to supply products and services. The energy efficiency is better, when the degradation of energy by its production, transformation and distribution is minimized.

3. Electricity Generation and Sources

3.1 General

Around 40% of the PEC is used for power generation. The gross power consumption rises by 7% from 2012 until 2040. This is an average increase of 0.2% per year. Compared to that, the average increase of the GDP in the same time range lies by 1.5%. As a result of that, the gross power generation is not rising more intensively due to the positive economic development of the increasing energy efficiency.

Primary Energy Consumption Input for Power Generation

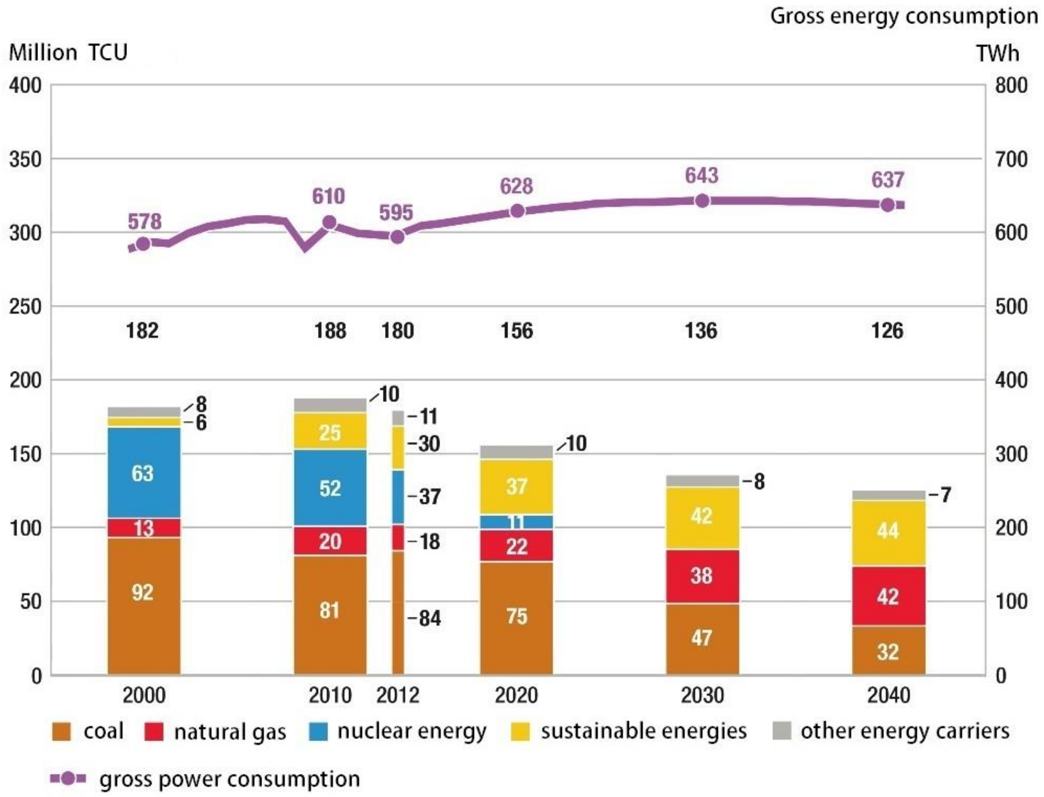


Figure 6

Even though the energy demand is growing, the primary energy input for electricity generation will decrease until 2040 by 30%. This drop is mostly caused by the changed energy mix: nuclear power plants, which have the lowest efficiency factor, being 33%, are bit by bit replaced with power stations with a higher effectiveness and a more energy efficient technology. As an example one can mention gas- and steam power plants, whose primary energy can be used by around 60%. As electricity was generated by 95% of weather independent energy carriers in 2012, it will change for the following decades enormously: The share of wind energy and photovoltaic will rise up to 21 million tons TCU, being 17%. The overall share of renewable energies as a primary energy input for power generation becomes around 35% in 2040 compared to 17% in 2012. As an essential stabilization for the basic services, natural gas plays a more and more important role, since it is a forthcoming and authentic option, with the cleanest burned fossil (see figure 6).

Natural gas is in direct competition with coal, which has the highest CO_2 emission. As long as the CO_2-costs are low, coal will block natural gas for power generation. This is however in a direct conflict to reaching the climate protection aims. Therefore a long term reorientation is necessary.

In total, the share of sustainable energies will rise up to 35% until the end of the forecasting horizon. Biomass and biogas will carry out the highest contribution. The most significance however will be on the extension of wind energy (see figure 7).

Primary Energy Consumption for Power Generation regarding Sustainable Energies

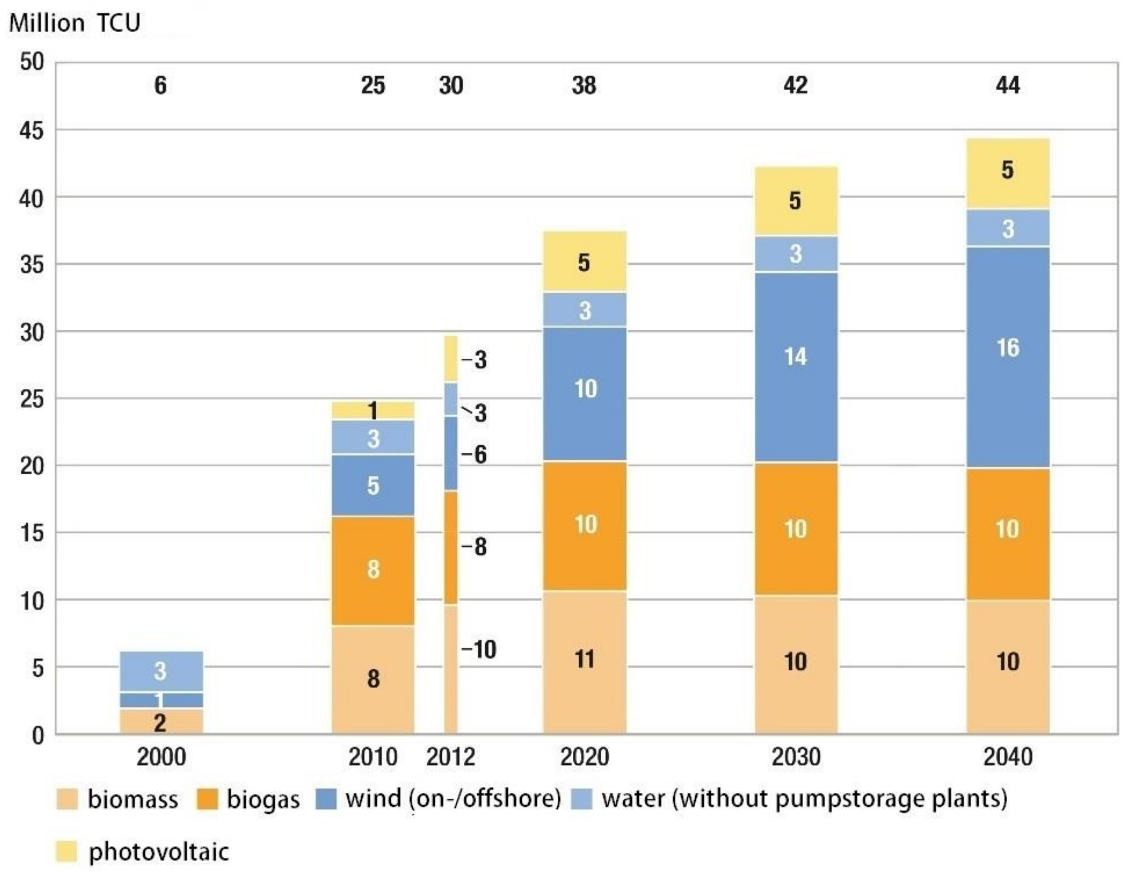


Figure 7

Summarized a safe, reliable and preferably environmentally friendly supply on Germany's power grids is not just simply ensured by a change in the energy mix. Parallel to this change, production capacities and the power grids themselves have to be upgraded, as well as new storage technologies have to be developed.

3.2 Forecast

The forecast seen in Figure 8 was evaluated by E-ON in 2012 [4]. It is an estimation of conventional power plants and renewable energies until 2030 based on the fact that nuclear energy will phase out and if the demand of power required will be reached. Conventional power plants need around 10 years from planning until it goes on the grid and are therefore accurate to estimate for future progresses in capacities and demand. Until 2030 many conventional power plants will be taken off the grid due to reasons of age. In 2010 power plants plus nuclear energy was able to provide a power capacity of 90,140 MW annually, which was always available. Even with the planning on new built conventional power plants the capacity will still drop to 39,530 MW in 2030. Predictions show that the newly installed renewable energies will reach up to 167,000 MW in 2030 (in 2010 it was 56,690 MW). However is the availability, unlike with conventional power plants, not guaranteed around the clock due to weather fluctuations and night times. Therefore it just yields an annual electricity production of 29,300 MW in 2030.

The annual maximum demand on electricity is expected to decrease by 5% until 2030, due to higher electricity efficiencies. This would bring an annual maximum demand of 74,000 MW in 2030. As can be clearly seen in Figure 8, after the complete phase out of nuclear energy, the amount to provide a security of supply will not be given anymore and new additional conventional power plants will become necessary.

Power Plant Capacities and Annual Maximum Demand in Megawatts

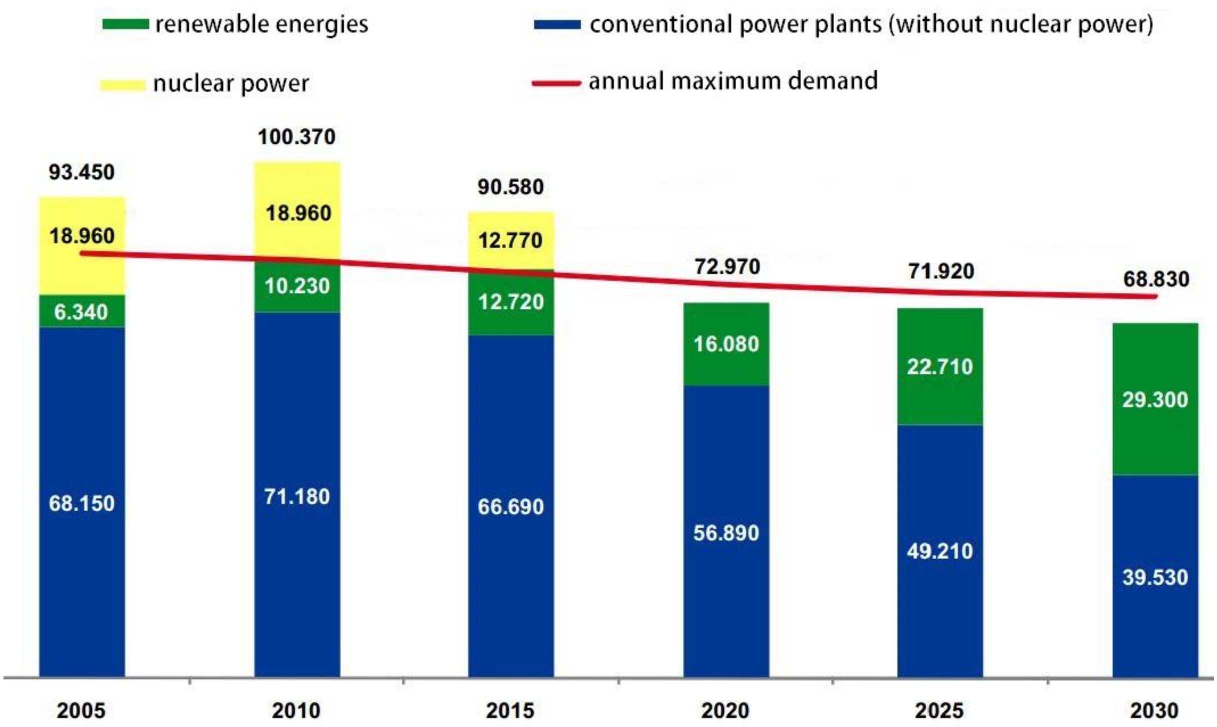


Figure 8

3.3 Subsumption

The German government made a fundamental decision about an enduring energy supply for the coming decades. The long-range development path is based on its main supporting pillar: renewable energy. The ambitious energy concept focuses on Germany to become the world's most energy efficient as well as environmentally friendliest economy, simultaneously keeping an affordable energy price plus a high level of prosperity. In the face of the dimensions of the energy concept, the size of Germany's energy intense economy as well as Germany's location in the center of the European energy system, further measures are necessary to find the right balance for the energy transition in terms of sustainability, affordability and competitive capability. Furthermore, Germany's decisions with this great magnitude about the energy policy, are of huge significance on their impact for neighboring countries and have to be seen in a broad European context as well.

4. Germany as part of Europe

In the upcoming years, the energy transition will not only be discussed in Germany, but in the other 27 EU states as well. Europe as a whole has to be considered while concentrating on the energy transition, since imports and exports of energy have a huge impact on a sole country. Political decisions, which are agreed on in one country, have direct impact on the neighboring countries, their system and financiers, connected through trans-border power grid cables. Therefore, a precise political coordination is necessary on a European scale. With this, long-lasting, safe and affordable energy maintenance can be achieved.

As the World Energy Council (2013) claims, the European internal energy market is far from being one market. Just nine out of the 28 EU states do not have regulated end customer prices; being Austria, the Czech Republic, Finland, Germany, Great Britain, Luxembourg, the Netherlands, Slovenia and Sweden. The resulting consequences are not just a blocked competitor-based business for end customer sales, but also "a reason for the distorted competitive situation faced by electricity intensive industry in the EU." [5]

As Olaf Osica[4] stated in 2013: „I believe that the German government came to the understanding, that the energy transition, if it wants to survive, has to be Europeanized. This raises the question, whether the European Union will Europeanize the energy transition or will the German energy transition play the role model for the European Union and its further politics." [freely translated]

The following sub chapter will deal with the actual energy production in Europe (+ United States) and afterwards German energy market key data will be provided correspondingly.

[4] He has a PhD in Political and Social Sciences from the European University Institute (EUI) in Florence. In 2005-2010 he worked as an expert at the Natolin European Centre

4.1 Energy in Europe

Since the German energy transition has high impacts on surrounding countries (Poland, Czech Republic, France) concerning a stable power grid, a lot of countries want to accomplish the energy transition to be on a European level and not just on a German level [6].

Pertaining to the energy transition, Germany did not incorporate with the EU. The energy mix is business of each individual member state, on which the EU has no direct influence on.

The electricity market was liberalized in 1998. It must not be regulated by the EU, since electricity is property of each national state. But a domestic market exists in Europe, where natives and foreigners can buy electricity equally.

One has to realize that each European country has a different resource position and therefore a varying energy policy coordination. These are commonly different evaluations on the endorsement of sustainable energy technologies, regulations on nuclear power and fuel and carbon price trends.

On March 3rd, 2010 the European Commission set up a 10-year strategy called "Europe 2020". This agenda was set to boost the economy in the EU, trying to support the change of the coordination of national and European policy into "smart, sustainable and inclusive growth" [7]. This strategy is subsequent to the Lisbon strategy, which lasted from 2000 to 2010 and was considered being a disappointment by many [8]. The agenda until 2020 sets up the target of achieving 20% of energy consumption from renewables and to raise energy efficiency by 20% until the end of this decade [9].[5]

Furthermore, it sets the aim for decreasing the primary energy consumption by 20%, resulting in a total primary energy consumption of 2.1 BTCE in 2020. While comparing this number to recent years, Europe seems to be on a good way on achieving their aim. From 2005 until 2008 the PEC was yearly about 2.6 BTCE. In the following years (2010 – 2012) it decreased from 2.5 BTCE to less than 2.37 BTCE. This is even lower than the 2.42 BTCE in 2009, which was due to the effects of the industrial sector resulting from the Eurozone Crisis. Even though (southern) European countries are still suffering from the economic crisis, a reduction of the PEC can be accredited towards developments in

[5]This translation to individual energy efficiency measures has a big potential on the employment market as well. It is estimated that it could produce and secure up to two million jobs by 2020 [10]. Furthermore the ability of the renewable energy sector development is expected for guaranteeing three million jobs by 2020 [11].

increasing energy efficiency and the positive trend of renewable energies. This can be mostly seen in the electricity sector, since renewable energy sources partly replaced the conventional ones resulting in lower energy consumption due to the fact that the power plants' own consumption is left omitted [12].

Primary Energy Consumption in Europe

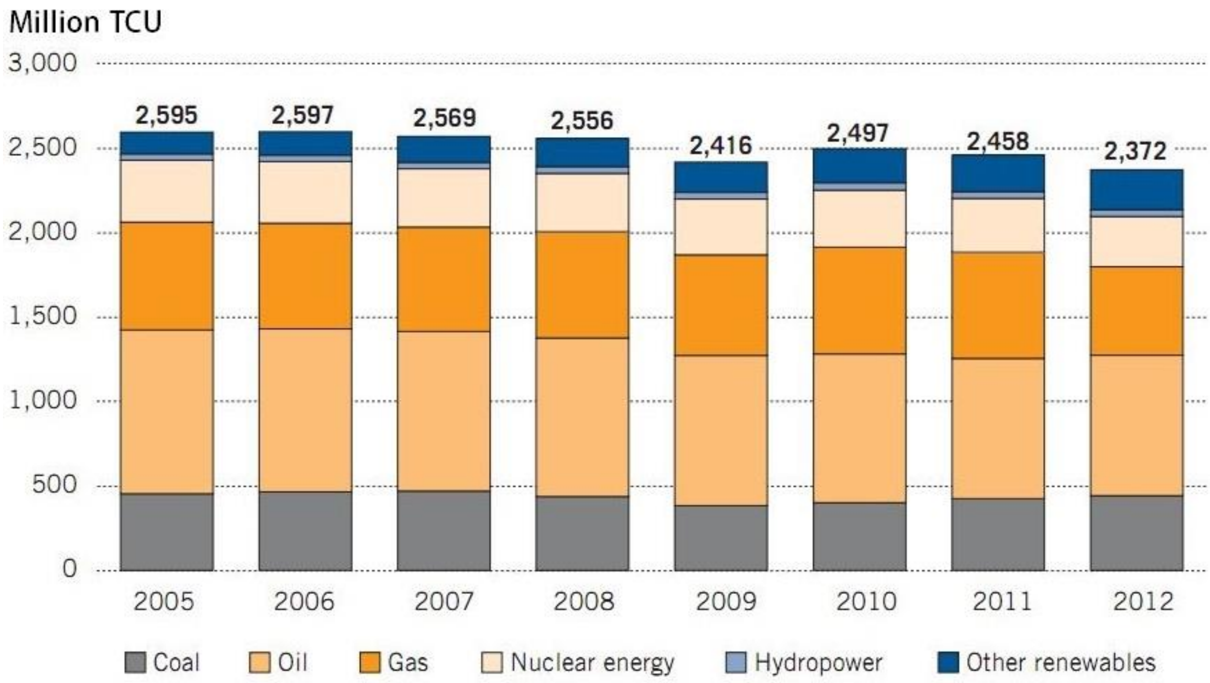


Figure 9

This rise of sustainable energy technologies for electricity production aroused a discussion on "the electric system's upgrading and ancillary cost due to increasing technical and market integration. There was also a debate about the sunken cost for renewable investments and the question of how consumers can bear the burden of that energy transition" [13].

While comparing the price difference of Europe and the USA, one can see that the energy price in Europe is a lot higher. This will give Europe a competitive handicap, leading to a change of assets, occupational qualifications and output of the economy towards the USA. Europe is still reliable on cheap coal for its energy production. As far as there are no European laws with restrictions on CO_2 costs and trading to abridge the use of coal, it will maintain the essential fuel to produce power. On the other hand, shale gas has a strong opposing force against it in most European countries (only potential in United Kingdom, Poland and Ukraine [14]), since hydraulic fracking and horizontal drilling are considered hazardous towards the environment. This brings up the discussion on natural gas and its dependency for most of Europe on Russia and their imports.

Some expectations are predicting that natural gas costs in Europe will continue to be high due to Russia's "feed-in monopoly" and their corresponding oil-indexed pricing. The Russian "long-term oil indexed natural gas" secured the energy supply in Europe in the past decades [15]. On the other hand some expect a break of Russia being the main supply due to the image shift of natural gas and the attractiveness aroused by it to many more countries with resources. Furthermore will this break of the monopoly change the market dynamics and create cheap costs for buyers on a short basis compared to long-term contracts [16]. This switch will have major consequences on European geopolitics.

There are many chances as well as threats, which have to be analyzed, of producing natural gas, for European countries. (see chapter: Opportunities and Threats of Natural Gas) These threats should not be outvoted in advance, but rather a workable, sophisticated, ecologically sustainable procedure should be found, by governments and economies together, to gain recognition and acceptance on a widespread basis. The step towards self-produced natural gas is necessary for Europe to maintain its position as a competitive environment for industry.

Hans-Josef Fell[6] explains the dilemma why regulations are necessary: "Always when the sun is shining, or the wind is blowing, a lot of cheap electricity is created, since it has no fuel costs. This cheap electricity goes on the stock market and lowers the average electricity stock exchange price. But the electricity stock exchange price is the basis for the calculation of cost over-runs for the renewable energies, and when the basis drops lower the difference gets bigger. Therefore the renewable energies drop the electricity price and are defamed as profiteer, while the companies do not give the decreasing electricity stock exchange price towards the customers, but simply maximize their profits themselves."

Primary Energy Consumption in Europe 2012

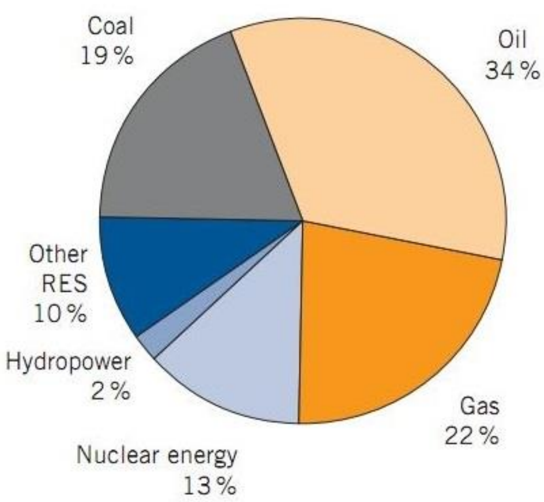


Figure 10

According to the World Energy council in 2013: "A pan-European[7], coordinated energy and electricity system offers advantages with respect to total costs in comparison to individual national solutions. The main policy challenges here are to push forward the move from uncoordinated

[6] Hans-Josef Fell is a member of the Green Party in the German Parliament. Fell framed the German Renewable Energy legislation.

[7] advocacy of political or economic unity among European countries

national approaches to a pan-European solution. In addition to the development and integration of renewable energy, this also concerns the development of unconventional fossil fuels. These cannot be completely excluded from the EU even in the future, for reasons of security of energy supply" [17].

Following is some data provided by the International Energy Agency (IEA) based on the energy contribution in Europe in 2012. Accordingly (compare figure 10) the energy is still mostly provided by conventional sources, such as nuclear energy and fossil fuels, who are summing to around 88% of the total ~2,400 MTCE contributed. Out of these, fossil fuels alone provide around 76%. On the other side are sustainable energy technologies in the European energy supply, with a share of 8.3% or 200 MTCE. A trend can be recognized that right now it is more economic for power generation to use coal instead of gas. This shift is due to low carbon prices and relatively high gas prices [18]. Therefore a shift by 3% was made from gas to coal in 2012. Since each European country has its own energy policies its supply contributions vary a lot. But the economic developments of each country can be assigned to a positive switch in their energy consumption. Three main factors are decisive for the development, being the support of renewable energy technologies, the evaluation of fuel and carbon prices and safety issues regarding nuclear power.

Even though the PEC is declining, the consumption of electricity (COE) stays more or less constant (see figure 11). The energy mix is switching more and more to renewable energies regarding electricity production; namely it increased by around 9% (including hydropower) to 23% in 2012. As the IEA states, the new installations for wind and solar power plants did not suffer of the financial crisis. The European Photovoltaic Industry Association (EPIA) stated that solar energy reported rapid progress in 2011 and 2012 toward the competitiveness in the electricity sector. It even reached new records of installments in these years [19]. But it still varies harshly among different member states of the EU. When considering renewable energies including hydropower, the largest production of these is reported in Austria, Sweden and Latvia (60-70%). Without hydropower Germany, Spain, Italy and the United Kingdom have the highest share on electricity generation by sustainable energies. Although renewable energies are on a rapid increase, fossils still maintain a dominant share of 50% in 2012.

Consumption of Electricity

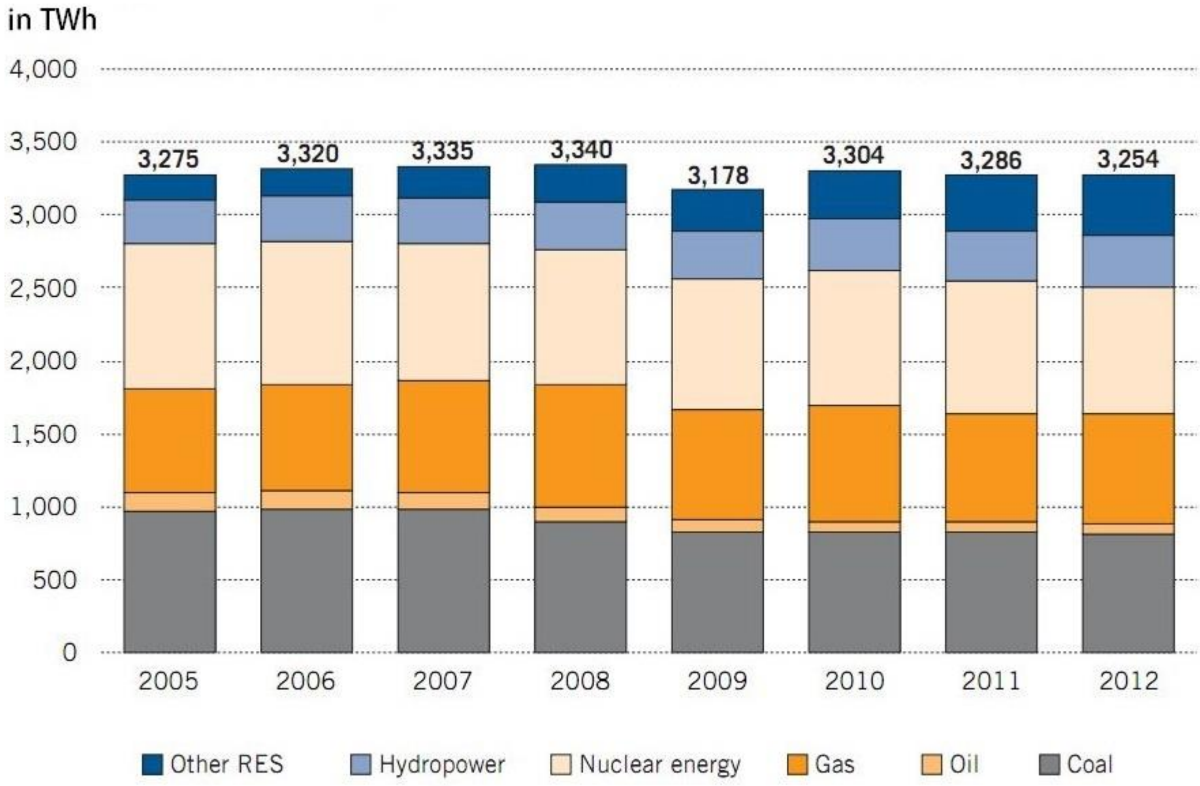


Figure 11

In 2012 the EU showed the biggest global share of new installations around the world. These new and old installations regarding the renewable energies mainly add up to the following shares. Hydropower has the biggest contribution with 11%. Following is wind power with a share of 6%. Wind power mainly consists of onshore plants (annual growth rate of 7% between 2010 and 2012), but a lot of offshore wind parks are being built right now, since its development is ready for commercial application. Therefore an increase in the following years is expected. The 3rd biggest contributor is biomass with 5%. Despite the fact that electricity production by photovoltaic increased from 2010 to 2012 by far the most (annual growth rate of 25%), it still only has an electricity production contribution of less than 2%.

Consumption of Electricity in Europe 2012

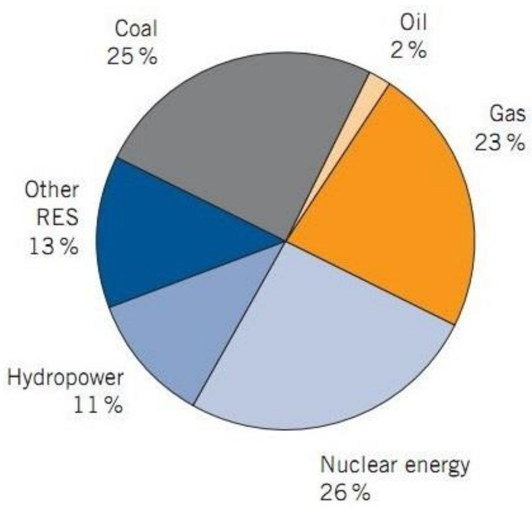


Figure 12

Even though the EU has the greatest global contribution of new installations, it is anticipated that the highly financed support for renewable systems will drop or has already dropped in a lot of EU countries. Therefore these record figures will not increase as rapidly anymore in the near future.

Furthermore, nuclear energy splits the opinion regarding different nations in three. First of all, Germany and Belgium are completely phasing out the use of nuclear energy in the coming years. Secondly, for example Spain and Switzerland, are not building any more nuclear power plants, but still keep and extend the existing ones for a foreseeable future. The third group still keeps on building new reactors, being France, United Kingdom and Finland. Therefore the use of nuclear energy will still play a role in the European energy mix for electricity creation in the coming future.

4.2 Subsumption

In Europe the COE was mostly stable throughout the past years, whereas the PEC showed a decreasing tendency. But one cannot neglect the fact that the consumption is still under the subsequent influences of the economic as well as the Eurozone crisis. Therefore, it is hard to estimate, which downward trends resulted from the crises or from shifts from conventional towards renewable energies and higher energy efficiencies. But dependent on these facts is the execution of the European 2020 targets, which involve the decrease of energy consumption and the resulting droppings in CO_2 emission. Even though the Eurozone crisis was harsh to the market, it did not let the new installation boom of solar systems decrease. Those developments are mainly focused on the electricity section and the accomplishment of the goals of the 2020 targets. Other areas, such as transport, industrial and building heating, are not focused upon, but rather need further aid and stimulation by the government. This also applies for the efficiencies of sustainable energy technologies, which rely on further incentives for their increasing development. But as can be seen in Germany, Spain and Italy in terms of subsidies for photovoltaic installations, the government is not able to afford the support due to national budget deficits anymore. The focus now tends towards further development of renewable energies.

Besides the development of power generating plants, future developments are anticipated to take place for the development of grid networks and storage sites. This will require massive further financial support. Therefore the discussion about a pan-European solution is in progress, providing a benefit of expenses compared to individual national solutions.

However, the international energy agency (IEA) has announced in their newest survey (2014) that the security of supply is going to lack in the following years. This is due to unbalanced high investments in renewable energies, instead of backing up conventional power plants as well. The IEA estimates that until 2025 the European supply will demand around 100 GW more stable load capacity by gas- and coal power plants to compensate the renewable energies sufficiently. This means that every fifth installed conventional power plant in Europe of today would have to be replaced or that we need to build an additional 200 new gas power plants. The calculated costs by the IEA to achieve this transition in Europe in the next 20 years are at 1.6 trillion Euros [20].

5. Energy in Germany

5.1 International Comparison

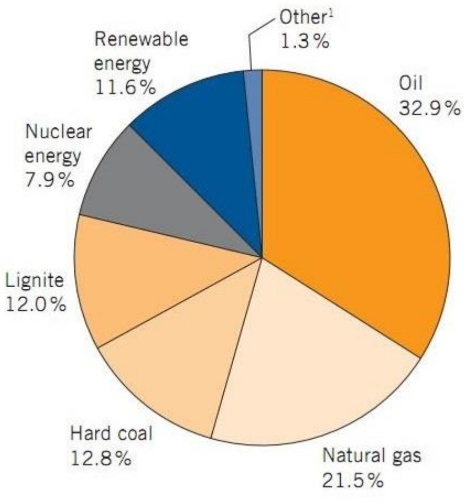
Throughout the whole world, Germany was ranked 7th largest energy market, behind China, USA, Russia, India, Japan and Canada, in 2012 [21]. Germany used almost 470 MTCE (see figure 3, PEC Total). This broken down by its population gives an energy consumption of 5.7 TCE per person per year. As a comparison, it is twice as much as the average worldwide, but only half the consumption per person in the USA. When considering goods and services produced, one can see that in Germany the energy is utilized quite efficiently. This is shown by the energy consumption, which was at ~ 180 KgCE / 1000€ GDP in 2012 (see figure 1 and figure 3), being only half of the global average.

Craig Morris, the lead author of "German Energy Transition", states that German energy resources mainly consist of coal. Its portion on global oil and gas reserves is little and therefore the industry and government are dependent on imports [22].

5.2 Germany's Dependency Situation

The total 470 MTCE of PEC are splitted up as shown in figure 13 (compare with figure 3). 40%, or 188 MTCE, of this energy was produced in Germany (including nuclear energy). Out of this domestically produced energy coal, being lignite and hard coal, contributed 68.3 MTCE, whereas renewable energies provided 53.9 MTCE. The other 60% of energy consumption was imported. By 2012 Germany was mostly dependent on Russia reserves and their exports. Russia exported natural gas, crude oil and hard coal to Germany, which represented more than 1/3 of the entire imports. Russia was followed by Norway, the Netherlands, the United Kingdom, USA, Libya, Columbia and Nigeria.

Primary Energy Consumption in Germany by energy source in 2012



1 Other solid and gaseous fuels, as well as imported electricity.

Figure 13

Hard coal is provided by the USA and Columbia. The crude oil imports come from Libya and Nigeria and Norway. Norway and the Netherlands also export natural gas to Germany. All of these imports have a net cost of 98.2 billion Euros, where oil had a share of 65.6 billion Euros and natural gas 29.0 billion Euros.

Energy Import Dependency in 2012

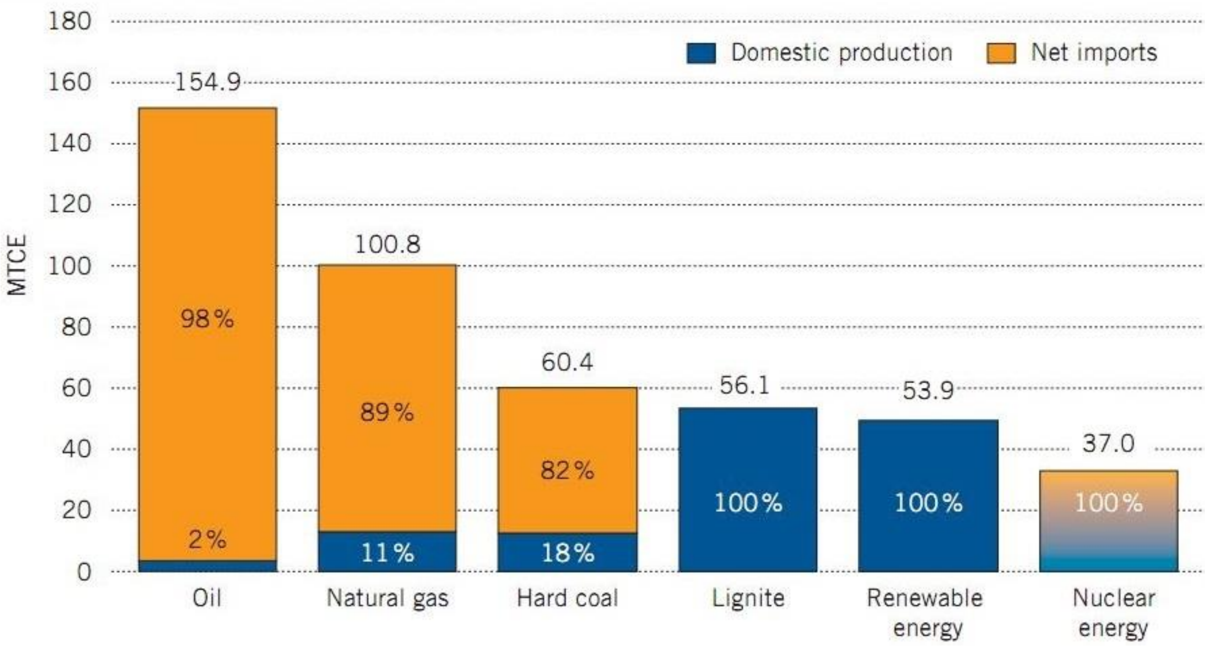


Figure 14

5.3 Political Involvement

The balancing of import costs are accounted for by consumption taxes (electricity and fuel tax) for consumers, which totaled to almost 50 billion Euros, being half of Germanys energy import costs, in 2012. Out of the consumption taxes, taxes on fuel had a share of 75%, which totals to 35 billion Euros in revenue. However for producers, coal and natural gas used as an energy source for electricity generation are excluded by the energy tax.

As Eurostat[8] released in 2013, Germany had the highest CO_2 emission in the EU per capita (8.89 tons), totaling to 728 million tons, which makes it a prime reason for the German government's energy transition plans. Compared to the year before it decreased by 0.9%, while comparing it to data from the 1990's the CO_2 emission dropped by almost 22% [23].

[8] The statistical office of the European Union

5.4 Detailed Sources

Below is a detailed list on imported and domestically produced energies used in Germany. The informations are based on energy consumptions in 2012 for the following: Renewable energies, oil, natural gas, hard coal and lignite. The values are calculated and converted to a common basis, mostly TWh (including its respective efficiency factor), and rely on tables published by the Arbeitsgemeinschaft Energiebilanzen[9] (AGEB: freely translated: Working committee for energy balances)

5.4.1 Renewable Energy

In 2012 renewable energies had a share of 11.6% of the PEC, which was mostly accounted for in the electricity sector. The gross domestic electricity consumption consisted of 23%[10] of produced electricity by renewable sources, both industrial and private operator plants. This totaled to 138 TWh, of which the main suppliers was wind energy with 50.5 TWh. Additionally 35.1 TWh was produced by biomass, 26.4 TWh by solar power and 21.4 TWh by hydropower. This comprised in terms of megawatts of plants' net installed capacity sums up to about 75,000 MW (31,000 MW by wind, 32,000 MW by solar, 6,000 MW by biomass and almost 6,000 MW by hydropower), which gives renewable plants a share of 42% of all installed power plants capacities in Germany.

The earnings by sales of this energy accounted for 2.763 billion Euros. Net support payments summed up to 16.519 billion Euros, totaling to 19.282 billion Euros of compensation and premium payments to plant operators. The feed-in volume only by renewables summed up to ~114,000 GWh. The mean net support rate sums to 14.4 cents/kWh[11].

[9] The AGEB consists of 7 unions by the German energy economy and three in the field of energy entrepreneurship development. Energy balances are made accessible for the public by the AGBE, who evaluates statistics of all fields for the German government

[10] Compare with figure 6

[11] $16{,}519 \cdot 10^{9} / 114{,}000 \cdot 10^{6}$

5.4.2 Oil

Just 2% of the total oil required can be produced locally in Germany. Therefore crude oil relies mainly on imports. In 2012 the imported oil summed to 125.7 million tons, where 74.3% were crude oil itself and 25.7% accounted for oil products. Germany relies on imports from the North Sea (26%), Eastern Europe/Asia (46%) and Africa (22%). The imported oil was processed in German refineries, which totaled to a final product of 106.5 million tons. The domestic sales of consumption was mainly used for road transport (petrol: 18.5 million tons and diesel: 33.7 million tons). The share of distribution for each area is: 56 % for transport, 25% for industry, 18% for households and small consumers and 1% for electricity supplier power plants.

5.4.3 Natural Gas

Germany's consumption of natural gas is 6.5 times higher than the consumption of sources by renewables in 2012. This gives a natural gas consumption of 909 TWh. Most of the produced natural gas (89% out of 1,102 TWh) was imported from numerous countries, mainly Russia (31%), Norway (24%), the Netherlands (23%) and Denmark (11%). The import is mostly based on long-term contracts between supplier and German import companies. The other 11% are produced in Germany. (see also chapter: Opportunities and Threats of Natural Gas) Out of total, 372 TWh (41%) were used in the industry sector and another 15% for power plants' application. However, the largest share on natural gas consumption has the households and small consumers. They consume 44%, which is mainly due to gas-heated apartments[12]. Another 196 TWh were delivered to users in different European countries. Due to the rising importance of liquid natural gas markets and the deviance towards oil-linked import prices, the prices have to acclimatize and pricing mechanisms for long-term contracts have to be adjusted in the near future [24].

5.4.4 Hard Coal

Hard coal has a total consumption of 60.4 MTCE, of which 11.1 MTCE (18%) were locally produced. Right now there are 3 mines working (2 coal mines were closed in 2012), of which one will close in 2015 and the remaining 2 in 2018. This is due to the phase-out process on a European level in decreasing the CO_2 emission and the energy transition. So far 82% of the hard coal consumption are imported, mainly by Russia, USA, Columbia, Poland and Australia. Out of the total consumption, power plants used 40.1 MTCE and the steel industry used 15.4 MTCE. The rest was used by the heating market.

[12] Almost 50% of all apartments in Germany have natural gas heating.

5.4.5 Lignite

Germanys' base load for electricity generation is based on lignite, which is almost completely (99.9%) produced in Germany. Imports only account for 0.05 MTCE. In 2012, Germany generated 56.1 MTCE, which is equal to 185.4 million tons of lignite. 89.6% of the produced lignite was supplied to power plants, which generated public energy. Lignits' gross electricity production summed to 159 TWh. Almost everything (97.3%) accounted for providing public energy (154.8 TWh). National customers get 80% of the domestically produced lignite for electricity and heat generation or for industrial processes.

5.4.6 Electricity

To summarize the individual contributions in terms of electricity produced in Germany, the gross electricity production summed up to 628.7 TWh in 2012 [25]. The energy consumed by the power plants itself attributed for 36.7 TWh. This subtracted from the total, yields a net electricity production of 592 TWh (see also figure 6). Out of this, the power plants, which were run by energy suppliers generated 93% and industry power plants contributed the additional 7%. These 592 TWh were produced by the following sources: 148.4 TWh lignite (25.1%); 138.8 TWh renewable energies (23.4%); 106.5 TWh hard coal (18.0%); 94.2 TWh nuclear energy (15.9%) and 73.4 TWh natural gas (12.4%). The rest of 5.2% was produced by heating oil and other energy sources. The whole production was fed with 44.2 TWh of bought electricity from other countries, which showed a decrease of 11.1% compared to 2011. The domestically produced electricity was exported, with a gain of 20.2% towards the year before, with 67.3 TWh. This great increase of electricity exports was due to the high rise of renewable energies and their contribution to power generation in Germany. As Rainer Baake[13] states: "Foreigners buy gladly our [German] electricity, especially around noonday, when electricity is the most expensive in Europe, but quite cheap in Germany, because of photovoltaic power generation. To buy it from Germany is cheaper [for foreign countries] than to use their own produced electricity by conventional power stations." [freely translated] The net electricity consumption summed to a total of 533.2 TWh. The shares of this consumption are split as follows: industry with 248.0 TWh (46%); domestic homes consumed 137.0 TWh (26%); business, trade, public institutions and agriculture comprised 131.7 TWh (25%) and the leaving 3% were used by transportation. These numbers for consumption are expected to remain constant in the following years, even though the demand is increasing, but due to the rise in efficiency for electricity usage and the reduction of current intensity levels. Corresponding information can be found in figure 15 and 16.

[13] Director of Agora Energiewende, and Permanent State Secretary in the German Ministry of Economics

Power Plant Capacity in 2012

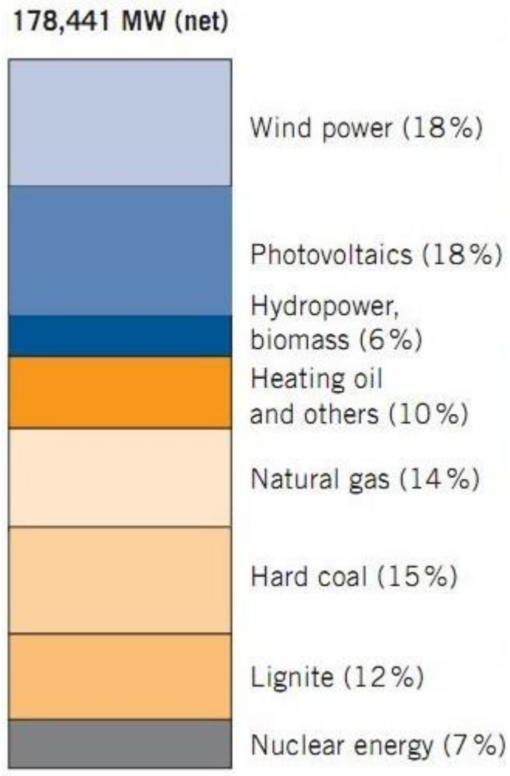


Figure 15

Net Electricity Production in 2012

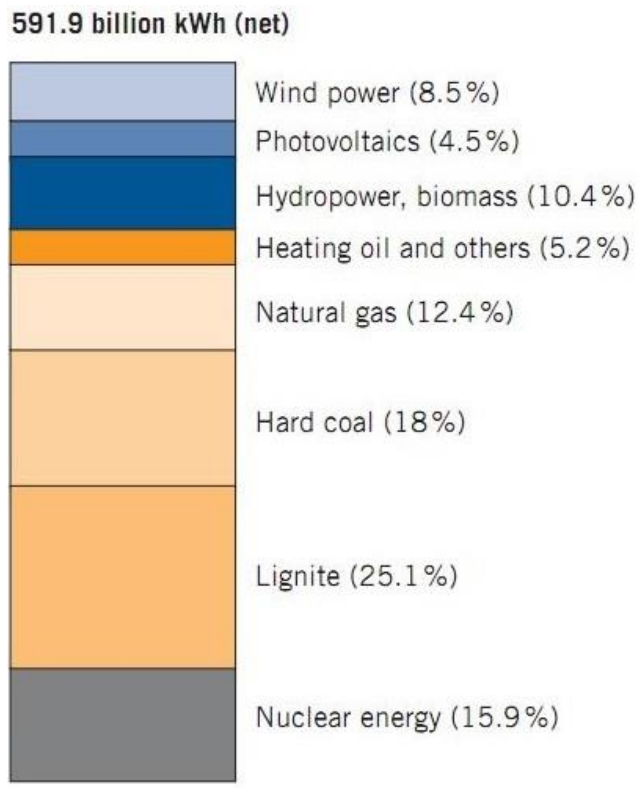


Figure 16

5.5 Subsumption

Germany is located in the center of the European energy trade. It is connected to a good gas supply- and storage-infrastructure and has strong domestic feed-in companies. The diversity of gas-supply-routes towards Germany has been upgraded, especially by the opening of the North-Stream-Pipeline [26], which provides annually an additional import capacity of 55 billion cubic meters.

The usage of mineral oil still plays a major role as an energy source, even though its usage has been on the decline in the last decade. The state rarely has domestic oil resources and its demand depends mostly on imports. Germany offers a diversified and flexible oil-supply-infrastructure in terms of pipelines and import terminals. Additionally is the German oil market liberalized and has a broad number of market participants.

In 2007 it was decided that subsidies for domestic stone coal extraction will be phasing out and that all stone coal mining plants, which have an annual production rate of 8 million tons, will close down by 2018. Furthermore is expected that due to EU-guidelines on large-scale firing plants, older coal-fired power stations have to be taken off the grid. However, various large-scale coal-fired power stations are being built at the moment, which will also form a main pillar in the German electricity production. The technical life-expectancy of these power plants is estimated to be at least until 2050. The energy concept assists the trial and if applicable utilization of the CCS-technology[14] works, it will keep CO_2 at a minimum. Due to the closing of all domestic stone coal mining plants, the new coal-fired power plants purely rely on coal imports.

[14] Carbon Capture and Storage (CCS) is a technology, which can capture up to 90% of CO_2 emission before entering the atmosphere, by storing it underground in depleted oil and gas fields or in porous rocks filled with very salty water.

6. Political Influence

6.1 EEG – Erneuerbare-Energien-Gesetz

The main legislation in Germany concerning the energy transition is the Erneuerbare-Energien-Gesetz (EEG – freely translated: renewable energy act), which came into effect in April 2000. It is the primary driver for the development of renewable energies, and was revised multiple times to customize it towards current trends. The EEG guarantees compensation for operators of renewable-electricity-generation sites. It provides an accessory compensation per kilowatt hour for the subsequent 20 years after installment. The value of compensation for electricity fed into the grid is dependent on type, location and size of the electricity plant. Refunds on individual plants stay the same for 20 years, but are subject to annual degression for a certain percentage. This means that the guaranteed remuneration for feed-in drops the later the plant goes on the grid. The degression is a main principal of encouragement provided by the EEG to provide stimulation for cost reduction and innovation and to bring renewable energies faster on the market. Another important pillar for the EEG is the feed-in priority for electricity of renewables. This means that the operator has the right to an immediate and preferential connection of their plant to the power grid.

The EEG was originally implemented to promote the development of renewable energies and to bring them towards marketability step by step. On the one hand, was the price of conventional electricity being artificially kept low by decades of subventions for coal and nuclear energy, and on the other hand, does the price of conventionally produced electricity not include external costs – plus the originated pollution of the environment and the CO_2 emission. The EEG tries to compensate for this disadvantage and reflects the benefits of renewable energies until these are cost efficient enough. Thereby a relatively stable framework requirement was created, which provides investment security, and therefore builds a solid base for further developments. This achievement is already visible, since about 25% of electricity was produced by renewables in 2012.

But there are also critics in politics and economics about the EEG. A main argument are the related cost increases for the end customer, which are initiated due to the introduced energy transition and the correlated EEG-contribution. Even though a lot of energy intensive large-scale customers in the industry sector are exempted by the EEG-contribution, it does not reduce costs for the consumer. Although prices on the electricity stock exchange are considerably lowered due to the supply on renewable energies, it is not handed to the end customer. This is due to unexpected – not anticipated by the German Federal Government – devaluations of assets for industries in that field. Financial input for renewable energies, electricity networks and energy efficiency measures will constantly be necessary. So far, energy supply companies were the main investors. But due to the political decisions about the energy transition, the income of energy companies has dropped. The companies' earning power has shrunk and investment demands are rising, ultimately due to the result of a changed production mix brought about by the legislator. Many energy supply companies are suffering from high debts, as they cannot provide the billions required to finance the energy transition by themselves [27]. Due to this indebtness, many companies are freed from the "electricity contribution", to still be able to compete on an international level and to keep the economy running. This loss on contribution totals to 5.1 billion Euros, which is then carried on and compensated by the end customer [28]. Since individual consumers have to pay the full "electricity contribution", it is estimated that a family with 4 persons has to annually pay an extra 220 Euros (electricity contribution of 6.24 Ct/KWh).

This has been noticed by the government and new amendments to the EEG act are being discussed at the moment. The Federal Minister of Economics in Germany, Sigmar Gabriel, has announced (2014) that "it is an illusion to believe that the energy transition can be simply achieved by a fast and rapid construction of renewable energies, but rather has to be an all-round development, which is secure and projectable. Power grids have to be adjusted, and synchronization between the electricity production by renewables, as well as the electricity provided by coal and gas plants, has to be matched." (freely translated) [29] Additionally, he announced that the EEG, which gave compensation for renewable energy investors for 14 years, had to be paid for by end customers and had raised the electricity price. Therefore, an upper limit on substitutions and further development is planned, being an annual increase of maximal 2500 MW for on-shore wind energy and 100 MV for biomass. Furthermore, a limit of 6500 MW of off-shore wind plants until 2020. For the expansion of photovoltaic power no limit will be set.

6.2 Measures taken by the German government

To accomplish the goals set for a successful energy transition towards renewables, research and development is required. The fossil sources are limited. The special case in the electricity- and gas industry is, that it is not necessary anymore to increase the production year by year. More likely a more efficient handling with energy is demanded. Two important things have to be taken into account, while achieving this change. Firstly, the customers' comfort has to be protected and secondly, it has to be affordable for everybody. Power plants have to produce more energy with the same amount of raw material. No valuable energy can be lost during this process. The production of electricity by water, wind, biomass and the sun is considered to be the most efficient and cheapest solution right now. The consumption rate of electric products has to decrease while keeping its performance, which means a better efficiency of the product.

In its 6th "Energy Research Program of the Federal Government" [30], which was published in cooperation with the Federal Ministry of Economics, the government tries to evaluate its research fundings pertaining to its three objective targets, being the energy political triad: economic feasibility, security of supply and environmental safety. For short and medium periods the program provides concrete approaches for achieving the political guidelines. It mainly aims for a balanced energy mix, more productivity by the conversion of energy and a higher contribution of renewable energies in general. Furthermore, it discusses topics on the nuclear safety- and ultimate disposal research as well as on fusion research. The German government provided 3.5 billion Euro for boosting the research and development of modern energy technologies between 2011 and 2014.

In 2050, Germany aims to supply 80% of its electricity demand by renewable sources [31]. To counteract short term fluctuation up to the saving of energy in a long term sense of a couple of months, it is required to have storage. This is necessary to keep the electricity supply consistent with electricity demand. Besides, a well established storage system, intelligent load management and new network configurations are needed to provide a security of supply on a long term basis. The federal government supports this in their "Förderinitiative Energiespeicher" (freely translated: support initiative energy storage) in phase 1 (until 2014) with 200 million Euro [32]. This initiative supports mainly developments on storage for electricity and heat.

The energy transition and its related success towards an ecologically compatible society is also of big concern for the Federal Environment Ministry. They provided 128 million Euro for the research and development in renewable energies, mostly for solar and wind energy. The energy-research-programs financed by the Ministry are focused mostly on fundamental research and projects, which receive a total of 325 million Euro annually. Furthermore, the Ministry subsidized the construction of geothermal energy plants. Besides producing heat, they also generate electricity. All these activities are listed in the program "Grundlagenforschung Energie 2020+" (freely translated: fundamental research energy 2020+) by the German Federal Ministry of Education and Research. Additionally they discuss the exploration of nuclear fusion [33].

6.3 Subsumption

The federal government has been successful in terms of encouraging investments towards renewable energies. However the federal government lacked to optimally control and supervise the amount of new energy connected to the power grid. The German energy political aims are developed on a long-term basis and to achieve them a reliable policy- and regulation framework is necessary. Sudden changes in the aiding arrangement might reduce costs in short-terms, but will weaken the confidence of investors and will increase costs in the long run due to higher risk premiums. Regarding amendments of the EEG, one has to realize the benefits of competition. Furthermore, one has to consider the location and development-speed in terms of balancing them with the infrastructure requirements; plus enough security for investors has to be provided, while always covering the energy demand. To assist with this potentially difficult adjustment and to minimize the risk of phasing out incremental capacities too early, response mechanisms should be installed, which instead of relating to the price are rather linked to the fundamentals of demand and supply.

7. Nuclear Energy

7.1 Phase out

After the nuclear accident in Fukushima in March 2011 the government passed a bill to phase-out of nuclear energy. The eight oldest nuclear power plants in Germany were immediately shut down and the remaining ones are going to be closed by 2022. The closings left a lack of capacity of 8.4 GW, which has been compensated for up to now without any supply shortfalls, by renewables, coal and gas. There are nine nuclear power plants still running, which produce an annual rate of 12.7 GW, being 97.2 billion kWh of electricity, which is the annual demand of electricity required for 27.7 million households. The reserve margins are sufficient until 2015 at least. However, concerns are being raised, to what extent the present electricity market arrangements can take care of the required investments to keep a safe and reliable electricity service.

7.2 Calculation: Compensation by Renewables

To give an example on how many renewable energy carriers are necessary to compensate these closings:

One nuclear power plant provides yearly approximately 1.4 GW, being 11 billion kWh (11 TWh), which is the annual demand of electricity of 3.14 million homes. To relate this with wind or solar energy, offshore, onshore wind parks as well as solar small plants (roof top) and photovoltaic parks will be considered with German weather conditions. A nuclear power plant runs 8000 hours a year, only annually closing for 10% due to maintenance (a year has 8750h).

Offshore: A 5 MW offshore wind turbine in the wind park “alpha ventus” (12 wind plants) located in the North Sea produces annually 22.25 GWh [34]. An estimate of 4000 wind hours per year is considered. To account for the 11 TWh electricity produced by a nuclear power plant, one would need 495 5-MW-windturbines or 42 offshore wind parks of the typ “alpha ventus”

Onshore: An onshore wind turbine runs with 2.5 MW and produces approximately 4.5 GWh per year [35], with an estimate of 1800 wind hours. Therefore 2445 2.5-MW-windturbines would be necessary. To compare: by the end of 2012 there were 23,000 wind turbines installed in Germany.

Photovoltaic park, open area: A photovoltaic park has an estimated electrical peak capacity of 5 MW. With the average value for Germany of 900 full load hours per year we gain 4.5 GWh per year. Therefore 2445 PV-parks would be needed to compensate one average nuclear power plant.

Single Photovoltaic, roof top: A roof top installation has an average of 5kW, being 0.005 MW. With the same estimation of annually 900 full load hours, 0.0045 GWh per year are reached. This yields 2.44 million PV-installations on roof tops to balance the shutdown of one nuclear power plant.

8. Opportunities and Threats of Natural Gas

As various experts (e.g. Shell; the *BDEW: Bundesverband der Energie- und Wasserwirtschaft (freely translated:* German Association of Energy and Water Industries)) argue in the field, the use of natural gas for the energy transition in Germany is indispensable. Natural gas will form a necessary and close partner for the renewable energies, which have to be compensated quickly by arising fluctuations [36]. Despite the already discussed economic benefits, such as climate protection and CO_2 emission, where natural gas has a superior position compared to hard coal and lignite (see figure 17), its attractiveness further comes from the other two requirements of the energy policy triad[15]. Germany has to be supplied by reliable and affordable energy in the future. Even though renewables are the cornerstone of the German energy transition, it is not yet foreseeable, when renewable energies are able to be economically used on a big scale. Furthermore, sufficient energy storage of renewables is still in research. Plus the development and construction of such is connected to high financial expenditures. Therefore, scooping out the existing potential in Germany might be essential to keeping, for example the electricity price development, in economically agreeable conditions. The positive effect for the economy by utilizing the natural gas potential can be seen in the current situation in the USA [37]. As the "Bundesanstalt für Geowissenschaften und Rohstoffe" [16] (BGR; freely translated: Federal Institute for Geosciences and Natural Resources) states, are the globally available resources of today able to cover the demand for the following 200 years [38]. Local extraction, modern transport possibilities[17] and some of the biggest storages in Europe already provide a basis that natural gas will be a reliably available in Germany in the future. In Germany, a high potential on natural gas from unconventional reservoirs is existing. To keep the domestic natural gas share stable or to increase it in the future, one has to rely on unconventional reservoirs, since the volume of conventional ones is decreasing. First of all, this would produce an even wider

CO_2 Emissions by Electricity Production

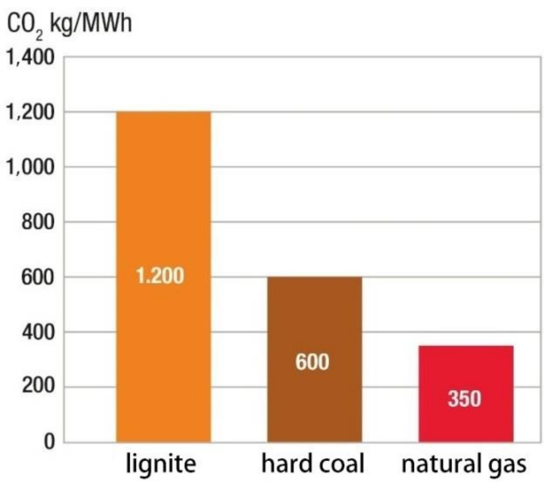


Figure 17

---

[15] Climate protection, Security of supply, Economic feasibility

[16] It is the central geoscientific authority providing advice to the German Federal Government and is subordinated to the Federal Ministry of Economic Affairs and Energy (BMWi)

[17] For example: LNG = Liquefied Natural Gas is not dependent on pipelines anymore, but can be transported by ship

diversified supply, and furthermore, would a local extraction minimize transport ways. Shorter domestic transport distances for natural gas are estimated to save up to 5 million tons of CO_2 emission annually [39]. A study by the BGR is estimating a potential on shale gas reservoirs in Germany to be between 6.7 and 22.7 trillion cubic meters. [How much of this potential is actually economically exploitable is not estimated yet.] In the USA, dependent on which reservoir, 10% to 35% can be used. Even though one would estimate the German rate at just 10%, the technical minable shale gas quantity would be at 2,300 billion cubic meters. This would be 200 times more than the annually extracted natural gas at this moment. A comparison of the potential versus extraction and consumption can be seen in figure 18.

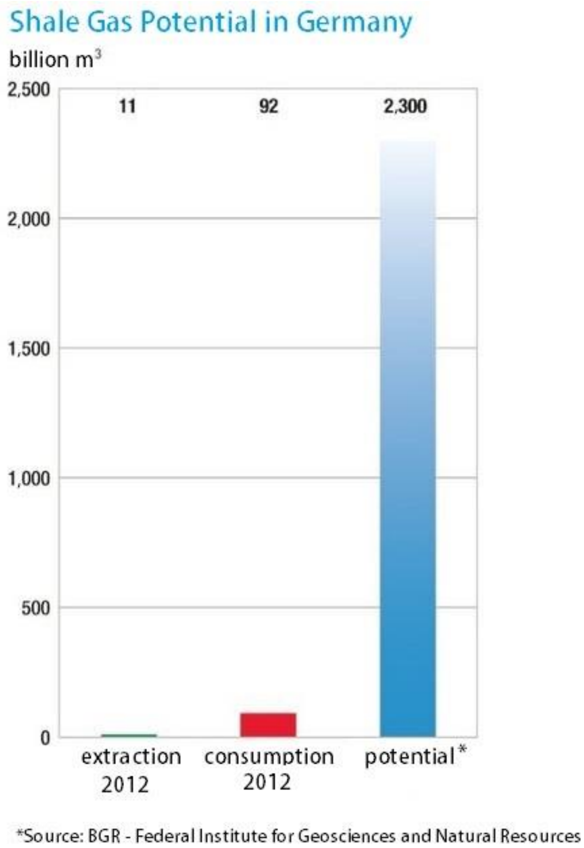


Figure 18

Even though natural gas has high potential and great benefits, a lot of people are worried about the risks related to fracking. First of all, natural gas is comprised mostly by methane, which mishandled can even more boost the greenhouse effect. Concerns are raised about public safety due to contaminated ground water through fault well constructions or chemical spills at the surface. Additionally, the waste water, which is used in the process of hydraulic fracking, and the water set free by the shale can damage the ground water. Furthermore, toxic and smog-forming pollutants can arise by extracting gas, which can leak into the atmosphere. Industrial companies, academic experts and scientist are working together to handle these occurring concerns and to minimize any risks. The federal government is enacting guidelines and regulations to secure public safety. But still, a communication with the public has to take place, to provide them with the right to learn and make informed decisions on behalf of developments within their borders and to receive public acceptance.

9. Outlook

9.1 General

The German government wrote a monitoring statement (2014) on how far the transition of the energy concept of 2010/2011 has proceeded. This statement shows clearly that the energy transition is an important and necessary step for the energy of the future. The main points mentioned being accomplished by the energy transition is to secure the economic revival, future-proof workplaces, innovations and the modernization Germany's [40]. As the federal minister of economics Sigmar Gabriel[18] explained towards the statement by the federal cabinet in April 2014: "The new regulations about the particular compensation regulations keep the ability to compete in our electricity intensive industry in Germany, which has to stand its ground in a hard international contention. Simultaneously is this readjustment in agreement with the EU-regulations and therefore provides an investment security. […] In sum the energy transition will not lead to a surplus load for the German electricity intensive industry. […] The Energy transition does not just mean to provide a fast development for renewable energies, but rather also a network expansion, an electricity market design and the European integration." (freely translated)

Furthermore the German "Erneuerbare-Energien-Gesetz" (EEG (freely translated: Renewable-Energy-Law)) creates conditions to change the energy supply step by step to renewable energies. The EEG-reform is one of the main tasks for the German government. It provides a governmental security towards the public for the further upgrading for electricity from wind, sun and other renewables [41]. The EEG-reform tries to slowdown the further increase of costs for renewables, to navigate the development of sustainable energies tactically and to push the market integration forward. But as the Federal Ministry for Economic Affairs and Energy (German: Bundesministerium für Wirtschaft und Energie, BMWi) clearly announces as well, is the development of the electricity tariff. The cost of electricity is a central competition factor for energy intensive companies. The ability to compete on an international level and to save the resulting jobs has to be a priority, since electricity tariffs are already relatively high in Germany compared to its competition [42]. Because the industrial core of our economy is the key for wealth and employment in Germany.

The energy concept until 2050 plans to turn around the whole German energy supply for the benefit of everybody. Its goal is, to become one of the most environmentally friendly and most energy saving economies in the world, with competitive energy prices and a high prosperity.

[18] Minister for Economic Affairs and Energy and Vice Chancellor of Germany

To achieve these goals the development of renewable energies as an alternative to nuclear energy is the main concept. The share of energy delivered by the sun, wind et cetera for electricity production is supposed to be raised to 40-45 percent until 2025 and another 15 percent (55-60%) until 2035. Nowadays renewable energies provide 23% of the electricity mix [43].

But an energy supply, which is based on renewables, comes with a lot of challenges: There will be more installations, which produce electricity, because a single plant will not produce as much as today, since they are on a smaller scale compared to large power plants. The individual produced electricity has to be fed into the grid and has to be transported to the consumer. A lot of off-shore wind parks are built in the north of Germany, which will shift the production location and will implicate the extension on big supra-regional power grids and distribution grids to feed the south of Germany equally. Furthermore the need for storage capacity will increase, since renewable energy production is inconsistent compared to fossil power plants and therefore energy produced in the peak period has to be saved to be used in off-peak seasons. And for the case that the stored energy is not enough, flexible power stations have to be built, which can be started up quickly. To make renewable energies affordable, the storage capacities and the power grid itself have to be optimized by developing the technology further and further.

9.2 Renewable Energy Developments

The renewable-energy-law stays to be the most important tool for the development of renewable energies. By now photovoltaic, waterpower and biomass are already a major component of the electricity mix.

The German government plans on strengthening the onshore wind energy and to replace older wind turbines by newer, more efficient ones. The offshore wind energy in the North- and Baltic Sea will be subsidized by the new German Reconstruction Loan Cooperation-Offshore-Program with 5 billion Euros [44]. Two wind farms already received agreements to get funding provided, another proposal is in the decision phase and some more are being reviewed and inspected right now. Furthermore a new centrally organized coupling, a sort of multi-outlet power strip at sea, is being established. With this development wind farms can be connected faster and more environmentally friendly than with the single connections available now. In addition to that clear accountability laws for the grid connection of offshore-wind farms were determined, to minimize and fairly distribute the risk of disconnections.

The share of costs, for consumers, which pay for renewable energies, was raised in 2014 to 6,24 ct/KWh. Also the compensation for renewable energies was adapted [45].

9.3 Power Grids and Storage

By now the German power grid does not cover an area-wide transport for renewable energies. The German government has 24 development plans classified as “urgent”. Almost one quarter of them is completed, being 200 out of 850 kilometers of new power grids. The 850 kilometers are supposed to be finalized by 2015. The so called „Netzbaubeschleunigungsgesetz“ (freely translated: power grid development acceleration law) takes care that planning processes for high-voltage grids over border can be minimized from 10 to 4 years [46]. Additionally the German government introduced in 2012 the “Bundesbedarfsplan” (freely translated: governmental demand plan) to accelerate the power grid development. It contains 36 plans, which are necessary to modernize the system in the next ten years. Intended are power grid extensions on nationwide 2800 kilometers of new and 2900 kilometers of upgrading and strengthening existing grids. The costs are estimated to be around 10 billion Euros [47]. A crucial step with this venture is the collaboration between the federal government and the federal states. The federal states will assign major competences towards the federal government to accelerate the network expansion. The “Bundesbedarfsplan” law came into effect in July 2013 and is worked upon since then.

Also small plants are important for a stable network. Owners of older solar plants are advised to convert their plants to a newer one, to counteract the capacity overload at the 50.2 Hertz limit[19] [48]. Furthermore the intelligent electricity meters are optimized, to show when there is too much electricity produced and therefore should be used right away. This helps the consumer to better regulate the current demand and the electricity generation by themselves.

To store the fluctuating energy produced by wind and solar energy and to provide a security of supply for the consumer, energy storage has to be improved as well. The German government invests 200 million Euros for research and development in energy storage until the end of 2014. Furthermore energy storages are free of grid fees and are exempted from the EEG-contributions.

The federal Network Agency is concerned about congestions due to the nuclear phase out in Germany until 2022. This would mostly occur in the winter periods of the year, when renewables are not that efficient. Gas and coal power plants have to absorb the lack of renewable supply. Additionally the power grid stability as well as the fluctuation caused by renewable resources has to be counteracted by conventional power plants. But the annual report of the federal Network Agency in 2013 is expecting an indeed tense, but still controllable situation for the following years to manage [49]. Furthermore the federal government passed laws for the quick development of additional capacities.

[19] In Europe the grid frequency is at 50 Hertz at normal conditions. Is this limit reached the plants turn automatically off to avoid an over load. Therefore major black-outs could be caused by the 50.2 Hertz problem since decentralized solar plants would turn off simultaneously if the frequency is too high.

Already gas and coal power plants with a total capacity of ten gigawatts were enabled until 2013 and an additional ten gigawatts are supposed to go online until 2020.

If it is a realistic approach has to be determined throughout the coming periods, but by now the government aims to decrease the primary energy consumption by 50 percent until 2050. This goal is just accomplishable if we save energy in all areas of our life. In Germany almost 40 percent of the used energy is consumed by habitation. Until 2020 the federal government tries to lower the heat requirement on the whole real estate situation in Germany by 20 percent [50]. Afterwards realistic aims are that houses will become almost climate neutral, meaning to provide the houses own needs just by renewable energies, until 2050 [51]. By now the federal government supports property owners to sanify their houses, for example by better heat insulation or more modern heating installations, with 1.8 billion Euros. Furthermore regulations are planned to get electrical devices off the market, which use too much power, and to introduce “green” devices, with better energy efficiency.

10. Conclusion

10.1 General

The Bundesverband der Deutschen Industrie (BDI – freely translated: Federation of German Industries) has estimated that 350 billion Euros, of which 200 billion Euros are just due to the energy transition, have to be invested in the German electricity sector until 2030 [52]. Momentarily the electricity market is well developed in Germany, but there are severe problems concerning the infrastructure of the north-south network. It causes bottleneck situations, where undesired load flows through the networks of neighboring countries, mainly Czech Republic and Poland. The European Commission (EC) suggests that these issues need to be adequately solved to prevent obstacles for the collaboration between Germany and neighboring states. Furthermore, the EC states that "congestion management and transparency provisions for access to the network for the cross-border exchange of electricity should be introduced and national transmission capacity in the north-south direction reinforced, particularly in the light of offshore expansion plans and the integration of onshore renewables from wind and solar." [53] Additionally, the Commission recommends that Germany determines the connection between gas requirements and the corresponding electricity, primary on winter days. However, both points are already addressed by the German Federal Government, nonetheless decisions are still inexistent.

The energy concept of the German federal government bears high expectations towards the German energy supply. It has to be secure, economic and climate friendly. The challenge in the future will be to bring these three coequal criteria in balance.

Considering the contemporary energy sources in this regard, a lot of them are able to fulfill individual criteria. Coal, for example, is interesting for economic reasons, but has a high, and therefore climate unfriendly, CO_2 emission. On the other hand, renewable energies are strong concerning climate protection, but are at the moment not economically advantageous. However, renewable energies form the basis of the energy transition, and will rise about 50% in terms of electricity production by 2040. This is necessary, to compensate for the missing nuclear energy by 2023, the coal mining closure and to lower CO_2 emission in general. Even though its share will consist of one third in electricity production, mostly weather dependent photovoltaic and wind, it needs a strong and dependent partner source to keep stability during its fluctuations. This role is expected to be filled by natural gas, which is the cleanest fossil energy carrier and available during the upcoming centuries. Domestic extraction and the already existing infrastructure make it economically attractive. As a reliable and climate friendly basis for electricity production it is not just necessary, but indispensable. The share of natural gas is expected to rise up to over 33% until 2040.

Dr. Klaus Engel[20], one of the leading and most influential characters in the German industry, finds the qualified words in a statement in 2014 about Germany's energy transition and its future: „Germany has taken on this globally unexampled and very ambitious project – and now we are willing to realize it. The opportunities coming along with the energy transition are enormous: less dependency on fluctuating commodity prices and politically unstable exporters, fewer emissions and new technologies, which, if they are operating accordingly in Germany, can be exported around the globe. But until then, it will be a long, steep and very costly way. […] A survey by the Westphalian energy department came to the result, that the total costs solitary by the EEG-contribution will reach 110 billion Euros until the end of 2014. Until 2050 around 500 billion Euros will be invested, to be able to accomplish the energy transition aims set by the government. […] Stimulations for investments have to be created. For example tax incentives for investments in power grids or for research and development. The reason is that we do not just need investments in new power grids, but also in enhancements of current plants and grids – and especially for storage systems. The whole energy transition rises and falls with the development of more efficient power storage systems. We [The industry] have to be technically able to store surplus electricity and to access it at all times, to provide sufficient grid stability. And if we are able to store the produced electricity by renewables in noteworthy amounts, we will be able to fully operate our growing utilizations at full capacity. Otherwise we will always have the dilemma that we have to pay our neighboring countries [the Netherlands, Poland, Czech Republic] to take our spare produced electricity at peak times for free. Almost 20 billion Euros are invested by Germany this year in the energy transition. If just 10% would be consequently invested in the development of storage systems, I am confident, that our companies and engineers will find a solution, which is needed for the next development phase and we are therefore desperately looking for. […] Modern coal and gas plants are still the backbone of our electricity supply. Without the electricity contribution of conventional power plants there is no functioning system in the long-term view. They deliver independent of wind and weather at all times and they therefore contribute great stability to the power grids. The question is not about, whether we need conventional power plants or not, but rather how do we keep them in operation and how is it financed. On this topic politics play the main role. They have to formulate an authentic general framework, on how to preserve and operate the power plants with an economically safe investment cycle. To already formulate binding agreements about the remaining periods of modern coal plants is of no avail. Ultimately nobody can exactly calculate, how many conventional power plants we need in the future or for how long." [54]

[20] He is the chairman of the Executive Board of Evonik Industries AG, one of the world´s leading specialty chemicals companies, owned by RAG Foundation.

10.2 Special case: Natural gas

Natural gas is predicted to take over the leading position of mineral oil as primary energy carrier in 2030. In 2040, the share of natural gas will most likely reach 34% and will therefore be the number one in the German primary energy consumption. The high demand of natural gas can be covered by regional and global supply. Broad import structures, as well as flexible transport options, make sure that natural gas will be a reliable source in the future. Furthermore, Germany has a high potential of unconventional natural gas resources. It is important to explore the domestic deposits in more detail and to communicate modern extraction methods with the involved parties. In this field of natural gas Germany has the possibility to set new standards. If the natural gas sources can be used efficiently in the future, it will not just have a positive effect towards the security of supply and economics, but also on the German climate balance. Natural gas can not only strengthen but also make a valuable contribution towards the achievement of the goal and aims of the energy political triad.

The International Energy Agency states in their new survey (2014) about Germany that natural gas is a flexible energy supply source, which is able to make a smooth transition, after the nuclear phase out, to a CO_2 low emissive power sector. In the face of the structure of the German energy supply in the next ten years, a need on bigger mid-load capacities is necessary to compensate for the fluctuation of renewable energies. Furthermore, if Germany wants to keep its aims on lowering its greenhouse gas emission by 40% until 2020, a cleaner alternative to coal is needed [55]. Measures have to be developed for a long-term investment in flexible gas-fired capacities instead of a short-term sight in buying and burning cheap coal from the USA[21].

[21] Since the use of coal is declining rapidly due to the boom of unconventional gas in the USA, coal can be cheaply imported from there to Europe at the moment.

10.3 Final statement

The energy transition is one of the most important economic projects in Germany in the years to come. The dependence on its success will determine if Germany can keep the ability to compete on an international level as an industrial location. But as the energy transition raised awareness in the media, the Federal German Government and the public is mostly concerned and discussing new amendments for the EEG. Besides its self-evident importance, one has to realize that a lot more influencing factors play a role for the success of the energy transition, besides just cheap electricity and low costs for consumers. As analyzed throughout this Thesis, further developed constructions with a higher efficiency than today regarding renewable energy plants as well as a strong and reliable partner in natural gas are the main parts to compensate for the nuclear energy phase out and to secure the political trial. Supporting elements are the development of more intelligent power grids as well as more cost-effective financing models. Furthermore technical advances in the energy storage are of crucial necessity. Additionally, reliable long-term planning criteria set by the government are important for the public and industries investor's trust on a German as well as a European level. Further key factors will be more strict conditions for the energy efficiency and the accomplishment of a decentralized electricity system. These factors form a complex tangled interaction with each other and will, if acted jointly, provide the basis for the achievement of the set aims until 2040.

To conclude my Bachelor Thesis, I can positively answer my problem statement. An energy transition in Germany is possible with the help of renewable energies in the upcoming decades to compensate the phase-out in nuclear energy. It will need a strong and reliable partner, which will be the use and supply of natural gas. There is a great potential for more domestic exploration. With long-term financial support by the government the necessary research and developments needed, will be achieved to guarantee the political targets, being security of supply, economic feasibility and climate protection.

11. Bibliography

11.1 Figures

Figure 1: Stapelberg, Dr. H. H. by EMCEHG (2013). "Bruttoinlandprodukt." Energieprognose Deutschland. Retrieved 13.05, 2014.

Figure 2: Stapelberg, Dr. H. H. by EMCEHG (2013). "Bevölkerung." Energieprognose Deutschland. Retrieved 13.05, 2014.

Figure 3: Seiler, G. by EMCEHG (2013). "PEV Gesamt." The Outlook for Energy. Retrieved 16.05, 2014.

Figure 4: Seiler, G. by EMCEHG (2013). "PEV Erneuerbare Energien." The Outlook for Energy. Retrieved 16.05, 2014.

Figure 5: Stapelberg, Dr. H. H. by EMCEHG (2013). "Energieeffizienz." Energieprognose Deutschland. Retrieved 13.05, 2014.

Figure 6: Seiler, G. by EMCEHG (2013). "PEV Einsatz zur Stromerzeugung gesamt." The Outlook for Energy. Retrieved 16.05, 2014.

Figure 7: Seiler, G. by EMCEHG (2013). "PEV Einsatz zur Stromerzeugung mit erneuerbaren Energien." The Outlook for Energy. Retrieved 16.05, 2014.

Figure 8: E-ON by Prognos AG (2011), Energy Forecast. Retrieved 16.05, 2014.

Figure 9: Eurostat (2013), IEA statistics, BP statistics. Weltenergierat – Deutschland estimates. Retrieved 29.05, 2014.

Figure 10: Eurostat (2013), IEA statistics, Weltenergierat. Retrieved 29.05, 2014.

Figure 11: Eurostat (2013), IEA statistics, Weltenergierat. Retrieved 30.05, 2014.

Figure 12: Eurostat (2013), IEA statistics, Weltenergierat. Retrieved 30.05, 2014.

Figure 13: Arbeitsgemeinschaft Energiebilanzen (AGEB), Working Group on Energy Balances (2013). Retrieved 31.05, 2014.

Figure 14: Arbeitsgemeinschaft Energiebilanzen (AGEB) (2013). Retrieved 31.05, 2014.

Figure 15: Bundesverband der Energie und Wasserwirtschaft e.V (BDEW) (2013). Retrieved 09.06, 2014.

Figure 16: Bundesverband der Energie und Wasserwirtschaft e.V (BDEW) (2013). Retrieved 09.06, 2014.

Figure 17: Gas Naturally (2013). "CO_2 Emissionen in der Stromerzeugung". Retrieved 14.06, 2014.

Figure 18: Bundesanstalt für Geowissenschaften und Rohstoffen (BGR). "Schiefergas-Potenzial in Deutschland". Retrieved 17.06, 2014.

11.2 Literature

[1] Hennicke, Prof. Dr. P. & Fischedick, Dr.-Ing. M. (2010). "Erneuerbare Energien." Mit Energieeffizienz zur Energiewende **2**.

[2] Presse- und Informationsamt der Bundesregierung (2014). "Forschungsförderung." Retrieved 15.05, 2014, from http://www.bundesregierung.de/Webs/Breg/DE/Themen/Forschung/EnergieKlima/forschungfoerderung/_node.html.

[3] AG Energiebilanzen, Statistisches Bundesamt, BDEW (2013). "Energieintensität 1991 bis 2012." Retrieved 16.05, 2014, from https://www.bdew.de/internet.nsf/id/C125783000558C9FC125766C00057196/$file/Energieintensit%C3%A4t%201991%20bis%202012.pdf.

[4] E-ON & Prognos AG (2010). "Bedarf an konventioneller Kraftwerkskapazität in Deutschland.“ Retrieved 16.06, 2014, from http://www.metropoleruhr.de/fileadmin/user_upload/metropoleruhr.de/Regionalplanung/Energiewirtschaft_Fernwaerme/04b_02_Bedarf_konventionelle_Kraftwerkskapazitaet_Juni_2010.pdf

[5] World Energy Council (2013). "World Energy Resources – 2013 Survey.“ Retrieved 16.05, 2014, from http://www.worldenergy.org/wp-content/uploads/2013/09/Complete_WER_2013_Survey.pdf.

[6] Laabs, D. (2013). Experiment Energiewende - Deutschlands einsame Revolution, ZDF.

[7] European Commission (2014). "Europe 2020: Commission proposes new economic strategy." Retrieved 15.05, 2014, from http://ec.europa.eu/news/economy/100303_en.htm.

[8] Wyplosz, C. (2010). "The failure of the Lisbon strategy. " Retrieved 17.05, 2014, from http://www.voxeu.org/article/failure-lisbon-strategy

[9] (2013). "Europe 2020 Targets: climate change and energy." Retrieved 17.05, 2014, from http://ec.europa.eu/europe2020/pdf/themes/16_energy_and_ghg.pdf

[10] COM (2011). "Energy Efficiency Plan 2011." Retrieved 17.05, 2014, from http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0109:FIN:EN:PDF

[11] COM (2011). " Renewable Energy: progressing towards the 2020 target." Retrieved 17.05, 2014, : http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0031:FIN:EN:PDF

[12] World Energy Council (2013). "World Energy Resources – 2013 Survey.“ Retrieved 16.05, 2014, from http://www.worldenergy.org/wp-content/uploads/2013/09/Complete_WER_2013_Survey.pdf.

[13] World Energy Council (2013). "World Energy Scenarios – Composing energy futures to 2050.“ Retrieved 20.05, 2014, from http://www.worldenergy.org/wp-content/uploads/2013/09/World-Energy-Scenarios_Composing-energy-futures-to-2050_Full-report.pdf.

[14] World Energy Council (2013). "World Energy Scenarios – Composing energy futures to 2050.“ Retrieved 20.05, 2014, from http://www.worldenergy.org/wp-content/uploads/2013/09/World-Energy-Scenarios_Composing-energy-futures-to-2050_Full-report.pdf.

[15] World Energy Council (2013). "World Energy Scenarios – Composing energy futures to 2050.“ Retrieved 20.05, 2014, from http://www.worldenergy.org/wp-

content/uploads/2013/09/World-Energy-Scenarios_Composing-energy-futures-to-2050_Full-report.pdf.
[16] Torello, A. (2010). Sale of Azeri Gas Field Will Test EU's Pipeline Strategy. The Wall Street Journal. Retrieved 23.05, 2014.
[17] Weltenergierat – Deutschland (2014). "Energy for Germany 2013 – Facts, outlook and opinions in a global context". Retrieved 26.05, 2014.
[18] Macmillan, S. & Antonyuk, A. (2013). "Gas to Coal Competition in the U.S. Power Sector". IEA Publications. Retrieved 26.05, 2014.
[19] Masson, G. & Latour, M. (2013). "Global Market Outlook for Photovoltaics 2013 – 2017". European Photovoltaic Industry Association. Retrieved 26.05, 2014.
[20] Vogel, H. (2014). IEA warnt vor Strompreisschock. n-tv Wirtschaft. Retrieved 14.06, 2014.
[21] International Energy Statistics (2014). "Germany – Country Analysis Note". U.S Energy Information Administration. Retrieved 27.05, 2014.
[22] Morris, C. (2014). "Closer look at German energy dependence on Russia." German Energy Transition. Retrieved 27.05, 2014, from http://energytransition.de/2014/03/closer-look-at-german-energy-dependence-on-russia/.
[23] Eurostat (2013). "Estimates of CO2 emissions from energy use". Retrieved 28.05, 2014, from http://epp.eurostat.ec.europa.eu/cache/ITY_PUBLIC/8-29052013-AP/EN/8-29052013-AP-EN.PDF.
[24] Hegde, K. & Fjeldstad, E. (2010). "The future of European long term natural gas contracts". Retrieved 28.05, 2014, from https://www.bergen-energi.com/arch/_img/9548380.pdf.
[25] Gazprom (2014). "Nord Stream". Retrieved 12.06, 2014, from http://www.gazprom.com/about/production/projects/pipelines/nord-stream/.
[26] AGEB (2014). "Energiebilanz 2012". Retrieved 29.05, 2014, from http://www.ag-energiebilanzen.de/.
[27] (2013). Zu hohe Schulden: Unternehmen reduzieren Investitionen in Erneuerbare Energien. Deutsche Mittelstands Nachrichten. Retrieved 01.06, 2014.
[28] Marx, B. (2014). Bundeskabinett beschließt EEG-Novelle. Deutsche Welle. Retrieved 02.06, 2014.
[29] Gabriel, S. (2014). Pressekonferenz von Bundesminister Gabriel zum Kabinettsbeschluss zur EEG-Reform. ZDF.
[30] Federal Ministry of Economics and Technology (2011). "Research for an environmentally sound, reliable and affordable energy supply". 6th Energy Research Programme of the Federal Government. Retrieved 02.06, 2014, from http://www.bmwi.de/BMWi/Redaktion/PDF/Publikationen/6-energieforschungsprogramm-der-bundesregierung-en,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf.
[31] Frondel, Prof. Dr. M. & Schmidt, Prof. Dr. C. M. (2013). "Marktwirtschaftliche Energiewende: Ein Wettbewerbsrahmen für die Stromversorgung mit alternativen Technologien". Zeitschrift für Energiewirtschaft. Retrieved 05.06, 2014, from http://link.springer.com/article/10.1007%2Fs12398-012-0098-9
[32] Alpha Ventus (2012). "Fact-Sheet Alpha Ventus". Retrieved 12.06, 2014, from http://www.alpha-ventus.de/fileadmin/user_upload/av_Factsheet_de_Dez2012_2.pdf
[33] Bundesverband WindEnergie (2012). "Status des Windenergieausbaus in Deutschland". Retrieved 13.06, 2014, from http://www.wind-energie.de/sites/default/files/attachments/press-release/2013/jahresbilanz-windenergie-

2012-stabiles-wachstum-deutschland-im-turbulenten-weltmarkt/fact-sheet-statistik-we-2012-12-31pdf.pdf
[34] Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (2013). "Förderinitiative Energiespeicher". Retrieved 05.06, 2014, from www.bmub.bund.de/P829/
[35] Bundesministerium für Bildung und Forschung (2013). "Grundlagenforschung Energie 2020+". Retrieved 08.06, 2014, from https://www.ptj.de/lw_resource/datapool/_items/item_228/grundlagenforschung_energie.pdf
[36] Bundesverband der Energie- und Wasserwirtschaft (2013). "1. Rolle von Erdgas in der Energiewende". Retrieved 08.06, 2014, from http://www.bdew.de/internet.nsf/res/E82A40FC67D06BC8C1257BCC004CA1DE/$file/BDEW-13-00025_Erdgas_Kapitel_1.pdf
[37] Gossett, S. "Natural Gas and the Transformation of the U.S. Energy Sector". National Renewable Energy Laboratory. Retrieved 10.06, 2014, from http://www.nrel.gov/docs/fy13osti/57726.pdf
[38] Andruleit, H. (2013). "Energy Study 2013 – Reserves, Resources and Availability of Energy Resources". Federal Institute for Geosciences and Natural Resources. Retrieved 10.06, 2014.
[39] Wirtschaftsverband Erdöl- und Erdgasgewinnung (2013). "Erdgas Produktion in Deutschland". Retrieved 12.06, 2014, from http://www.gdfsuezep.de/cms/upload/PDF/Flyer_WEG/Erdgasproduktion_in_Deutschland.pdf
[40] Die Bundesregierung (2014). "Schritt für Schritt voran". Retrieved 14.06, 2014, from http://www.bundesregierung.de/Content/DE/Artikel/2014/04/2014-04-07-monitoringbericht-energiewende.html
[41] Die Bundesregierung (2014). "Chancen der Energiewende". Retrieved 14.06, 2014, from http://www.bundesregierung.de/Content/DE/Artikel/2014/04/2014-04-08-eeg-reform-kabinett.html?nn=391850#Start
[42] Bundesministerium für Wirtschaft und Energie (2014). "EEG-Reform". Retrieved 15.06, 2014, from http://www.bmwi.de/DE/Themen/Energie/Erneuerbare-Energien/eeg-reform.html
[43] Steffel, Dr. D. (2013). Frontal 21, ZDF.
[44] Bundesministerium für Wirtschaft und Energie (2014). "KfW Programme". Retrieved 16.06, 2014, from http://www.offshore-windenergie.net/en/politics/kfw-programme
[45] DPA (2013). 6,24 Cent pro Kilowattstunde: Ökostromumlage steigt auf Rekordwert. Spiegel Online Wirtschaft. Retrieved 16.06, 2014.
[46] Bundesministeriums der Justiz und für Verbraucherschutz (2011). "Netzbaubeschleunigungsgesetz Übertragungsnetz". Retrieved 16.06, 2014, from http://www.gesetze-im-internet.de/bundesrecht/nabeg/gesamt.pdf
[47] Bundesministeriums der Justiz und für Verbraucherschutz (2013). "Gesetz über den Bundesbedarfsplan". Retrieved 16.06, 2014, from http://www.gesetze-im-internet.de/bbplg/BJNR254310013.html
[48] E-ON (2013). "50,2 Hertz Problematik". Retrieved 16.06, 2014, from http://www.eam.dede/netz/erzeugungsanlagen/50-2-hz-problematik
[49] Bundesnetzagentur für Elektrizität, Gas, Telekommunikation, Post und Eisenbahnen (2013). "Jahresbericht der Bundesnetzagentur 2013". Retrieved 16.06, 2014, from

http://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Allgemeines/Bundesnetzagentur/Publikationen/Berichte/2014/140506Jahresbericht2013
[50] Die Bundesregierung (2014). " Energiewende – Fragen und Antworten". Retrieved 16.06, 2014, from http://www.bundesregierung.de/Webs/Breg/DE/Themen/Energiewende/Fragen-Antworten/1_Allgemeines/1_warum/_node.html
[51] Die Bundesregierung (2014). " Energiewende – Energie sparen". Retrieved 16.06, 2014, from http://www.bundesregierung.de/Content/DE/StatischeSeiten/Breg/Energiekonzept/02-energieeffizienz.html
[52] Bundesverband der Deutschen Industrie (2013). "Energiewende auf Kurs bringen, Handlungsempfehlung an die Politik für die erfolgreiche Umsetzung der Energiewende". Retrieved 16.06, 2014, from http://www.bdi.eu/Publikationen_13111.htm
[53] Eurostat (2011). "Germany – Energy Market". Retrieved 18.06, 2014, from http://ec.europa.eu/energy/gas_electricity/doc/de_energy_market_2011_en.pdf
[54] Gruß, Dr. A. (2014). Die Energiewende betrifft alle. CHEManager, **10**. Retrieved 12.06, 2014.
[55] International Energy Agency (2014). " Energiepolitik der IEA-Länder". Retrieved 16.06, 2014, from http://www.iea.org/media/executivesummaries/GermanyExecSumDEUTSCH.pdf