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The German energy transition (*Energiewende*)

Policy, Energy Transformation and Industrial Development

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PRESENTATION

Emiliano López Atxurra

President of the Committee of Sponsors of the Energy Chair of Orkestra-BIC

In the European Union and particularly in the French-German axis the energy transition has taken centre stage in the debate on energy policy. Historically, such transitions have occurred when the structures of energy sources have been modified in different regions or countries, or when technological changes have brought about important transformations, thus creating opportunities for new energy sources and relegating others in importance.

In Europe, countries such as Germany and France have initiated processes of change in their energy structures from different perspectives. The transition in Germany is particularly important for two reasons: firstly, because of the country's importance and weight in Europe; and secondly, because the process of energy transition and transformation is linked –sometimes structurally– to industrial policy.

As this study shows, these processes of change began several years ago in Germany and have gained greater momentum since the 21st Conference of the Parties on Climate Change, held in Paris at the beginning of December 2015.

For a number of reasons of varying importance, including a recognition of the preeminent role of Germany within the Union and because of its role as a reference point in industrial and technological policy centring on energy and mobility, and because of its particular defence of its industrial model, the Energy Chair of Orkestra felt it would be of interest to make an in-depth and wide-ranging analysis of the issue of German energy, rigorously identifying what the *Energiewende* involves, what its aims are and at what phase it currently stands.

"The German Energy Transition (*Energiewende*). Policy, Energy Transformation and Industrial Development" addresses key aspects of this important process from an all-embracing perspective.

The report is divided into four basic blocks: the first deals with policy; the second with the energy structure in Germany; the third with the concept and details of the *Energiewende*; and the fourth with industrial matters. The study concludes with some reflections and final considerations.

The first block (on policies) reviews the background and reasons for energy transitions and goes on to analyse the political framework and the important role the authors believe the Greens have played in the process.

To understand the *Energiewende* it is important to know the current situation and historical development of the German energy transition. The second block therefore provides analysis of primary and final energies, examining oil, gas, coal and electricity in detail to give a comprehensive picture German energy structure.

The third block, which constitutes the core section of the report, deals with the *Energiewende* itself. It identifies the basic objectives and the way in which they are being developed, looking at key issues of the energy transition in Germany and sketching out the future vision contained in the horizon to 2050. It also analyses key basic regulation, entering into some detail on the mechanisms of the "feed-in tariffs" for renewable energies and how they have developed.

Given the impact of this process on increases in electricity prices, it also analyses trends in prices, particularly for the high energy-consuming industries most affected by the process.

No less importantly, this section also contains a discussion of the implications and difficulties that have arisen.

The last block, before the final reflections and considerations, examines the industry surrounding renewables, with a comprehensive analysis of wind energy, photovoltaics, biomass and biogas. The authors provide a detailed list of German companies operating in these sectors, analysing the effect of the energy transition on the renewables industries. In order to put this issue into context, a review of the perspectives of both European and German industrial policy is also provided.

The study thus allows a broad first-hand analysis from which the authors draw a number of reflections and final considerations in the final chapter.

Given the importance of the energy transition and energy efficiency, a discussion of Germany's position with regard to EU industrial and energy policies may be useful, offering relevant reference points for the future design of our energy and industrial policies.

I would like to conclude by thanking the team that have prepared this study –Eloy Álvarez Pelegry, Iñigo Ortiz Martínez and Jaime Menéndez Sánchez– for their commitment and dedication to the work of the Chair.

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1. INTRODUCTION

This introduction provides some references and thoughts on energy transitions and sets out the scope and objectives of the study.

On energy transitions

According to Smil (2010),[2] there is no generally accepted definition of the term "energy transition". The concept is normally used to describe the change in composition or structure of primary energy supply, as well as the gradual transformation from a specific model of energy supply into a new stage of the energy system.

Nordensvärd, J. *et al*.[3] argue that the term refers to changes involving the replacement of certain energy sources that affect a country's economic activities. There have been a number of energy transitions throughout history, particularly in developed countries. Certain key landmarks can be identified, such as the transition from the use of manpower and beasts of burden to traditional biomass (firewood, harvest waste and manure); from traditional biomass to coal (with 1860 as the key year); from coal to oil (1880); and finally from oil to gas (1900). Other key milestones include the introduction of natural gas in power and heating (between 1900 and 1910) and the introduction of nuclear power (1965), renewable systems and hydroelectric plants (1995) in power production.

The term "energy transition" may also refer to the gradual spread of new devices, such as the replacement of human and animal labour by mechanical engines. This mainly consists of changing patterns of energy use, modifying energy quantities (from energy shortage to abundance or *vice versa*) and making substantial changes in energy resources, such as the production of electricity from wood.

Comprehensive energy transitions in large economies inherently take a long time. Various decades are usually needed to complete these processes. Normally, the greater the dependence on a particular source of energy or driving element, the longer the use of existing sources will persists and, consequently, the longer the time required for their replacement. This might seem obvious but it is seldom taken into account, hence the abundance of failed predictions on the imminent success of new energy sources or new technologies.

Driving elements also play an important role in energy transitions. Smil (2010), for example, notes the extremely long periods of time between the discovery of scientific principles and the development of patents and industrial applications with growing economies and volumes.

Therefore, not only do energy transitions require time, but they do not guarantee the total eradication of earlier, profitable energy sources either (with low prices, costs or other advantages). Furthermore, technology clearly plays a key role in time-

[2] (Smil, 2010)
[3] (Nordensvärd & Urban, 2015)

to-market. And finally, but no less importantly, the combination of the market with technological and energy developments is also required for successful transformations.

The current context of energy transitions

The recent COP21 (Twenty-First Conference of the Parties) organized by the United Nations Framework Convention on Climate Change (UNFCCC) (Paris, 30 November-12 December 2015) accepted[4] that the global energy transition had already begun and would continue to develop.

In relation to the energy transitions currently being implemented and those yet to be undertaken, Jean-Claude Juncker, President of the European Commission,[5] told the conference that "European cities, and at the forefront, innovative companies, are committing to energy efficiency and the development of renewable energies. This energy transition is charting a new world, a low-carbon world, rich in opportunities". Speaking in similar terms, Miguel Arias Cañete, European Commissioner for Energy and Climate action, said[6] that "this COP has a very clear message; every country has to make a transition towards clean energies, renewable energies, energy efficiency and good management of agriculture, forestry policy, transport and building".

European energy policy is currently designed towards 2020, 2030 and even 2050. As IPPC and IEA energy scenarios show, energy systems are very likely to see substantial changes in the future (IEA, 2014b) (IPPC, 2012), highlighting the importance of designing appropriate energy policies.

In Europe, energy is an issue of great concern for the European Commission, due to its position as an input in industry and the key role it plays in achieving an environmentally sustainable economy. As a result of the Communication from the Commission to the European Council and Parliament, *An Energy Policy for Europe*, some regulation in this area was developed which is expected to extend beyond the energy sector (Directive 2009/28/EC, Directive 2009/29/EC, among others).

Directive 2012/27/EU, published in the Official Journal of the European Union (OJEU) in October 2012, sets a general target of reducing European primary energy consumption by 20% by 2020, as well as achieving new improvements in energy efficiency. Energy efficiency is therefore also a major aspect in the European strategy for sustainable growth to 2020. It is also one of the pathways for ensuring energy supply security and reducing greenhouse gas emissions.

The European Union remains committed to meeting its 20-20-20 targets by 2020. These consist of: a) 20% reduction in Greenhouse gas (GHG) emissions, compared to 1990; b) a 20% reduction in energy consumption, through greater energy

[4] (Pellerin-Carlin & Vinois, 2015)
[5] Statement retrieved from https://www.youtube.com/watch?v=WorPDG0be9Y
[6] Statement retrieved from https://www.youtube.com/watch?v=m0Ko9buZ1sM

efficiency; and c) a 20% contribution of renewable energy to final gross energy consumption.

It also targets a reduction of 40% in GHG by 2030 (compared to 1990 levels) and 80-95% by 2050; 27% renewables in final energy consumption by 2030 and a 27% reduction in total energy consumption (compared to current levels) by 2030.

Any achievement of climate targets by a member state (whether self-imposed or set by the EU), has to be performed within the current context of a move towards an Energy Union, another important development in the European energy scenario. Through this process, the EU intends not only to achieve environmental improvements, but also goals related, *inter alia*, to issues such as supply security, completing the energy market and improving interconnections in peripheral countries.

In this context, Germany announced the start of its energy transition in June 2011, with the establishment of its energy plan following the Fukushima accident in Japan in March 2011.[7] The German energy transition (*Energiewende* in German) aspires[8] to transform the German energy system by focusing on renewable energies as the fundamental tool for improving energy efficiency and confronting the challenge of climate change.

The *Energiewende* is being played out at a time when a number of countries are studying or searching for energy systems with lower emissions of greenhouse gases, particularly CO2; such systems are normally known as low-carbon economies or low-carbon energy systems.

In the United States, the Obama administration has launched an ambitious program for promoting renewables and closing coal-powered plants under the *Clean Air Act*, further backed by the low price of natural gas (Burtraw, Linn, & Mastrangelo, 2014).

On 4 August 2015, speaking in the White House, President Obama launched the *Clean Power Plan*, which targets a 32% reduction in emissions from thermoelectric plants compared to 2005 levels. In this way, Obama hopes to meet the US's commitment to reduce its contribution to climate change (Redacción BBC Mundo, 2015).

Some authors also consider the case of Japan to be important. The country appears to be pursuing a similar line to Germany, although it is important to note that its objectives are determined more by necessity (Heuskel, D., 2013). Since the accident at Fukushima (here a parallel can be seen with the German situation), Japan has begun cutting nuclear generation. The result has been an energy shortage in all sectors, which has sparked debate on the right level of reduction. The potential of renewable energies and distributed generation to cover this shortfall has been

[7](Bayer, 2015) (Martí Font, 2014) (Öko-Institut e.V., 2013)(Von Hirschhausen, 2014)

[8] Possible dates for the beginning and development of the *Energiewende* are examined in detail in Point 2. As will be seen, the origins of the *Energiewende* concept can be traced to before this date.

considered, although Japan's small land area is a major limitation to concentrated solar and wind generating operations.

Turning again to the European framework, on 4 August 2015, after several months of discussions, France published a new act setting out targets for the country's energy transition: a 40% reduction in GHG emissions by 2030 (compared to 1990 levels); a 75% reduction from current emission rates by 2050; a 50% cut in 2012 energy consumption levels by 2050 and a 32% contribution from renewables by 2030. These measures affect not only energy and industrial operations, but also the construction and transport sectors.

In these contexts, the *Energiewende* has therefore aroused considerable interest, being seen as an example for other areas, especially other EU countries, since Germany is the first developed country with an ambitious plan for changing its energy system and also one of the strongest European economies. The interest is not just in analysing the situation and development of the *Energiewende*. It is also in predicting the possible impact it might have in other countries, and in determining best practises that can be implemented and drawing conclusions from them. However, it is debatable whether an energy transition like the *Energiewende* can be undertaken by other economies with similar ambitions.

Champions of *Energiewende* defend its potential while detractors are more sceptical about the policies, pointing to the cost and the economic and financial sustainability.

Objective and range of the study

The aim of this study is to analyse the energy situation in Germany and examine *Energiewende* targets from various perspectives ranging from political and regulatory issues to questions of energy structure and competitiveness. The relation between energy and industry is also considered.

Taking into account the continued strong influence of policy and regulation, it has been considered advisable to address these topics in Block I of this study, dealing with precedents and incentives.

The analysis shows that, far from being a recent issue, a great number of the ideas of the energy transition date back many years. For this reason, we examine the political context and path of the "Greens", since it is difficult to understand the process without examining and understanding the political context in which the energy transition has developed.

No analysis of the energy transition in Germany can be entirely divorced from the historical evolution of its energy structure, in terms both of primary and final energies and "basic" energies, such as oil, coal, gas and electricity. Following a description of the current situation, Block II therefore looks at the historic development of the energy structure.

Block III examines the basic objectives, with short and medium-term trends. It also looks at the future vision of the *Energiewende*, in terms of its targets. Finally, we conclude with a chapter identifying ten key topics.

Naturally, this section also deals with the regulatory framework, carefully examining changes in regulation of the German transition process.

Finally, this block addresses the implications for competitiveness and industry, trends in electricity prices and the cost of this transition, in order to provide a comprehensive understanding of the list of targets and their impact on prices.

In this chapter we also examine some other implications and review certain difficulties that have arisen in the process.

Block IV tackles a key element for the energy transition: industrial policy. With both successful and unsuccessful decisions along the way, this has gone hand in hand with the implementation of energy policies. We will therefore try to reflect German industrial policy within the wider context of European industrial policies.

Given that much of the debate and the relationship between energy and industry in the energy transition focuses on the development of renewables, Block IV contains a chapter specifically devoted to this issue. We offer a detailed list of companies operating in the wind, photovoltaic, biomass and biogas energy fields, with a number of appendices to support the analysis.

Finally, in the conclusions section, we identify key elements in the results of our analyses.

There are a number of areas which merit further examination, based on the results of this study. Although not included in this report, they might be earmarked for more detailed analysis in the future.

The first is related to energy efficiency and to analysing why, despite all the regulation and effort, progress towards the stated objectives has been so slow.

The second involves transport; although all authorities agree on the need to include this area in any integral energy transition, it still presents numerous difficulties.

The third great issue involves an analysis of the relationship between energy and industry to complement the analyses made in this report, in terms of net creation of industry and jobs, in the current situation of the *Energiewende.* A comparative analysis is also needed of the repercussions for industry of introducing energies such as oil, coal and nuclear power. In this regard, it would be of interest to examine the total and net costs of the *Energiewende* in greater depth.

Finally, one interesting topic from both from a conceptual point of view and in terms of its practical implications, is the role of markets and, particularly the electricity markets, given that a combination of incentives and subsidies, bound to regulation and a policy with binding targets, together with the growing development and incorporation of renewables, is inconsistent with the potentiation of electricity markets and has implications for their functioning.

2. PRECEDENTS AND CAUSES

Germany has implemented a process that will last for decades. It is designed to base its energy system on renewables to the greatest possible extent and to reduce the use of fossil fuels and nuclear energy as far as possible (including the elimination of their use in power generation). This "technical/economic/political" project is known as the *Energiewende* and has received considerable support in parliament and from society at large.[10]

The German *Energiewende* might be said to be a unique "historical-political" project that cannot and should not be transferred in its entirety directly to any other country or region. Nonetheless, a number of lessons can be learned from this project of large-scale transformation of existing energy systems.

One of the main thrusts of the German energy transition is a move from an energy mix (including not only electricity, as we shall see) with a relatively small contribution from renewable energy to one in which RE plays a vital role,[11] although reducing greenhouse gases emissions and increasing energy efficiency are parallel objectives. These goals, which include the phasing-out of nuclear generation, pursue effective results in the fight against climate change, while at the same time reducing external energy dependency and boosting the economy. They are both difficult and complex in nature.

One idea underlying this transition is to link energy policy to industrial and economic policy, together with an opportunity to develop new technologies or industrial sectors, especially those related to energy.

As we shall see, the issue of competitiveness – a key element–has been addressed partly by charging the highest costs for domestic consumption and partly by granting exemptions to power-intensive industry.

The following sections offer an analysis of the history of the *Energiewende* and the factors behind its momentum.

2.1. Precedents

Although the term *Energiewende* has only recently come into vogue and usually refers to the period from 2011, its origins can be traced back far earlier, to the early 1970s.

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[9] A map of the different federated states or *Länder* in Germany is included in Appendix 13.2.

[10] The decision to begin the nuclear shutdown was passed by an absolute majority in parliament in 2011 (with support from the SPD, Greens and FDP, as well as the CDU/CSU)(Müller, 2011). 69% of Germans favour the *Energiewende* and consider that its advantages outweigh its disadvantages (Morris & Pehnt, 2012).

[11] To provide a wider context for the starting point of the transition, in 2014 the primary energy mix in Germany contained 11.1% of renewables. In Spain, the figure was 27.1% (see Chapter 4 *Energy structure*).

1970s

Debates on the creation of an energy policy intended to establish a roadmap for abandoning fossil fuels and nuclear power go back to the political movements of 1968. It is important to remember the monopolist context of the time, in which power facilities were becoming larger and larger. The term *Energiewende* became popular to refer to greater democratic control, environmental activism and opposition to the nuclear industry.

Erhard Eppler, leader of the Social Democratic Party (SPD) and Federal Minister of Economic Cooperation, was the first person to establish the notion of *wende* (transition) in his book *Ende oder Wende. Von der Machbarkeit des Notwendigen* (End or Transition. From Necessity to Facilitation) in 1968 (Von Hirschhausen, 2014).

At the same time, following publication of the Club of Rome's report *The Limits of Growth* in 1972, the idea of making sustainable use of fossil fuels and opposition to nuclear energy began to spread (Von Hirschhausen, 2014).

The oil crisis of 1973 and 1979 led to the first energy efficiency policies and deliberation on ways of achieving an "alternative" energy supply. It also highlighted the economic risk of rising oil prices. In Germany, energy conservation was also seen as a way of reducing dependency on energy imports.

The *Energiewende* movement emerged at the same time as the anti-nuclear movement of the 1970s. In 1973, when plans were published to build a nuclear plant in Wyhl (a wine-growing region bordering France), students from the neighbouring region of Friburg joined forces with wine growers from the region and scientists such as Florentin Krause. In February 1975, they launched the German antinuclear movement.[12]

Nonetheless, the oil crisis of 1973 spawned a feeling that the country's energy supply was vulnerable, which helped sustain support for nuclear energy.

1980s

The term *Energiewende* appears to have been first coined in 1980 in a study by the German Institute of Applied Ecology (Öko-Institut) which set out the energy alternatives for ending the use of uranium and oil. The report, published at the height of the antinuclear movement, argued that an alternative energy supply was possible (Aykut, 2015).

This was one of the first reports to argue that economic growth was viable with lower energy consumption – an idea that was later taken up in other texts, such as *Factor Four* in 1998, though no specific solutions were proposed.

Another of the first references to *Energiewende* appeared in the contemporary book *Growth and Wealth without Oil and Uranium* (Krause et al., 1980). This was one of

[12] (Martí Font, 2014)

the first treatises to contain consistent proposals, fundamentally based on renewable energies and energy efficiency.

Thereafter, the *Energiewende* philosophy was promoted on various fronts. In addition to the Institute of Applied Ecology (*Öko-Institut*), a number of politicians also came out in support of renewable energies, amongst them Peter Ahmels of the Christian Democratic Union (CDU), director of the German Wind Energy Association (BWE or *Bundesverband WindEnergie*) for eleven years. Another prominent supporter was Franz Alt, author in 1999 of *Der ökologische Jesus* (*Jesus the Ecologist*).

In 1983, as a result of the antinuclear movement, the governor of the state of Baden-Württember called a halt to the Wyhl muclear plant project. This success encouraged the movement to believe it was really possible to stop the construction of nuclear power plants. It was also one of the factors leading to the formation of the Greens as a political party in 1980. One of the reasons for their success was the inclusive nature of the movement, with conservatives and ecologists working side by side from the outset (Morris & Pehnt, 2012). It is worth mentioning too that the idea of energy renovation included the intention of promoting and extending the use of renewables.

In April 1986, the accident at the nuclear plant in Chernobyl (Ukraine) that led to meltdown of the reactor core sparked international alarm due to the high levels of radioactivity detected and the subsequent environmental disaster. The resulting radioactive rain in Germany (as in other parts of Europe), together with other factors, led to a collapse in the German public's confidence in the security of nuclear power, leading to an increase in social alarm.

In August 198, as a consequence of the accident at Chernobyl, the SPD –which had supported nuclear energy in 1979– called for the abandonment of all nuclear energy in ten years. The most immediate result of this political change was the termination of R&D programmes in the SPD-governed state of North-Rhine Westphalia, both in high-temperature gas-cooled reactors and in fast breeder ones, after 30 years of work (World Nuclear Association, 2016). The federal government, led by the CDU, meanwhile maintained its support for nuclear energy until the party lost the 1998 elections (see Section 3.1).

After Chernobyl, the conservative government[13] with Chancellor Helmut Kohl and environment minister Professor Klaus Topfer, enacted the first law "on payment of renewable energy tariffs" in 1990. The act was devised following the suggestion made by the European Commission to stimulate renewable energy.

1990s and reunification

At the end of the 1980s, several public companies in three German states introduced the concept of "total cost compensation", regulating the first *Feed-in Tariffs (FiTs)* in Germany. Activist Wolf Von Fabeck became the first person to implement the feed-

[13] (Morris & Pehnt, 2012)

in tariffs in order to promote solar energy in his home village of Aschen at the end of the 1980s. In 1991, a law on FiTs –the *Stromeinspeisungsgesetz* (StrEG)– was enacted.

The *Energiewende* movement was further strengthened by the Green's first entry into a German government, in Hessen in 1985. In 1998,[14] Jurgen Trittin, a leading figure in the Green Party, became minister of the environment, thus gaining access to the dossiers on renewable energy held by the ministry for the economy, which had traditionally held the portfolio. The changes in German renewable policy may partly explain the successful inception of the *Energiewende*.

In 1998 the coalition government (see Section 3.1) decided to change the law on progressive withdrawal from nuclear energy and in June 2000 it agreed to an arrangement setting a limit for output from nuclear plants (equivalent to 19 reactors operating for 32 years). This was combined with other complementary measures, such as a tax exclusion and an examination of the safety of reactors in Germany, as well as maintenance of waste storage facilities in Konrad and Gorleben.

Start of a new century

The Renewable Energy Sources Act of 2000 (*Erneuerbare-Energien-Gesetz*, EEG) maintained the philosophy of the StrEG (Law for FiT) for specific technologies and as a long-term (20-year) support mechanism for renewable energies (mainly wind, solar PV and geothermal and later extended with regulations covering bioenergy). In addition, FiTs were disassociated from the percentage of the retail fee and differentiated by the actual costs of the specific investment in terms of size and type of technology. The ideological champions of this law were MPs Herman Scheer and Dietmar Schütz for the SPD, and Hans-Josef Fell[15] and Michaele Hustedt for the Greens.

Specifically, the act led to development of more wind energy. The "conventional" energy sector decided to take legal action. EU Commissioner for Competition, Karel Van Miert, went on the record as stating that he considered the FiTs to be unlawful subsidies and the German power company Preussenelektra (which merged with Bayernwerk in 2000 to create E.ON Energie), decided to take the matter to court. The case reached the EU Court of Justice, which in 2001 ruled that FiTs did not constitute public subsidies and were therefore not illegal, thus enabling the development of renewable energies.

Another tangible result of the political movement, within which the concept of the *Energiewende* can be encompassed, was the nuclear decommissioning approved in 1998 and implemented through an agreement with the nuclear industry in June 2001. That commitment involved a reduction in output after 32 years in service, leading to closure of Stade and Obrigheim (2003 and 2005 respectively) and of the

[14] (Von Hirschhausen, 2014)
[15] Section 3.2, explaining the phenomenon of the Greens, discusses Fell's essential influence in the drafting of the act.

inoperative Mülheim-Kärlich reactor, which began to be dismantled in 2003. The agreement also banned construction of new nuclear plants and introduced the principle of storing spent nuclear fuel at a single site (World Nuclear Association, 2016).

The Renewable Energy Sources Act (EEG) in 2000 was amended in 2004, and the *100,000 Solar Roofs*[16] programme for photovoltaic energy –which provided for a bonus (applied to the purchase price)– was cancelled; in its place solar panels were offered the advantages of FiTs. In 2009, the act was again amended by the coalition of Social Democrats and Christian Democrats (without the Greens in government) and it was realized that this support needed to focus on the markets. This encouraged wind energy producers to sell power directly to the market, instead of receiving FiTs, whenever it was more cost-effective to do so and offered a marketing bonus (Morris & Pehnt, 2012).

Another important element, and one that it is not often discussed in the literature, is the boost given by the European Commission to what later became included as the "third package" of energy policy, capable of breaking some of the vertical mergers in countries like Germany, resulting in major penalties from the European Commission. González Finat writes that "it was necessary in 2006 for the European Commission, using its exclusive authority on competition policy, to make an analysis[17] of the industry showing that the conduct of various stakeholders was opposed to Treaty principles. The threat of a consequent sanction led to what was known as the "third package", launched by the Commission in January 2007 and adopted in 2009. This represented a qualitative and important step forward on the road to the creation of an internal electricity and gas market within the European Union, given that the previous legislation had not achieved its stated objectives" (González Finat, 2013).

From 2010/2011

On 28 September 2010, the German Federal Ministry for the Environment, Nature Protection, Building and Nuclear Security (BMU or *Bundesministerium für Bildung und Forschung*) and the German Federal Ministry for Economic Affairs and Energy (BMWi or *Bundesministerium für Ernährung und Landwirtschaft*) published[18] a document entitled *Energy Concept*, which set out Germany's energy policy to 2050. It was built on an increase in renewable energy and the development of distribution grids and improvements in energy efficiency.

The conservative government that came to power in 2009 changed the timeline for nuclear decommissioning approved in 1998, extending the operating lifespan of German nuclear plant by 8 years in the case of power stations built before 1980, and by 14 years for those built after that date. At the same time, it also implemented

[16] It began in 1988 as *1,000 Solar Roofs*.
[17] (European Commission, 2007)
[18] (BMWi & BMU, 2010)

other measures, increasing the percentage of renewables, with a further €200 million in support for the period 2013-2016 and setting targets for GHG emissions reductions. A tax on nuclear fuel was also included.

On 11 March 2011, the Daiichi nuclear plant in Fukushima, Japan, was severely flooded and damaged as a result of a tsunami, causing radioactive contamination. That same month, the German government declared a three-month moratorium on the operation of all nuclear plants in order to conduct inspections and reconsider the country's nuclear policy. On 14 March 2011, it was announced that seven nuclear plants would close[19] in Germany, to be followed by all remaining plants by 2022. This closure plan has been dubbed the *Atomausstieg*.

In May 2011 the German Commission for Reactor Supervision, having examined 17 reactors, concluded that there was no problem in their continued operation. Nevertheless, given the opposition to nuclear power of some of the states in the federation, the Government decided to progressively close the plants by 2022, whilst still maintaining the tax on fuel. The *Bundestag* approved the measures with 513 votes in favour at the end of June and the decision was ratified by the *Bundesrat* on 8 June. Both chambers approved the construction of new coal and gas plants, as well as the development of more wind energy[20] (World Nuclear Association, 2016).

Chancellor Merkel might therefore be said to have adopted a "nuclear shutdown" in the *Energy Concept* plan, favouring approval of the move. On 6 July 2011, Germany passed[21] the 2010 energy pack; the date can be seen as marking the beginning of its energy transition, the *Energiewende*. The influence on this decision of a 2011 report[22] by the Ethics Commission for a Secure Energy Supply is important.

In social terms, *Energiewende* is a project that requires enormous citizen involvement and implementation of its vision will probably require changes in daily life and possibly in economic structure and activities. It will also require profound social changes, not only in the area of energy, but in architecture, urban planning, agriculture and the economy. Some analysts consider that the transformation is comparable to the change following the economic miracle of the post-war years.

One hundred and eighty universities and polytechnic schools are now working on the energy transition program and between 2011 and 2013, the Ministry for Research had a fund for grants related to this programme of €2 billion.[23]

Surprisingly, the change in government following the federal elections of September 2013 did not alter energy policy or the objectives of the *Energiewende*. The coalition agreement, known as the "Grand Coalition" of Christian Democrats and Social

[19] Note that this followed an analysis by the Oko-Institut and the WWF (World Wildlife Fund) (Öko-Institut e.V. & WWF, 2011)
[20] For the World Nuclear Association, the *Energiewende* is this substitution of nuclear energy by fossil fuels and subsided renewables.
[21] (BMWi & BMU, 2011)
[22] (ECSES, 2011)
[23] (Martí Font, 2014)

Democrats (which enjoys a majority in parliament of more than two thirds), has largely met the targets, confirming that the *Energiewende* is here to stay and removing any doubts as to possible changes to the programme of nuclear decommissioning.

2.2. Motivations. An initial approach

For Craig Morris,[24] there are various reasons for switching to renewable energy and increasing energy conservation and savings. Amongst the most important are: a) to stop climate change and reduce GHG emissions, b) to reduce energy imports and achieved greater energy security, c) to boost the national economy and d) nuclear energy decommissioning.

As we shall see below, the instruments required to address these targets focus on increasing renewables, energy efficiency and nuclear decommissioning (which runs contrary to a reduction in GHG emissions). We shall address these objectives in Chapter 5.

Climate change

The burning of coal, oil products and gas all contribute to global warming. One of the objectives of the German *Energiewende* is to remove carbon from energy supply, with increased incorporation of renewable sources and a reduction in demand through higher efficiency.

In order to maintain the carbon budget[25] at 450 ppm of CO_2 equivalent, a zero level of greenhouse gas emissions would be required by the beginning of 2030. Moreover, if we accept that developing countries will slightly increase emissions as they achieve greater development, the burden of emissions reduction will lie even more with industrialized countries. On this basis, it may be predicted that Germany will have to reduce its emissions by 95% –rather than 80%– by 2050 (compared to 1990 figures) in order to reach its targets.

The World Wildlife Fund (WWF) commissioned a study from the Institute of Applied Ecology of Germany, the Öko-Institut, and the consultancy firm Prognos[26] to establish the actions needed to achieve the 2050 targets, *inter alia* the 95% emissions reduction, without affecting Germans' standards of living. The study found that first and foremost, greater efficiency was needed to reduce energy demand, including energy in heating.

[24] (Morris & Pehnt, 2012)
[25] The *carbon budget* was established by the Global Carbon Project (GCP) in 2005 and is defined as the maximum quantity of carbon that a country or economy can emit in a given (and sufficiently long) time period, for which adequate mechanisms must be introduced to ensure the limit is not exceeded. It is assumed that in order to limit the average global temperature rise to 2 °C, emission levels must not exceed CO_2 eq. 450 ppm (GCP, 2015)(Greenpeace, 2014)(pwc, 2013).
[26] (Ziesing, Prognos, & Öko-Institut e.V., 2009)

Secondly, energy sources would need to be switched to renewable sources. Indeed, renewable energies can cover an ever larger portion of the energy still required for consumption.

The largest problem still remains in the transport sector, where ever more complex solutions will be required. However, according to the study, emissions from the transport sector can be reduced by 83% compared to the current level by 2050.

Energy security

As the table below shows, Germany is a major importer of primary energy and an exporter of electricity. The country imports approximately 70% of the energy it uses and, in 2012, the country spent €87 billion on energy imports.

TABLE 1. German energy mix: imports of conventional energy from 2005 to 2013 (%)

	NATURAL GAS	COAL	OIL	URANIUM	SOLID FUELS	DEPENDENCY ON IMPORTS
2005	79.6	57.5	97	100	31.7	60.4
2010	81.2	73.7	96	100	40.1	60.1
2012	86	81	98	100	40	61.3
2013	87.2	86	96.1	100	44.5	62.7

Source: Own elaboration from (European Commission, 2014), (European Commission, 2015) and BMW in (Morris & Pehnt, 2012)

Energy security can be defined as the secure availability of energy at affordable prices. In this regard, Germany is in a particularly vulnerable situation with regard to availability and price, since it imports most of the energy it consumes.

For defenders of the *Energiewende*, renewable energies reduce German dependency on energy imports, with a consequent economic benefit, and make the country less vulnerable to a rise in fuel prices and to the policies of exporting countries.

Energy efficiency can also contribute significantly to reducing energy imports. A scenario with more efficient energy consumption could reduce energy imports by approximately €4 billion by 2030 (as compared to a scenario with no progress in efficiency, in which case the figure would continue to grow).

Renewable energies and energy efficiency therefore help to reduce imports, increasing energy security and avoiding dependency on energy-exporting countries. The energy transition proposed under the *Energiewende* would therefore be a solution for reducing imports.

Local communities and economy

In Germany, about 380,000 people now work in the renewable energy industry and the German Renewable Energy Federation (BEE or *Bundesverband Erneuerbare Energie e.V.*) estimates that this number could increase to 500,000 by 2020. There are also nearly a million jobs in the environmental technology industry (water treatment plants, recycling, etc.)[27] Nonetheless, as a result of the crisis facing some companies in the photovoltaic industry, the figure of 380,000 fell to 320,000 in 2013. However, it should be noted that these figures do not take into account net job creation, as there was a reduction in other energy subsectors.

Furthermore, it is medium-sized companies that benefit most from a growth in demand for energy efficiency products and applications. More than half of the sales revenue of these companies[28] comes from goods for environmental protection (of which energy efficiency is a subcategory).

Supporters of the *Energiewende* aregue that when "communities" themselves invest in projects, the economic benefits more agents than when investment is made by large companies. As a consequence, citizen ownership of renewable energy generation systems (distributed generation) provides profit for the communities making the investment. They further argue that it is a way of keeping energy poverty in check.[29]

Nonetheless, there appear to be no studies offering a complete analysis of net employment in energy, taking into account the reduction of employment in nuclear industry and coal-fired generation. A study conducted in March 2013 by the Boston Consulting Group, entitled *Trendstudie2030+*, indicates that the real effects of the energy transformation on net employment and GDP cannot be measured, partly due to the existence of possible distortions that would probably influence the estimates of any study (BCG, 2013b).

Nuclear energy

The various factors cited above (the rise of the antinuclear movement and the Greens, Chernobyl and Fukushima) led the German Government to adopt a proposal by the Öko-Institut and WWF for nuclear disconnection.

The resulting controversy on nuclear energy in Germany was therefore one of the factors leading to the *Energiewende*, as if a gradual transition towards closure and decommissioning of nuclear plants would remove the risks facing the German population and put an end to the resulting protests and opposition movements.

It is also argued that as a result of the energy transition, there has been an increase in the installation of new nuclear plants within a distance of 20 kilometres across the Dutch and French borders. This poses a risk which should be avoided as it would mean being equally "surrounded" by nuclear plants (Sánchez, 2014).

[27] These numbers must be viewed within the context of a reduction in employment in other companies and/or technologies. See Section 4.6.
[28] The companies providing information are those with fewer than 250 employees.
[29] Energy poverty is defined as being the situation in which a household is unable to pay for sufficient energy services to meet their domestic needs and/or have to spend an excessive portion of their income on the household energy bill (Asociación de Ciencias Ambientales, 2015).

3. THE POLITICAL CONTEXT AND THE GREENS

We shall now examine the political context in which the *Energiewende* has developed.

Among other issues, it is necessary to look at the role of different governments at each stage in the German energy transition, from the first environmental movements, through the "decision" to implement the *Energiewende*, to the current situation.

3.1. General political context

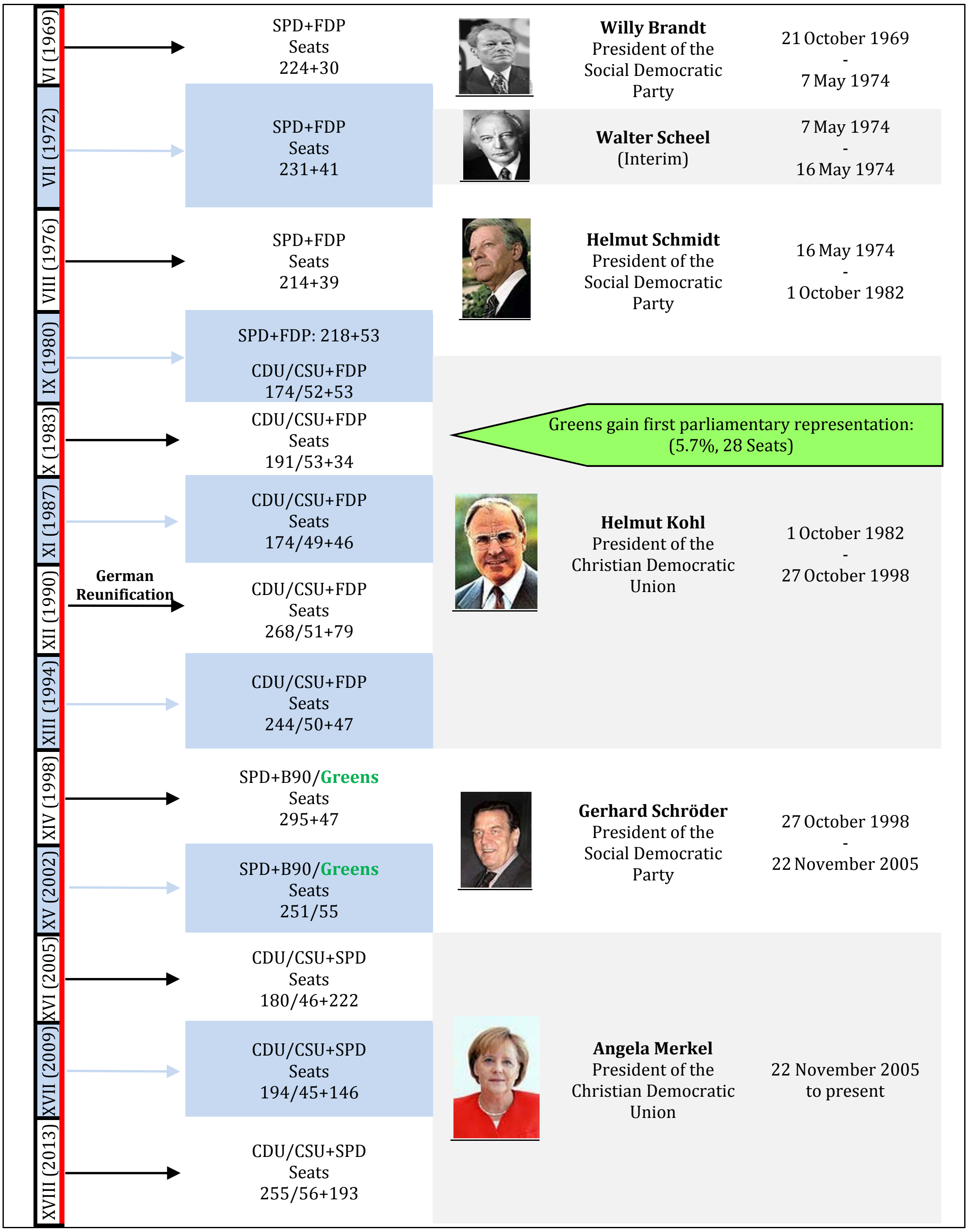
The Federal Republic of Germany is a democratic model with a multi-party system. Five major political forces have developed, following the consolidation of the Greens, in the 1980s and the success of the Unified Socialist Party (SED) from the former DDR following reunification of the country in 1990. Indeed, in the 2009 general elections, it was not only the CDU/CSU[30] and SPD, (traditionally considered "popular parties" because of their wide transversal representation amongst the electorate) that achieved two-digit result but also a number of "smaller" formations.

The table below shows the various federal governments and their parliamentary representation.

FIGURE 1. Timeline of German governments

ELECTIONS	GOVERNMENT COALITIONS	CHANCELLORS		TERM IN OFFICE
I (1949) Since WW II German Reunification	CDU/CSU+FDP+DP Seats 115/24+52+17		**Konrad Adenauer** President of the Christian Democratic Union	15 September 1949 - 16 October 1963
II (1953)	CDU/CSU+FDP+DP+GB/BHE 191/52+48+15+27			
III (1957)	CDU/CSU+DP Seats 215/55+17			
IV (1961)	CDU/CSU+FDP Seats 192/50+67			
V (1965)	CDU/CSU+FDP Seats 196/49+49		**Ludwig Erhard** President of the Christian Democratic Union	16 October 1963 - 1 December 1966
	CDU/CSU+SPD Seats 196/49+202		**Kurt Georg Kiesinger** President of the Christian Democratic Union	1 December 1966 - 21 October 1969

[30] The parties in the Union, which belong to the family of European Christian Democratic parties, are the Christian Democratic Union (CDU) and the Christian Social Union (CSU). Although the two are closely linked, the former operates throughout Germany with the exception of Bavaria, while the latter operates exclusively in Bavaria (La actualidad de Alemania. 2015).



Note: in order to obtain seats in the Bundestag (German Parliament) a political party must obtain a minimum of 5% of the total share of votes.

Source: Own elaboration.

Given the key role played by the Greens in the *Energiewende* (see next section), it is worth noting that they first entered parliament in 1983.

It is also relevant that Angela Merkel of the Christian Democratic Union was elected for as third term in office by the German population in 2013, following the decision on nuclear decommissioning (2011) and the *Energy Concept* (2010).

3.2. The Greens

The Greens have had a fundamental influence on the development of the German energy transition. They promoted essential regulation for the *Energiewende,* including the Law on Renewable Energies (EEG). Indeed, as has been discussed, the Greens developed into a political party as a consequence of the first antinuclear movements.

The Greens (*Die Grünen*)[31] were formed in the mid-1970s in the Federal Republic of Germany (FRG) as an alliance between diverse groups and popular initiatives, mainly representing the "new social movements" (environmentalism, feminism, pacifism, etc.). Several small environmental parties stood in regional and local elections, although they achieved almost no representation. However, between that time and the mid-1980s, some environmental local groups enjoyed a degree of success in local elections, thus becoming an important base for the foundation of the Green party.

The party was founded on 13 January 1980, mainly representing the incipient social movements of the time. Following reunification (1990), in 1993 they merged with the East German civil rights movement, *Bündnis 90* (Alliance 90), and were renamed *Bündnis 90 / Die Grünen* (Alliance 90/The Greens). However, the Greens' principal voter base continues to be in the west of the country. Despite its origins on the left, with most members coming from a range of civil groups, the party has now moved closer to the centre of the political spectrum. It formed part of the federal government from 1998 to 2005, combining its environmentalism with liberal positions on civil rights (Decker & Neu, 1980) (Bündnis 90 / Die Grünen, 2015).

Parliamentary representation[32 33]

The party first stood on a national platform in the European elections of 1979, headed by activist Petra Kelly, previously a member of the Social Democratic Party (SPD), and Herbert Gruhl, a former member of parliament. The list won 3.2% of the vote and one seat in the European parliament.

The Greens first achieved representation in the *Bundestag* in the 1983 federal elections, when they won 5.6% of the national vote and 28 MPs.

Following the federal elections of 1998, in which the coalition CDU/CSU and the FDP (Free Democratic Party) failed to achieve a majority, a coalition government was formed, led by the SPD and the Greens, with Gerhard Schröder from the SPD as chancellor. This was the Greens' first time in government and also the first coalition between the Greens and the SPD at federal level. At the 2002 elections, the Greens

[31] For further information on the Greens, see Appendix 13.3.
[32] Data below have been gathered mainly from (Bündnis 90 / Die Grünen, 2015) (Nordsieck, 2013) (Sawin, 2013)(Marcellesi, 2008) and (BMU, 2015).
[33] For additional information on Germany, see Appendix 13.2.

obtained 8.6% of the total vote and 55 seats, its best results to date, allowing them to form a government with the SPD.

Between 1998 and 2002, the renewable energy sector benefited greatly from the presence of the Greens in the federal government. An eco-tax was levied on energy consumption, a plan was enacted to abandon nuclear power (although only after 2021) and the Renewable Energies Act (EEG)[34] was passed into law.

In the federal elections of 18 September 2005, the Greens obtained 8.1% of the vote, a slight fall compared to the 2002 results (8.6%). This, combined with the SPD's electoral losses and the entry of *Die Linke* (The Left) into the *Bundestag* prevented a new red-green majority and the Green moved to the opposition benches.

In recent years, the Greens have continued to enjoy good results in regional elections, mainly in the west of the country. However, largely as a result of poor showings by the SPD, between 2005 and 2007 they failed to enter government in any state in the federation. In May 2007, the Greens obtained their best electoral result to date in the elections to the *Bürgerschaft* (regional Parliament) of Bremen[35] with a 16.4% share of the votes, enabling them to return to regional government there in coalition with the SPD.

In April 2008, the first coalition between the Greens and the CDU was formed in Hamburg, headed by Ole von Beust (CDU). This pact, which some years earlier would have seemed impossible on ideological grounds, highlighted an increasing rapprochement between the two parties and was seen as a model for a possible coalition at a federal level. However, the coalition collapsed at the end of 2010. In another state, Sarre, a CDU-FDP coalition survived for longer.

In the 2009 federal elections, the Greens increased their share of the vote to 10.7%, but remained in opposition due to the victory of the CDU and FDP. The main candidates in these elections were Renate Künast and Jürgen Trittin. In the coming years, the party benefited from changing public opinion on nuclear energy, particularly after the Fukushima accident, and for the first time they scored over 20% in voter intention polls and managed to gain a foothold in the parliaments of Rhineland-Palatinate and Saxony-Anhalt.

In March 2011, the Greens became the second-largest political force in the regional parliament of Baden-Württemberg, obtaining 24% of votes – more than twelve percentage points up on their 2006 result. For the first time, this gave them enough seats to lead a regional government in coalition with the SPD. Winfried Kretschmann (Alliance 90/The Greens) was elected first minister of the *länder*. These results were further improved in March 2016, when they won 30% of the vote.

[34] Hans-Josef Fell, a member of the Greens, wrote the draft for the EEG with Hermann Scheer of the SPD. Fell was also involved in drafting the amendment to the law in 2004.

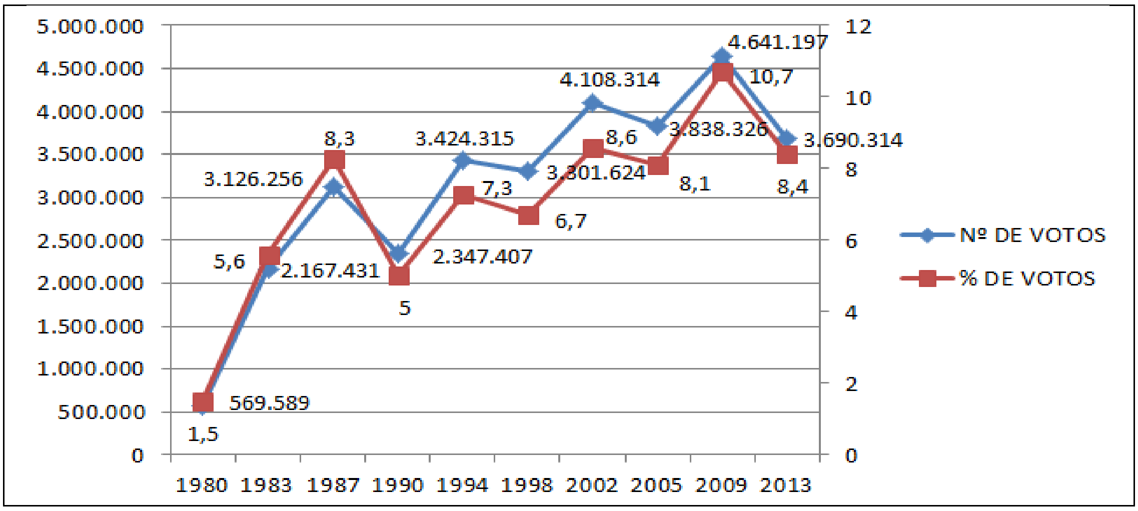
[35] The Greens' presence in the different federated states can be seen in Appendix 13.3.

In the 2013 federal elections, the Greens came fourth, with 8.4% of the vote and 63 seats (one less than The Left, the third most-voted party). At a European level, they form part of the European Green Party and have more than 11 members in the European Parliament (EP).

Electoral results

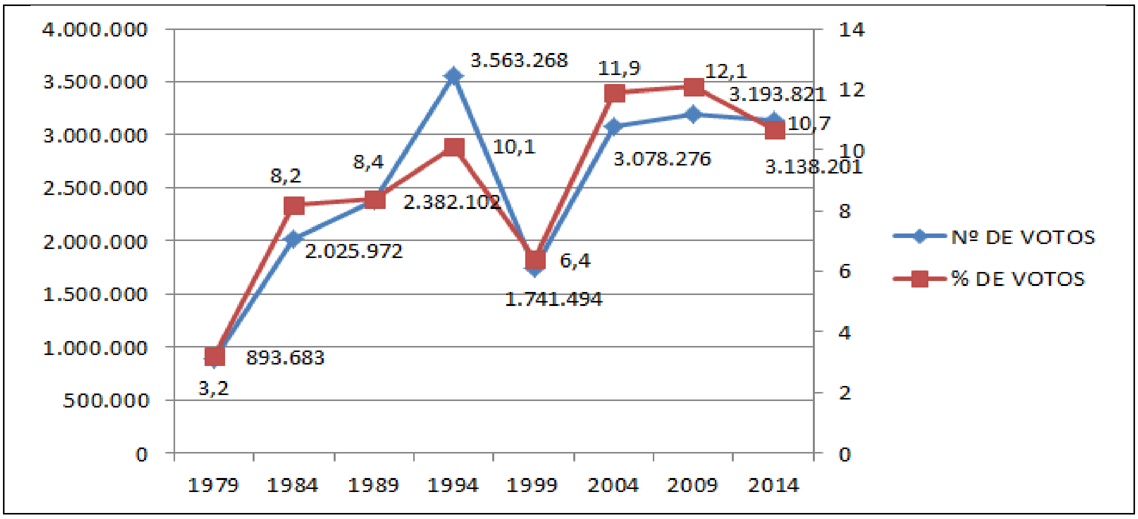
The graphs below show the Greens results (votes and percentages) in elections to the federal and European parliaments.[36]

GRAPH 1. Greens: results in federal elections



Source: Own elaboration.

GRAPH 2. Greens: results in elections to the European Parliament (EP)



Source: Own elaboration.

[36] More details of policies and results at federal and *Länder* level are given in Appendix 13.3.

Energy measures proposed by the Greens

The relationship between energy and the environment has been an issue that has concerned the Greens since their origins. This section describes their ideological position and the energy measures they have proposed.[37]

In the 1990 elections, the first in the reunified Germany, the party had an associated newspaper, *TZ*, whose slogan was "a newspaper as a lifestyle and as an environmentally-responsible way of life". They championed closure of the temporary radioactive waste storage facilities at Gorleben (northern Germany), a favourite hobby-horse of the antinuclear movement.

In 2000, the Greens supported the Renewable Energies Act (EEG) to guarantee a cost that would cover the tariffs of power generation from biomass, wind energy and solar energy and try to increase Germany's share of renewables.[38]

In 2005-2010, the federal government, with proposals and support from the Greens, earmarked about €800m for scientific research, limited to sustainable development, in the country.

The slogan of the European Green Party Conference in Berlin in 2010 was "We need to change our minds, not our climate". The congress was notable for promoting a range of values, such as a social Europe, human rights, environmental protection and job creation.

Three months later, in the German general elections, Alliance 90/The Greens committed to creating one million jobs in the areas of renewable energy, energy efficiency and health and care of children and old people. Their aim was to transform ecology into a lifestyle.

A basic plank of the Greens' environmental policy is sustainable development. This includes respect for the environment, protection of natural resources and the promotion of renewable energies. Indeed, in the last elections to the German Parliament, the first item in the electoral programme states: "We are committed to an energy supply that is 'citizen-owned', clean, secure, affordable and of course 100% renewable".

Respect for the environment and the abandonment of nuclear energy continue to be the key points of the Greens' electoral programme. In 2011, following a long internal debate, the German Greens decided at a bitter extraordinary congress in Berlin to support the nuclear "blackout" for 2022, proposed by the federal chancellor.

[37] Based on Probst, 2007 and Gómez, 2011.
[38] As mentioned, it appears to have been Hans-Josef Fell of the Greens, in collaboration with Hermann Scheer, Dietmar Schütz (both from the SPD) and Michaele Hustdt (Greens), who drafted the law. Fell was therefore involved from the amendment of the EEG in 2004.

II. ENERGY

4. ENERGY STRUCTURE

Having described the wider context of the *Energiewende* and in order to provide a better understanding of the importance and implications of the aims of the programme, we need to look at the country's energy structure, considering its current and past position, and ways in which it has developed.

This chapter describes the German energy structure through an analysis of its primary and final energy, oil, gas, coal, electricity and energy flows. The principal power companies are also briefly examined. A description of each component of Germany's current energy situation is followed by an analysis of its historical development, to show how the current situation has been reached.

4.1. Energy. Primary and final

This section describes the energy structure in relation to primary and final energy. Figures refer to the current situation and trends over former years.

Current situation

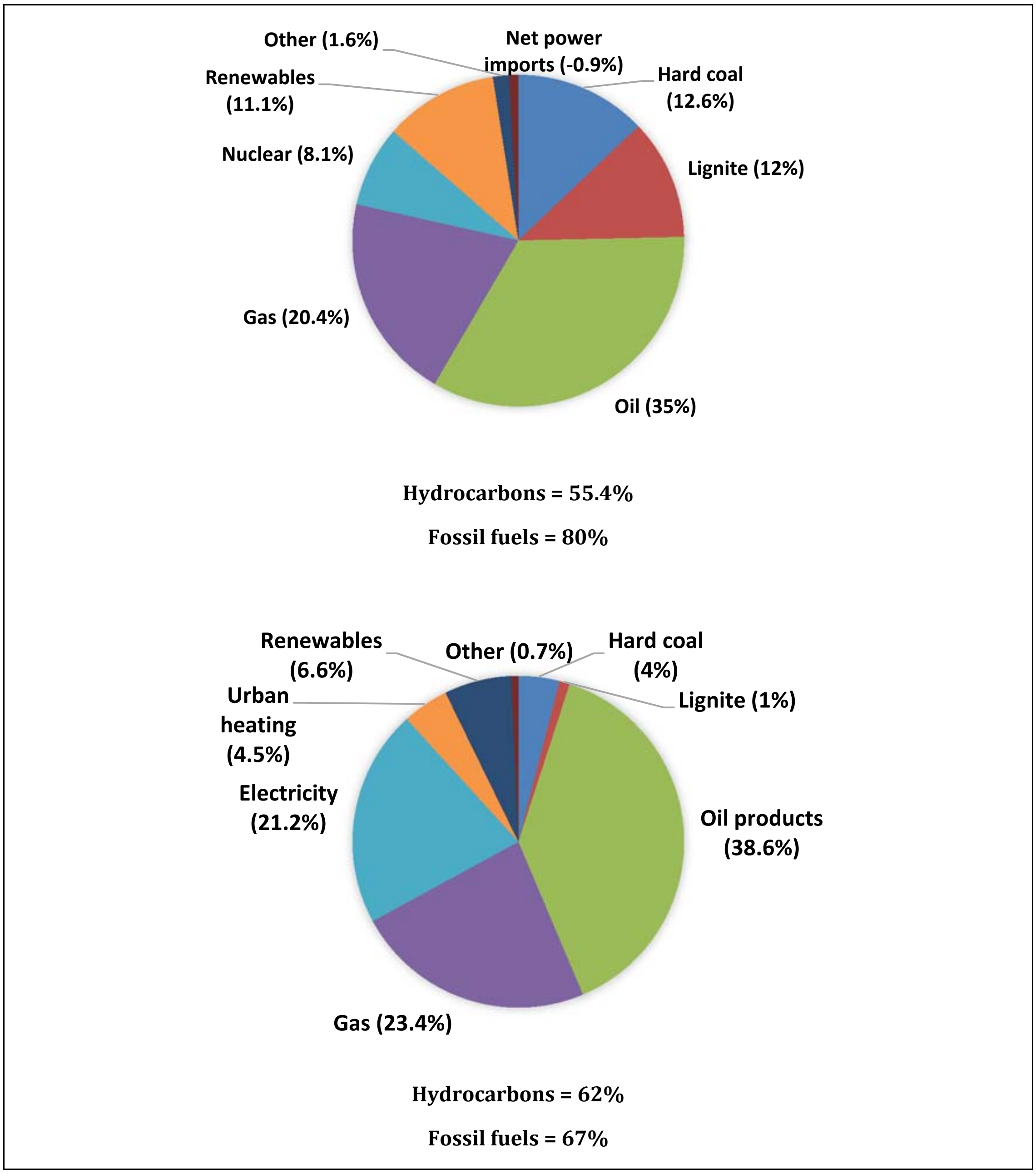
The graph below shows the primary and final energy structure in 2014. Throughout the text, we will also make reference to the same situation in Spain, as we consider it an interesting point of reference.

It is important to note that renewable energies represent 11.1% of total primary energy consumption. This is a long way behind other energy sources, such as oil (35%), coal (24.6% including both hard coal and lignite) and natural gas (20.4%). One might draw a comparison between German consumption of non-renewable primary energy sources (55.4% from hydrocarbons and 80% from fossil fuels) and the situation in Spain (62.6% and 72.7% respectively). This shows the importance of coal, and the small share of renewable energy in Germany (11.1%) (in Spain the figure is 14.5% (2014)).

Graph 6 shows the final energy situation in Germany in 2014. Here, hydrocarbons account for 62%, giving an overall fossil-fuel total of 67%. In Spain the figure for hydrocarbons was 68.4% and for fossil fuels in general, 70%. In Spain oil products play a more important role, which partly explains these differences.

Spain has a considerably higher share of renewables – 23.5 vs. 6.6% in Germany. The large share of oil products partly explains these differences.

GRAPH 3. Primary energy[39] (top) and final energy[40] structure (bottom) in Germany in 2014



Source: Own elaboration from (AGEB, 2015)

Most usage of renewable energies was for gross power production and only 6.6% was used directly (for heating, biofuels, etc.). This compares to a figure of 6.3% in Spain. However, the percentage in Germany is still a long way from the *Energiewende* target of 18% for 2020 (see Section 5.1 below).

[39] Primary energy structure in Spain in 2014 was as follows: oil, 42.7%; natural gas, 19.9%; nuclear, 12.6%; hydroelectric, 2.8%; wind, solar and geothermal, 6.4%; biomass, biofuels and renewable wastes, 5.3%; coal, 10.1% (MINETUR, 2014).

[40] Final energy structure in Spain in 2014 was as follows: oil products, 50.8%; gas, 17.6%; electricity, 23.4%; renewable energies, 6.3%; coal, 1.6%; coal gas, 0.3% (MINETUR, 2014).

Historical development

The following tables and graphs show the development of the primary energy structure in Germany over recent years in terms of demand and production.

TABLE 2. Development of primary energy consumption (Mtoe)

1995	2000	2005	2010	2012	2013
341.6	342.3	341.9	333.0	318.6	324.3

Source: Own elaboration from European Commission, 2015)

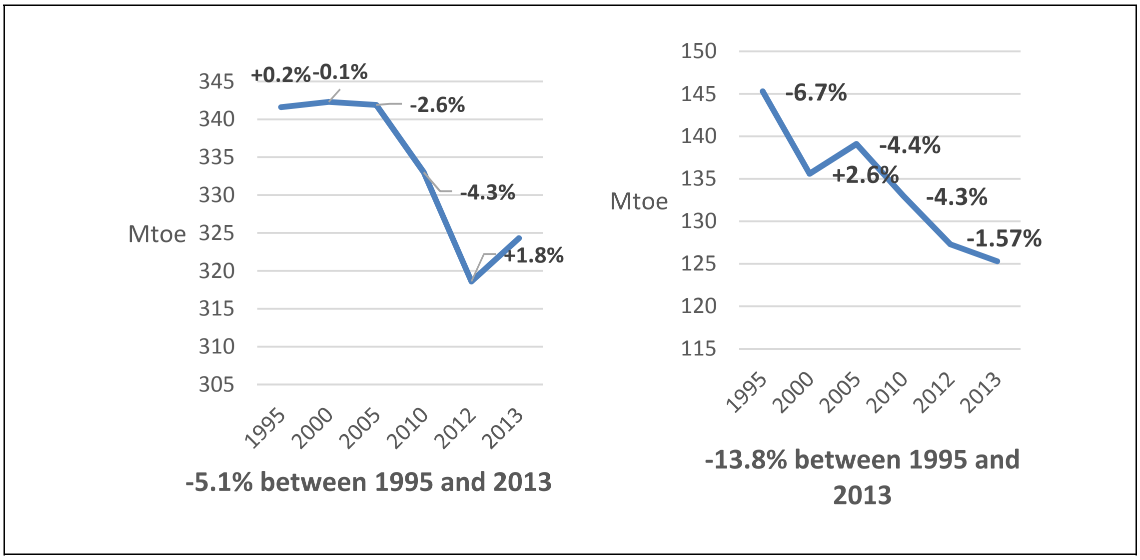
TABLE 3. Primary energy production development (Mtoe)

	1995	2000	2005	2010	2012	2013
Solid fuels (hard coal)	78.9 (38.1)	60.6 (24.2)	56.5 (18)	45.9 (9.2)	47.6 (7.6)	45.1 (5.5)
Oil and products (petrol and LPG)	4.3 (3)	4.7 (3.2)	7.5 (3.5)	8.1 (2.5)	8.3 (2.6)	8.5 (2.6)
Natural gas	15.1	15.8	14.3	11.1	9.6	8.9
Nuclear energy	39.5	43.8	42.1	36.3	25.7	25.1
Renewable	6	9	16.9	27.7	32.1	33.7
Non-renewable wastes	1.4	1.7	1.8	3.9	4	4.1
Total	145.3	135.6	139.1	133	127.3	125.3

Source: Own elaboration from European Commission, 2015

The energy structure has been characterized by a fall in demand of almost 14% in the same period. There was also an almost complete collapse of domestic coal production, while the rise in renewables has not compensated for the reduction in fossil fuel and nuclear power.

GRAPH 4. Development of consumption (left) and primary energy production per year and accumulated (Mtoe)



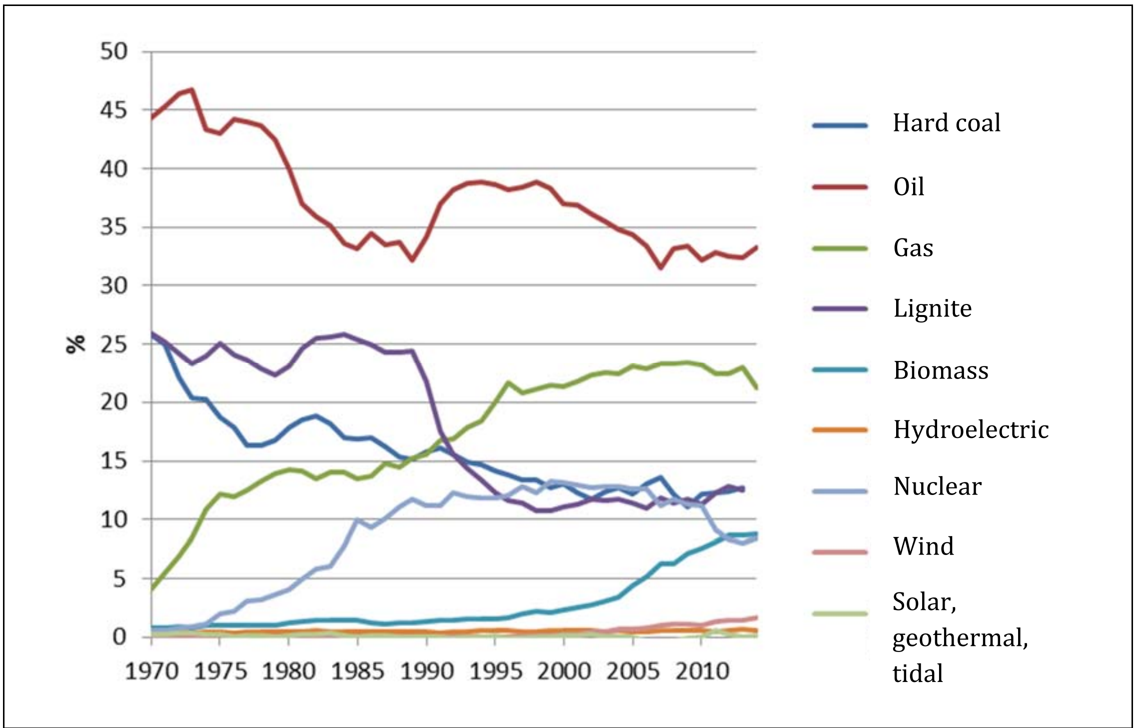
Source: Own elaboration from European Commission, 2015

Turning to the distribution of energy by source in German primary energy over the last century (see graph below), one can distinguish different periods. From the 1920s on, coal (lignite and hard coal) was widely dominant with percentages of 40-

50% of hard coal and 20% of lignite. This situation continued until the 1960s. Between the 1950s and the 1970s, and despite a fall in the share of hard coal, the proportion of lignite remained constant. From 1970 (see graph below), nuclear energy began to gain in importance, as did gas, which grew quite sustainably to attain a share of close to 20%. Finally, in the 1990s and following years, the share of coal weakened and started to decline, coinciding with a strong fall in nuclear energy. All of these factors encouraged fostered a growth in gas while oil remained stable.

Renewables, first introduced in the 1970s, saw greater and more sustained growth, particularly in the case of biomass, rising to a share of nearly 10%.

GRAPH 5. Historical origins of primary energy by source



Source: Own elaboration from (European Commission, 2015)

The implementation of nuclear energy was conditioned by restrictions imposed after World War II. The allies (France, United States and the UK) occupying the western area of the country avoided obstructing the introduction of nuclear power, in order to facilitate the development of an industrial base.

The construction of facilities for fuel enrichment and waste treatment, was conditioned by the risk of arms manufacturing. The aim was to build partnerships between Germany and third countries. For this reason, the United Kingdom and the Netherlands (Treaty of Almelo, 1970) allowed projects to be developed through internationalisation (Ruttem 2014).

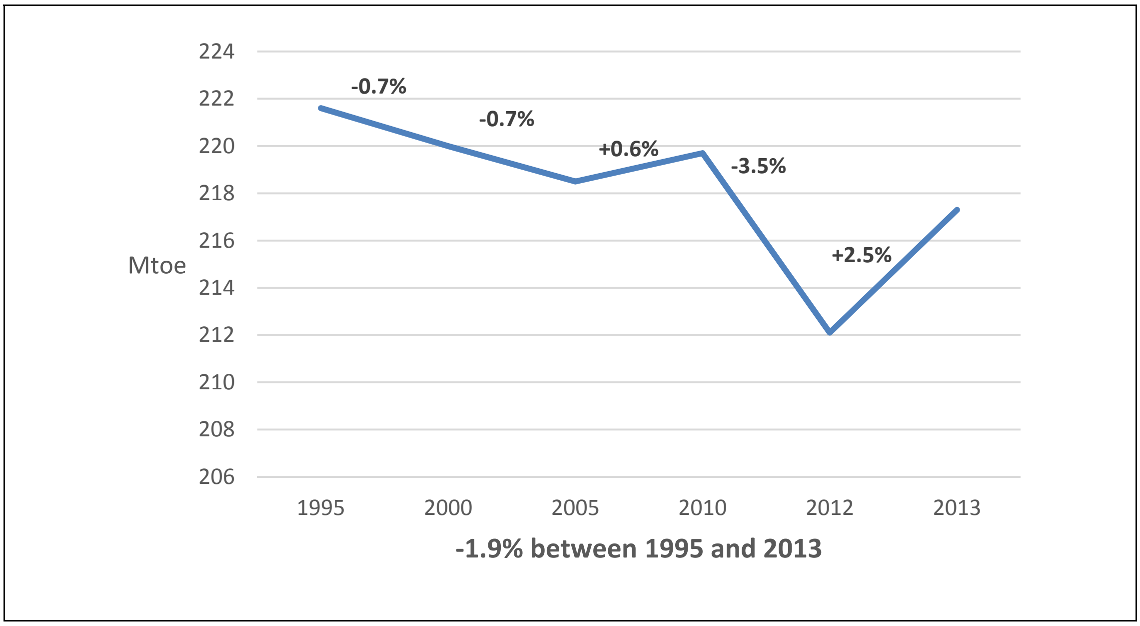
As regards final energy, the table and graph below show trends between 1995 and 2013, when a downward trend began (particularly in the use of fossil fuels) with a growth in electricity and renewables.

TABLE 4. Development of final energy consumption (Mtoe)

	1995	2000	2005	2010	2012	2013
Solid fuels	13.9	11	8.2	9.4	9.6	9.7
Oil and products	105.6	99.7	90.3	83.2	81	83.9
Gases	51.8	56.1	55.1	56.5	52.9	55.2
Biomass and renewable wastes	2.7	4.7	8.5	12.1	11.6	11.9
Solar	0	0.1	0.3	0.5	0.6	0.6
Geothermal	-	-	0	0.1	0.1	0.1
Electricity	38.8	41.6	44.9	45.8	45.2	44.5
Derivative heat	8.7	6.8	10.8	11.3	10.3	10.4
Non-renewable wastes	-	-	0.3	1	0.9	1
Total	221.6	220	218.5	219.7	212.1	217.3

Source: Own elaboration from (European Commission, 2015)

GRAPH 6. Development of final energy consumption by year and total (Mtoe)



Source: Own elaboration from (European Commission, 2015)

4.2. Oil

Current situation

In 2013, Germany produced 2.6 Mt of oil, accounting for 2.8% of its demand. The remainder of the country's consumption, 97.2% (90.4 Mt),[41] was imported at a cost of €55.3 billion, proving more expensive than coal or gas imports (Amelang, 2015). Production and the general situation are shown in a map in Appendix 13.5.

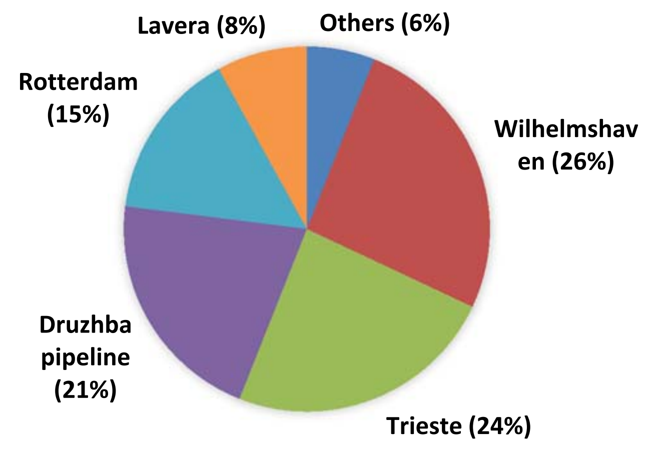
The consumption of oil products, which accounted for 35% of total primary energy in 2014, has been gradually reduced since 1995, as Table 12 shows; the principal consumer industries have been transport and heating. Based on these figures, it seems unlikely that the *Energiewende*, which focuses so heavily on power generation, will have a major impact on oil dependency. Nevertheless, what may

[41] By comparison, imports in Spain came to 57.8 Mt in 2013 (MINETUR, 2013).

drive a reduction in consumption is the plan to increase vehicle efficiency and reduce GHG emissions by promoting electric vehicles.

In any case, oil dependency is high, making the German economy dependent mainly on supplies from Russia (31.4 Mt or 35% in 2013), followed by Norway and UK (11 Mt and 9.3 Mt respectively). The graph below shows a diversification in supply routes (six).

GRAPH 7. Oil import routes in 2006



Source: Own elaboration from (BGR, 2009)

Most of the oil infrastructure shown in the figure below is a legacy of the country's pre-reunification west, where refining facilities were built on the periphery, near the boundaries shared with neighbouring countries through which oil pipelines had to pass (as they still do). The interchange capacity of oil products through this part of the national oil structure currently stands at 2,530 kb/d, as compared to 745 kb/d through the country's eastern boundaries.

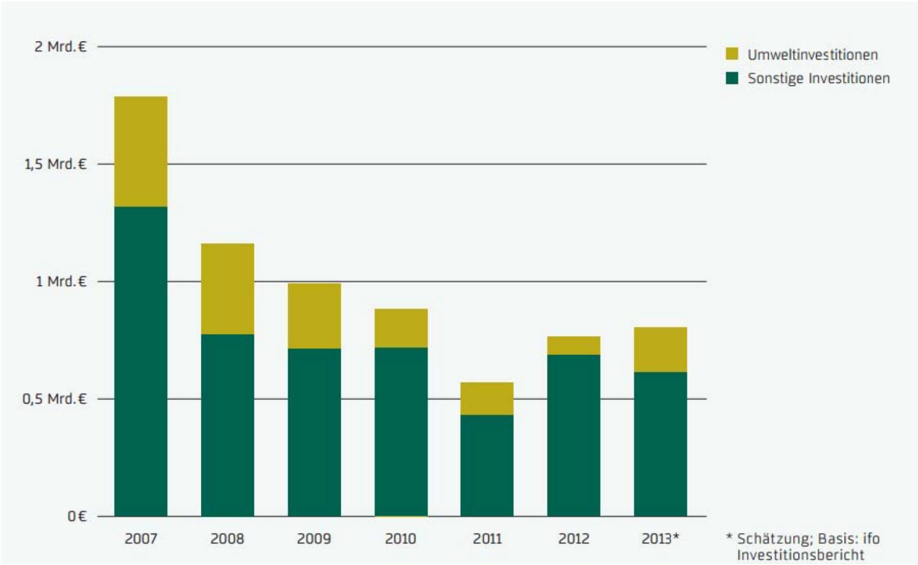
FIGURE 2. Oil infrastructure

Source: (IEA, 2014a)

Total refining capacity came to 2,060 kb/d in 2014 (Statista, 2015). The location and ownership of the refineries are shown in Appendix 13.5; note the strong presence of the leading oil and gas companies, such as Shell, BP, Esso and Eni. Different technologies are also shown in Appendix 13.5.

Despite a reduction in investment in recent years, the refining industry has adapted to its determinants, such as environmental improvements, which accounted for an average of 20% of total investments between 2007 and 2012, as Graph 12 shows. This can be compared to other industrial sectors, such as manufacturing, where such investments accounted for just 8% in the same period (Association of the German Petroleum Industry, 2015).

GRAPH 8. Recent investments in refining



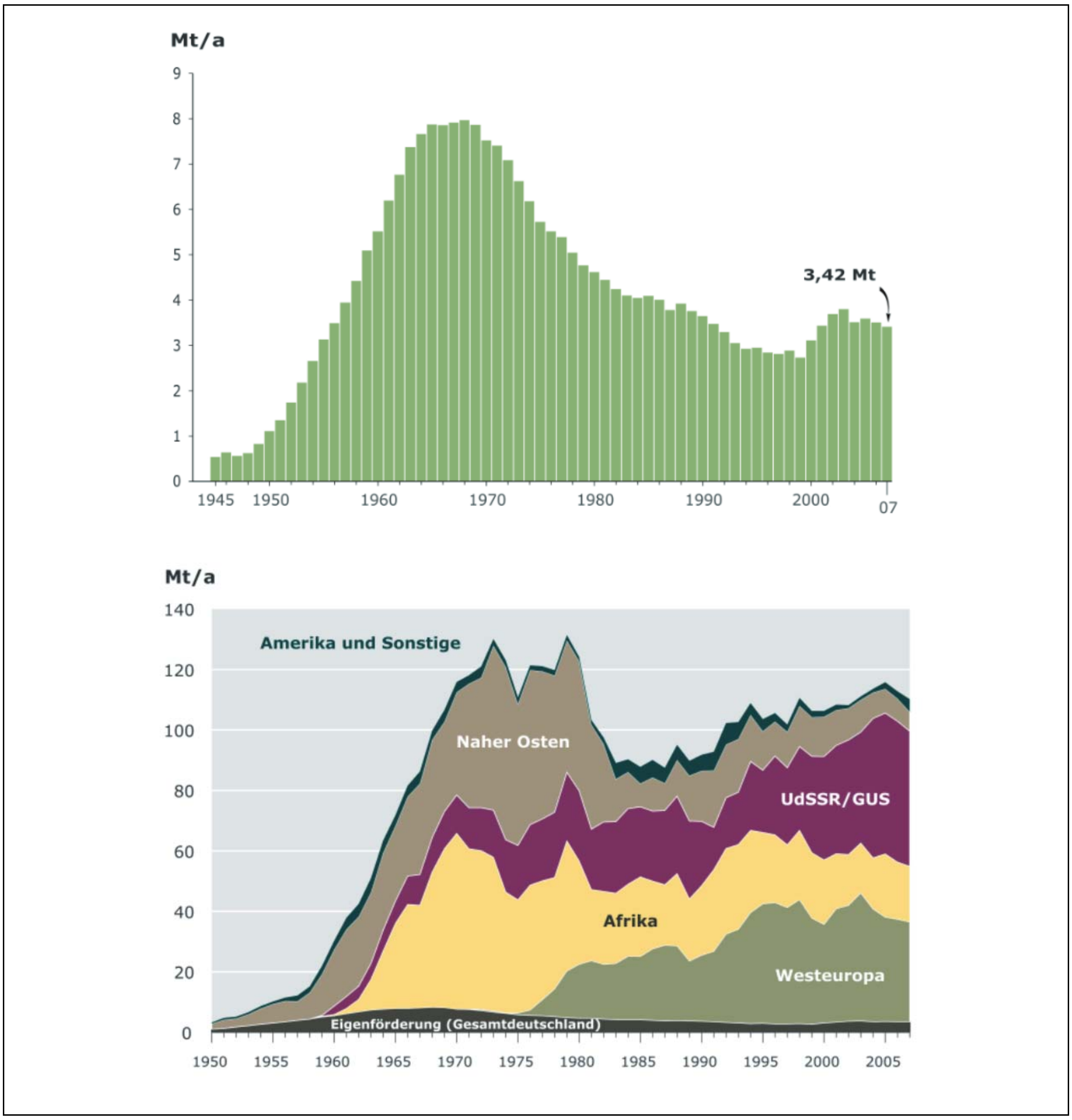
Source: (Association of German Petroleum Industry, 2015)

Historical evolution

Oil production in Germany peaked during the 1960s and part of the 1970s at 8-9 Mt/year. Since then, production has gradually fallen, to 3 Mt in 2007 and 2.7 Mt in 2013.

Imports from other countries have also declined, with supply sources gradually shifting from the Middle East and Africa towards West Europe and Russia-Eurasia during the same period, as the graph below shows.

GRAPH 9. Oil production (above) and imports by origin (below)

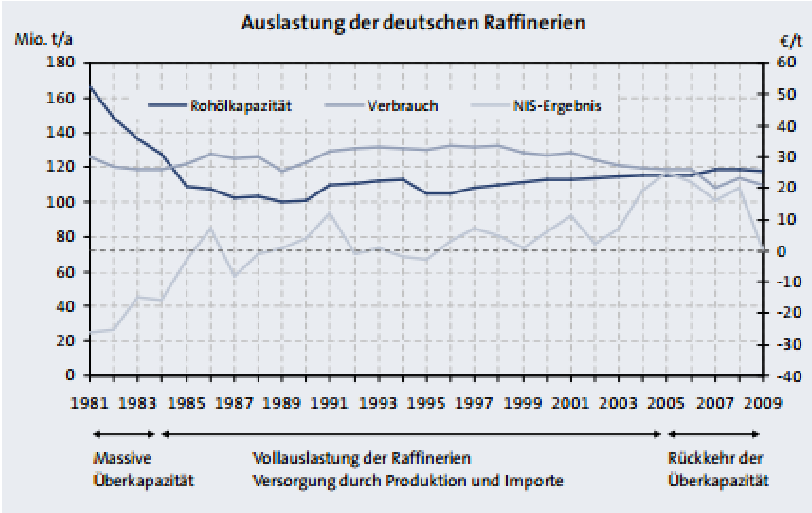


Source: (BGR, 2009)

Development of the industry is linked to a parallel development in the refining industry. In The following graphs show how a fall in production and imports led to high refining capacity in 1980 (3,422 kb/d) a figure never subsequently matched. By 2014, capacity had fallen to 2,000 kb/d. Despite the strong investment in environmental adaptation, there has been a general reduction in capital inflow.

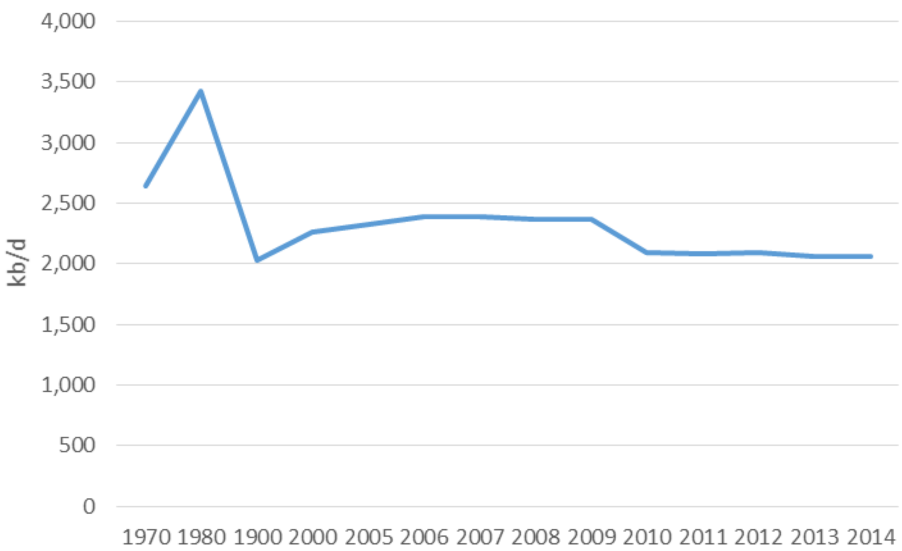
This contraction in oil processing has had an effect on the use of refineries in Germany, as can be seen below. Following an initial surplus in capacity from 1980 to the mid-1980s, during the following 20 years facilities were in full use (the increase in imports from 1985 can be seen in the following graph). Finally, from 2005, there was a return to a situation of surplus capacity.

GRAPH 10. Refinery use in Germany



Source: (HWWI, 2010)

GRAPH 11. National refining capacity (thousand barrels per day)



Source: elaboration from (Statista, 2015)

4.3. Gas

Current situation

Germany consumed 91 bcm in 2013, of which 90% was imported.[42] Domestic production currently stands at 9.7 bcm, although output from German fields is expected to fall over the next ten years. Most gas is used for domestic and industrial purposes, accounting for only a small share of the power mix (Amelang, 2015).

[42] For comparison, gas imports in Spain came to 375,421 GWh in 2013 MINETUR, 2013).

These gas fields and the general situation of extraction are shown on a map in Appendix 13.5.

In 2013, 39% of all imported gas came from Russia. Other major suppliers included Norway and Holland. Practically all gas comes to Germany through large gas pipelines, whilst liquefied natural gas (LNG) is exclusively imported from entry points in neighbouring countries (Zeebruge LNG in Belgium and Gate LNG in Holland), and the country has no regasification plants of its own.

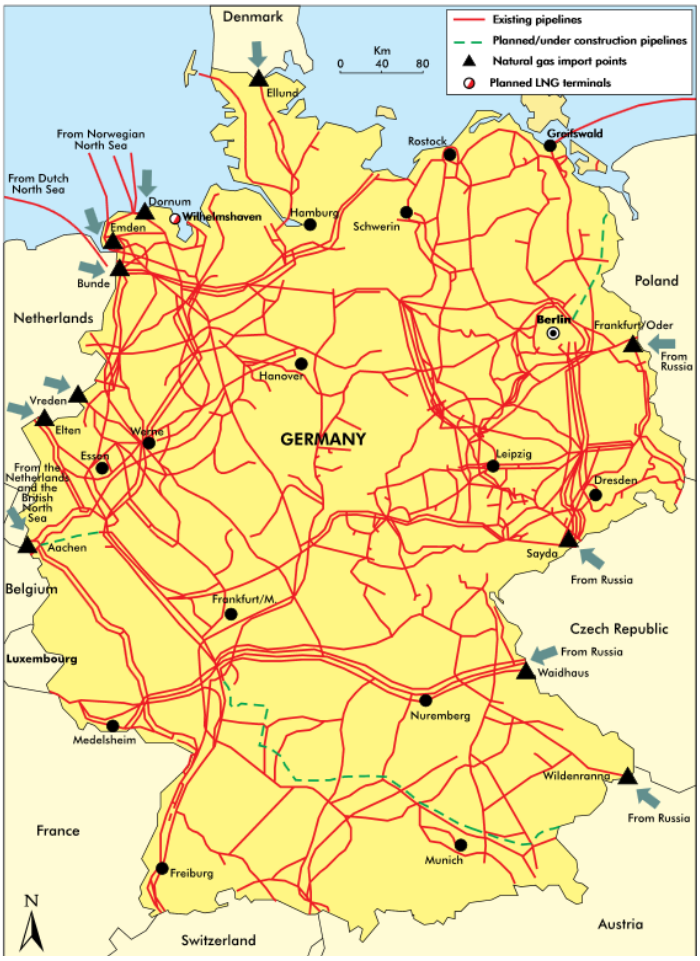
The possibility of importing liquefied natural gas through its own infrastructures requires political and financial support for some of the projects considered in recent years. Most of these initiatives have centred on the terminal at Wilhelmshaven, a €1.5 billion project which failed to get a green light, partly due to existing infrastructures in Holland (Der Tagesspiegel, 2015). The project is currently being reappraised to allow the plant to be used in the future for LNG supply for bunkering ships and LNG for trucks.

Another terminal for gas imports is also under consideration, although for the time being the project has not been launched. This is the one at Brunsbüttel, which at €500 million is considered more affordable than the other (DVZ, 2015). Other projects in with a chance are those in Hamburg and Lübeck. In these circumstances, the only project still in with a strong chance is a small-capacity terminal in Rostock, which would be developed in collaboration with the Russian company Gazprom (GIE, 2015).

Germany has a major network of gas pipelines. As the following figure shows, these provide the country with various connections across its borders with Poland, the Czech Republic and Austria, through which Russian gas is imported. There are also important connections with the Netherlands and the North Sea, which allow Germany to import gas from the North Sea and Norway.

One of the most important of the gas pipelines is the Nord Stream, which came on line in 2011 and allows direct connection between Western Europe (through the Baltic Sea and Germany) and Russia, thus avoiding East European transit with its geopolitical complexities. This consists of a 1,220 km pipeline with an initial capacity of 27.5 bcm per year which was extended with a second pipeline in 2012, to give a capacity of 55 bcm per year.

FIGURE 3. Gas infrastructure



Source: (IEA, 2014a)

However, this connection does not imply a reduction in dependency on Russian gas (60 bcm which does not come directly from Russia as opposed to 258 bcm that does) and no comparison can be made between routes not passing through the East and those that do (115 bcm vs. 203 bcm).

TABLE 5. Main supply gas pipelines to Western Europe through Germany

Pipeline	Annual capacity (bcm)
Nord Stream	55
Ukraine Corridor	170
Yamal-Europe	33
Europipe II	26
Europipe I	18
Nordpipe	16

Source: Own elaboration from (Nord Stream, 2009)

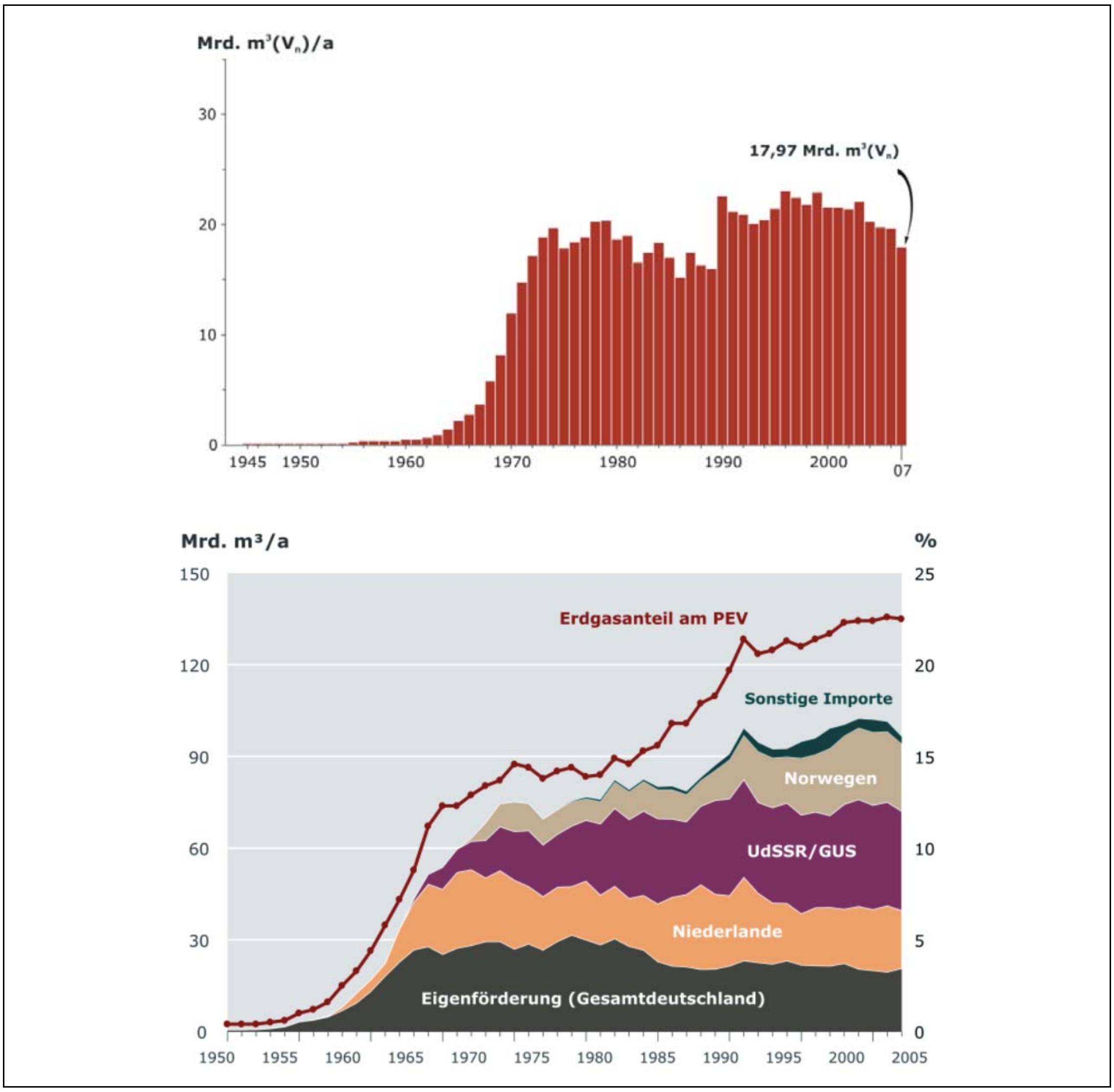
In addition, Germany has various stores of natural gas, oil and oil products, located in various places in the country as reserves, shown in a map in Appendix 13.5.

Historical development

As seen in the assessment of primary energy in Germany (Graph 3), gas experienced steady growth from the 1970s, outstripping lignite in the 1990s and leading to a historic change in the energy mix, since oil is the source with the greatest weight in Germany.

Domestic gas production and imports both saw continued growth up to 2005. In the following decade, production flatlined while consumption declined somewhat. It is important to note that the incorporation of imported gas has benefited Norwegian –and particularly Russian– imports, without a similar effect on imports from Holland, despite this country having an initial major market share. An overview of production and imports can be seen in the graph below.

GRAPH 12. Domestic gas production and origin of imports



Source: (BGR, 2009)

4.4. Coal. Lignite and hard coal.

Current situation

Coal plays an important role in Germany's power mix, although dependency varies from one kind of coal to another; in the case of lignite, imports are not required but for hard coal they are. Together, the two accounted for total consumption of 241 Mt in 2013.

Lignite is particularly important. The high production rate in the country, which consists of 183 Mt set aside for generation,[43] makes Germany the world's largest lignite consumer, while it also has important reserves. Despite this, on 2 July 2015, Germany agreed to close its large lignite plants before 2020. This will involve disconnecting 13% of total lignite capacity or 2.7 GW from the grid (Amelang, 2015). This agreement with Chancellor Angela Merkel was signed by the Federal Minister of Economy and Energy, Sigmar Gabriel, and the leader of the Social Christian Union (CSU), Horst Seehofer,[44] in an attempt to achieve carbon reduction targets of 11 Mt of CO_2 emissions per year.

The CDU leader said she was convinced that Germany could meet its commitment to reduce GHG emissions by 40% in 2020, although she acknowledged the need to strike a balance between that target, job protection and a sustainable energy supply. She also pointed out that "we have never promised that we would have abandoned coal by 2020, but this is still a cornerstone of our longer-term strategy" (EFE, 2015a).

Some coal plants are particularly important, since their large capacities have created important economies of scale, which together with the associated lignite mines, involve major infrastructures. One key example is the lignite plant in Jänschwalde (Brandenburg) which has a capacity of 3,000 MW and is operated by Vattenfall Europe Generation.

The figure below shows an open-pit lignite mine in the Jänschwalde region.

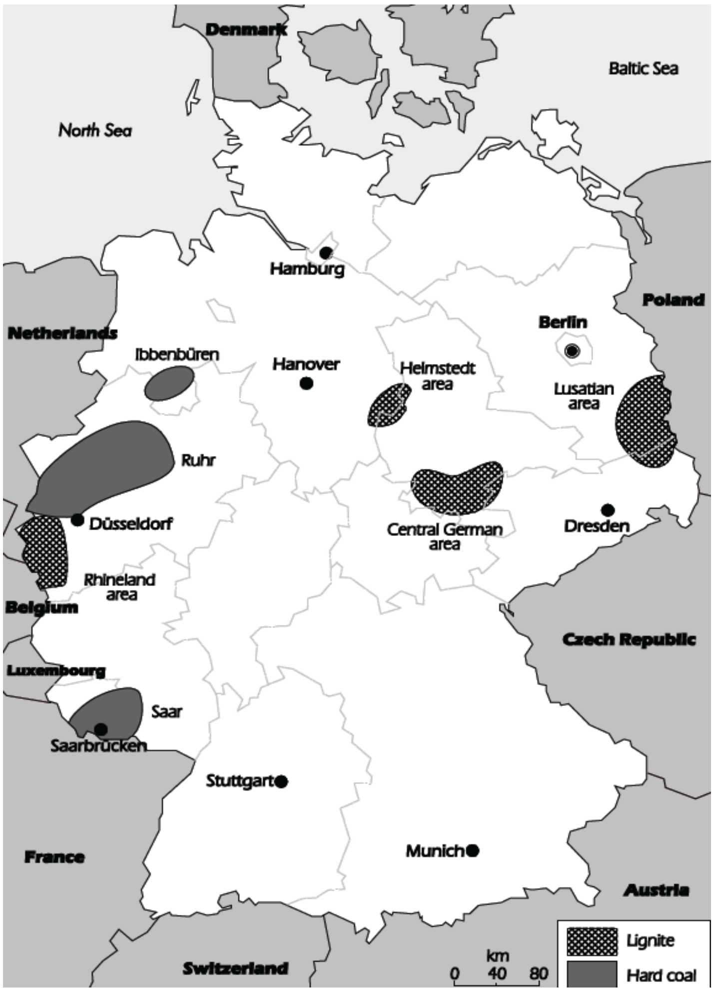
[43] By comparison, in Spain the consumption of lignite for power generation in 2013 came to 1.6 Mt (MINETUR, 2013).
[44] (Fortaleza, 2015)

FIGURE 4. Lignite mine in Jänschwalde region (Brandenburg)

Source: (TAZ, 2013)

The competitiveness of lignite means it can be developed without subsidies, making Germany the world's largest consumer and producer of this kind of fuel, outstripping even Australia, Russia and the US, with estimated reserves of 5 billion tonnes in current exploitations (Appunn, 2015). These concessions are for opencast projects in veins close to the surface, which occur in four main areas: the Rhineland, Lusatia, Central Germany and Helmstedt (see Figure 5).

FIGURE 5. Coal (lignite and hard coal) locations and lignite mines



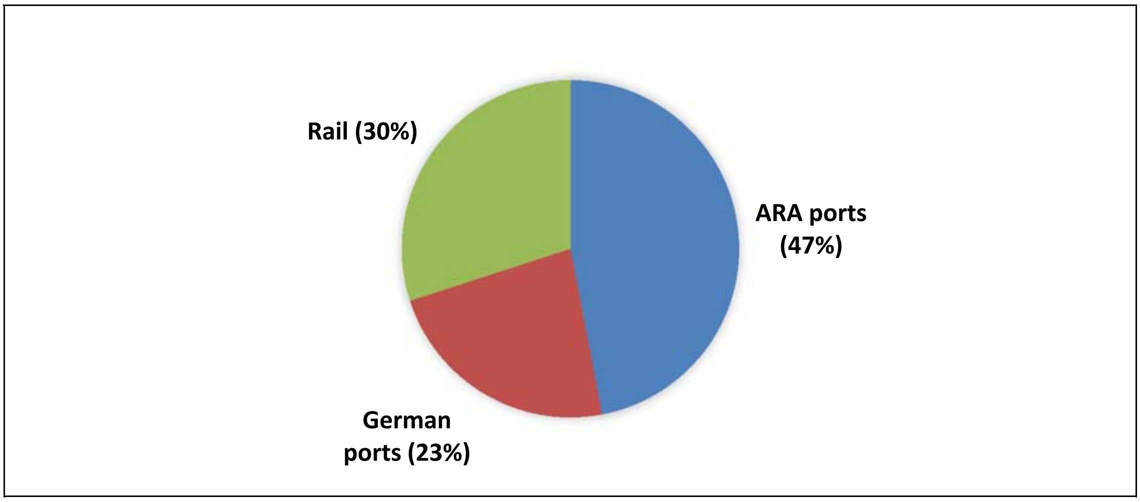
Lignite extraction areas	Number of Mines	Owner or operator	2005 (million tonnes)	2012 (million tonnes)	Variation (%)
Rhineland	3	RWE Power	97.2	101.7	4.64
Lusatia	5	Vattenfall Europe Mining AG	59.7	62.4	4.53
Helmstedt	1	Braunschweigische Kohlen-Bergwerke AG (BKB), which is 100% owned by E.ON Kraftwerke GmbH	2.1	2	-4.79
Central Germany	2	Mitteldeutsche Braunkohlengesellschaft mbH (MIBRAG)	19.1	19.2	0.73
	1	Romonta GmbH			
Bavaria	-	-	0.032	0	-100
Total	12	-	178.2	185.4	4.23

Source: (IEA, 2013)

Less than 10% of national production is used for manufacturing commercial and domestic fuel in the form of briquettes and pulverized.

As for hard coal, despite the existence of mines in the country, 90% is imported – 53 million tonnes in 2013.[45] As with oil, Russia is the main supplier, accounting for 29% of imports, whilst other sources such as Colombia and the US, represent 21% and 20% respectively. These imports are set to rise, as Germany has decided[46] to close all hard coal mines by 2018, which will mean importing 100% of its requirements. The graph below shows the main sources of imports.

GRAPH 13. Import routes for hard coal in 2007



Source: Own elaboration from (BGR, 2009)

As the graph above shows, imported hard coal mainly enters Germany by sea, and within this route, most commercial volume comes through the "ARA" portsd (Amsterdam, Rotterdam and Antwerp). The remainder comes by rail, mainly from Poland (BGR, 2009).

Domestic production is conditioned by the profitability of this activity. If the average cost of importing and mining are compared, the former came to €79 per tonne in 2013, whereas the latter cost €180 per tonne. The fate of the industry is therefore sealed, and there are no long term projects for the 36 million tonnes of extractable hard coal (of the 86 billion estimated to remain underground), particularly given that subsidies will end in 2018, under an agreement between government entities, the German Hard Coal Corporation (RAG Corporation) and the Mining, Chemistry and Energy Industry Union (IG BCE). As a result, just three mines now remain in operation, all in North Rhine-Westphalia (Appunn, 2015). Subsidies in 2014 came to €1,658 million (which can be compared with the €20 billion given to renewables, Graph 52), as shown in the table below.

[45] In Spain, by comparison, the consumption of hard coal for power generation was 13.5 Mt in 2013 (MINETUR, 2013).
[46] (EFE, 2007)

TABLE 6. Maximum subsidies by the Federal Government and North Rhine-Westphalia (million euros)

	2014	2015	2016	2017	2018	2019
Federal Government	1,284.8	1,332.0	1,053.6	1,020.3	939.5	794.4
North Rhine-Westphalia	363.8	171.4	170.9	161.2	151.5	220.6

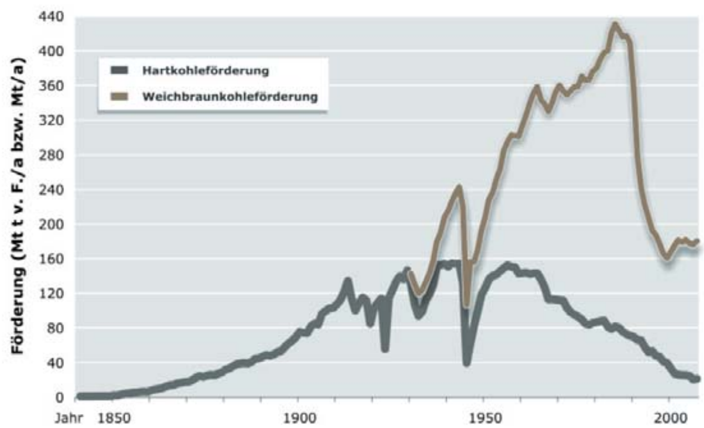
Source: BMWi (2015a).

Historical development

To a very large degree, lignite and hard coal have determined the development of German industry since the Industrial Revolution. Indeed, as already mentioned, it was not until the 1970s that coal clearly lost ground in the primary energy mix, with the rise of gas.

In domestic production terms, hard coal production grew significantly until the 1950s, while production of lignite continued to grow until the 1990s. Lignite and hard coal thus followed separate paths, resulting in opposing import requirements (none for lignite, high for hard coal). Only in the mid-1940s, following defeat in the Second World War, can a similar trend be seen for the two. This is also true of the downward trends in domestic production, although the reasons are perhaps different, political and competitive, given that large quantities of lignite are not considered desirable in the future.

GRAPH 14. Historical variation in hard coal and lignite production



Source: (BGR, 2009)

4.5. Wind energy, photovoltaics and biomass

Although we will describe the industry related to wind energy, photovoltaics and biomass in greater detail in Chapter 10, this section will offer an introduction to the renewable energy sources that have been integrated, in the form of primary energy, in Germany's power generation.

The country's potential for wind energy is significantly greater than for photovoltaic power. The north-west is the most suitable area for erecting wind turbines, both onshore and offshore (in shallow North Sea sites). Therefore, most of the electricity being generated in Germany, now and possibly in the future, is not located in the country's industrial centres.

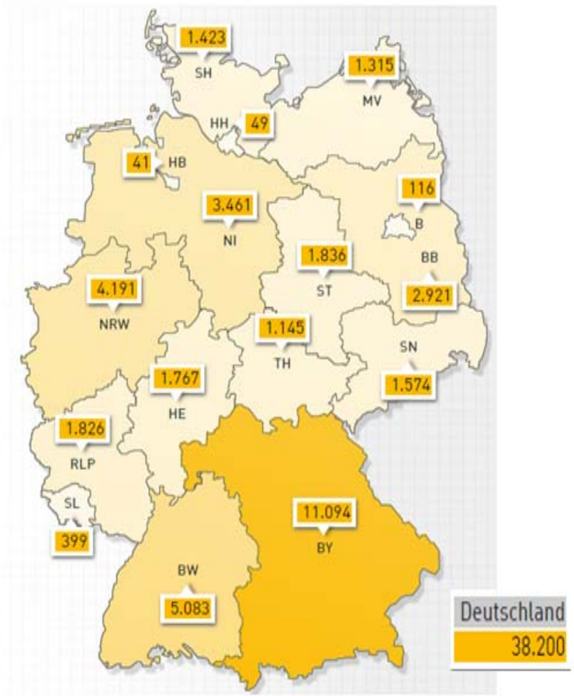
In the centre and south of the country there is great potential for developing wind energy. The amendment to the Renewable Energy Sources Act in 2012, a slight underselling of wind turbines and technological progress have all helped to make increasing numbers of locations viable.

The wind speed at which German wind turbines operate ranges between 3.7 and 7.9 m/s (6.3 m/s for places near the coast) for onshore farms, and between 7.9 and 10.3 m/s for offshore farms, taking a hub height of 80 metres. We can thus make a comparison of working hours at full load, since the range for onshore installations is between 1,500 and 1,800 and for offshore facilities between 2,800 and 4,000 (historical averages between 2006 and 2011, Peter et al., 2015). The highest onshore winds in Germany are found along the northern coast, due to sea breezes. The wind in this area at an altitude of 10 metres above sea level is in excess of 5 m/s on half the days of the year. In addition, inland areas from North Rhine-Westphalia to Brandenburg also have suitable wind conditions.

Over recent years, for example, high-performance wind turbines on towers, with a hub height of 100 metres or more, have made it possible to build economically profitable wind farms. Revenue for the government from leasing and taxing economic activities, the resulting boost to local economies, an energy supply with good future prospects and a positive social image (in terms of climate protection), are becoming more and more important factors in the decision to zone land as preferential (Gorozarri Jiménez, 2012).

As for photovoltaics, most of Germany's installations are located in Baden-Württemberg and Bavaria, the regions with the most hours of sun. Engineering companies and the capital goods industry are also located in these regions (Gorozarri Jiménez, 2012).

FIGURE 6. Location of solar photovoltaic installed capacity in Germany (MW)

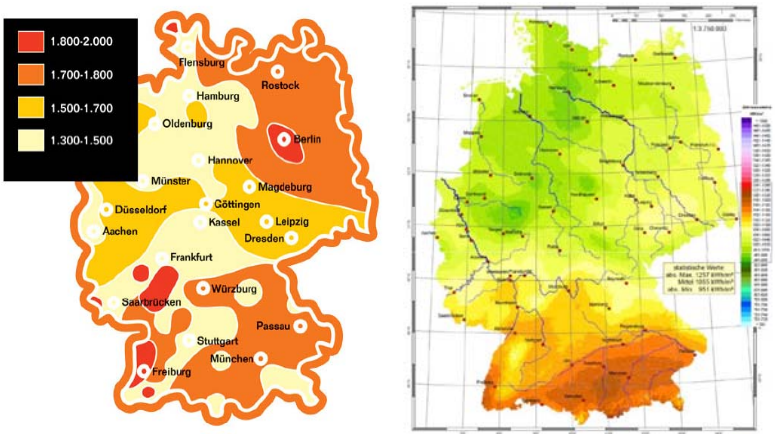


Main states for photovoltaic power (MW)
Bavaria (BY): 11,094
Baden-Württemberg (BW): 5,083
North Rhine-Westphalia (NRW): 4,191
Lower Saxony (NI): 3,461
Brandenburg (BB): 2;921

Source: (Agentur für Erneuerbare Energien e.V., 2015)

These areas, located in the south-west of the country, have the best conditions for this activity (in terms of irradiation, population density and per-capita income). Many of the benefits related to the photovoltaics industry are received by companies based in these regions and not elsewhere in the country. Development of the eastern regions, where photovoltaic production plants are installed, has also been important.

FIGURE 7. Areas in Germany with most hours of sunshine (h/year) and solar irradiation



Source: (DENA, 2015) and (Peter et al., 2015)

As for biomass, agriculture is an important supplier of resources for energy use. In 2011 about 2,000,000 hectares in Germany were given over to energy crops, nearly 17% of total cropland. The main use, accounting for approximately 910,000 hectares (2011), was for production of biodiesel from rape. By 2020 between 2.5 and 4 million hectares of agricultural land are due to be producing renewable raw materials (Gorozarri Jiménez, 2012). In 2014, 7% of German power demand was met by biomass.

FIGURE 8. Location of biomass and biogas power in Germany in 2012 (kW/km²)

Source: (DENA, 2012)

4.6. Electricity

This section discusses the current situation of electricity in Germany and its historical development.

Current situation

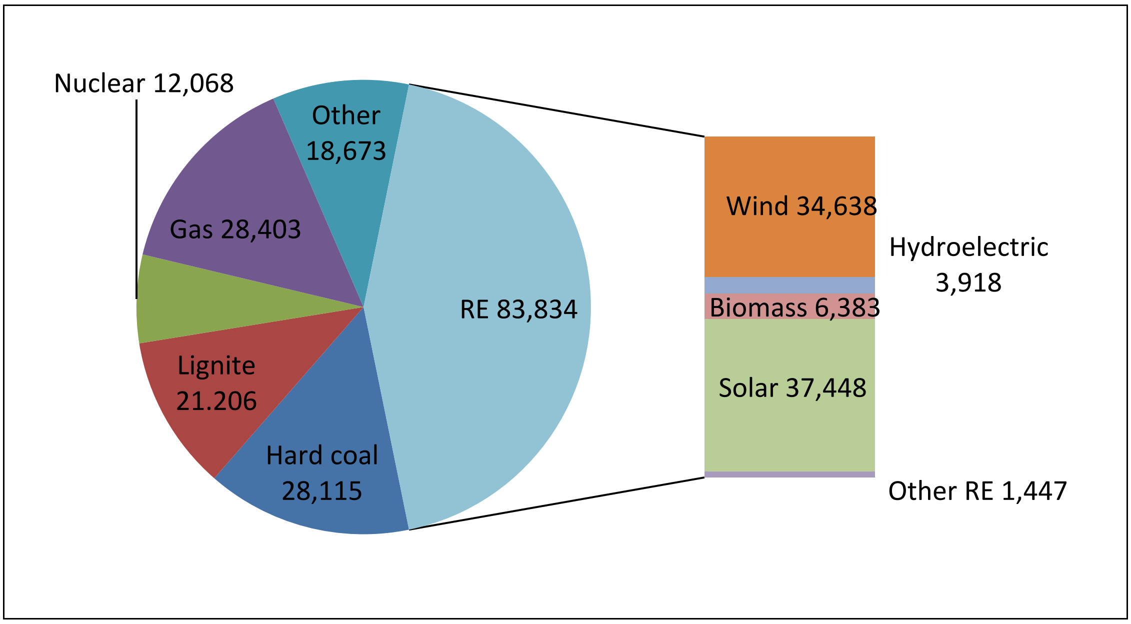
As we have seen, electricity in Germany accounted for 21.2% of the final energy consumed in 2014 (as compared to 23.4% in Spain). This meant a total installed capacity that year of 192.3 GW (Fraunhofer, 2015).

The graph below shows the installed capacity by technology type and the high percentage of renewable power (43.2%). Notably, photovoltaic and wind energies account for a larger share than fossil fuels or nuclear power.

Indeed, Germany has one of the highest levels of these energy sources and in 2012 it was the world leader in both (in the case of wind, it matched China and the US). In 2012 Germany accounted for 32% of the world's installed wind capacity (with 37.2% from the rest of the EU and 30.8% from the rest of the world). In the case of wind, Germany accounted for 12% in the same year (United States 21%; China 27%; rest of world 40%).

In 2015, renewable power surpassed 100 GW (83 GW in 2014) and represented more than 52% of total power in the German electricity system (about 196 GW).

GRAPH 15. Installed capacity in Germany in 2014 (MW)

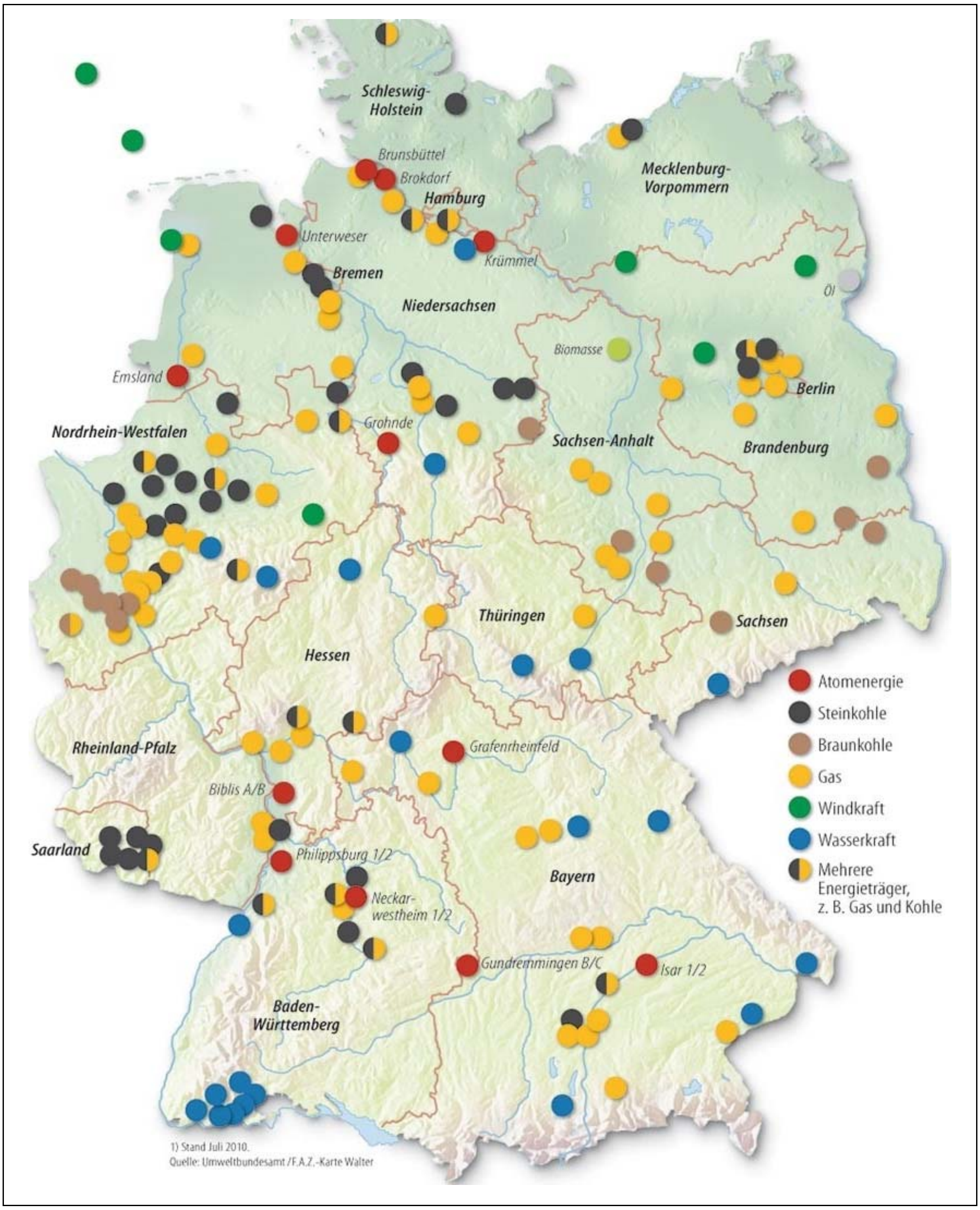


Source: Own elaboration from BNetzA in (Agora Energiewende, 2015c)

The installed capacity comes from a variety of power plants located throughout German territory. The position can be seen on the map below. Graph 31 shows the capacities of each generation centre on a map published by UBA (2014),[47] which provides the updated situation in the transmission grid.

[47]http://www.umweltbundesamt.de/sites/default/files/medien/376/bilder/dateien/kraftwerke_und_verbundnetze_in_deutschland.pdf

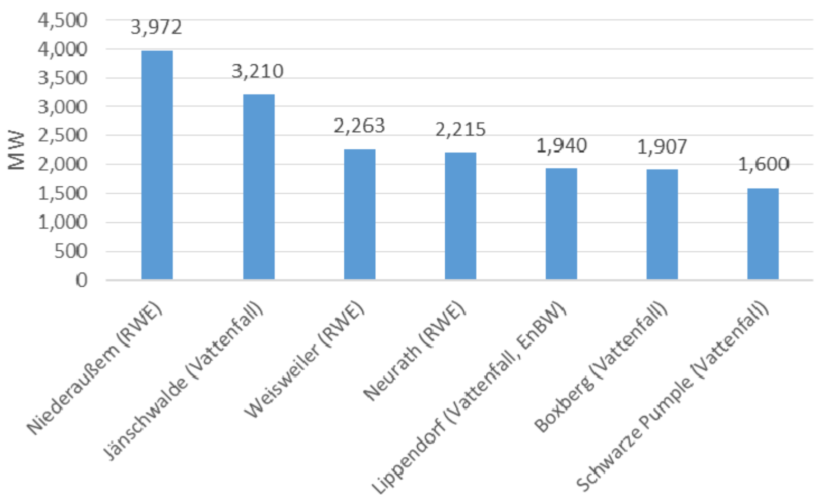
FIGURE 9. Location of power plants from 100 MW gross power



Source: (BGR, 2009)

Lignite plants have high installed capacity, but also have various units in the same location. The graph below shows the plants with the highest installed capacity.

GRAPH 16. Largest lignite plants in 2014



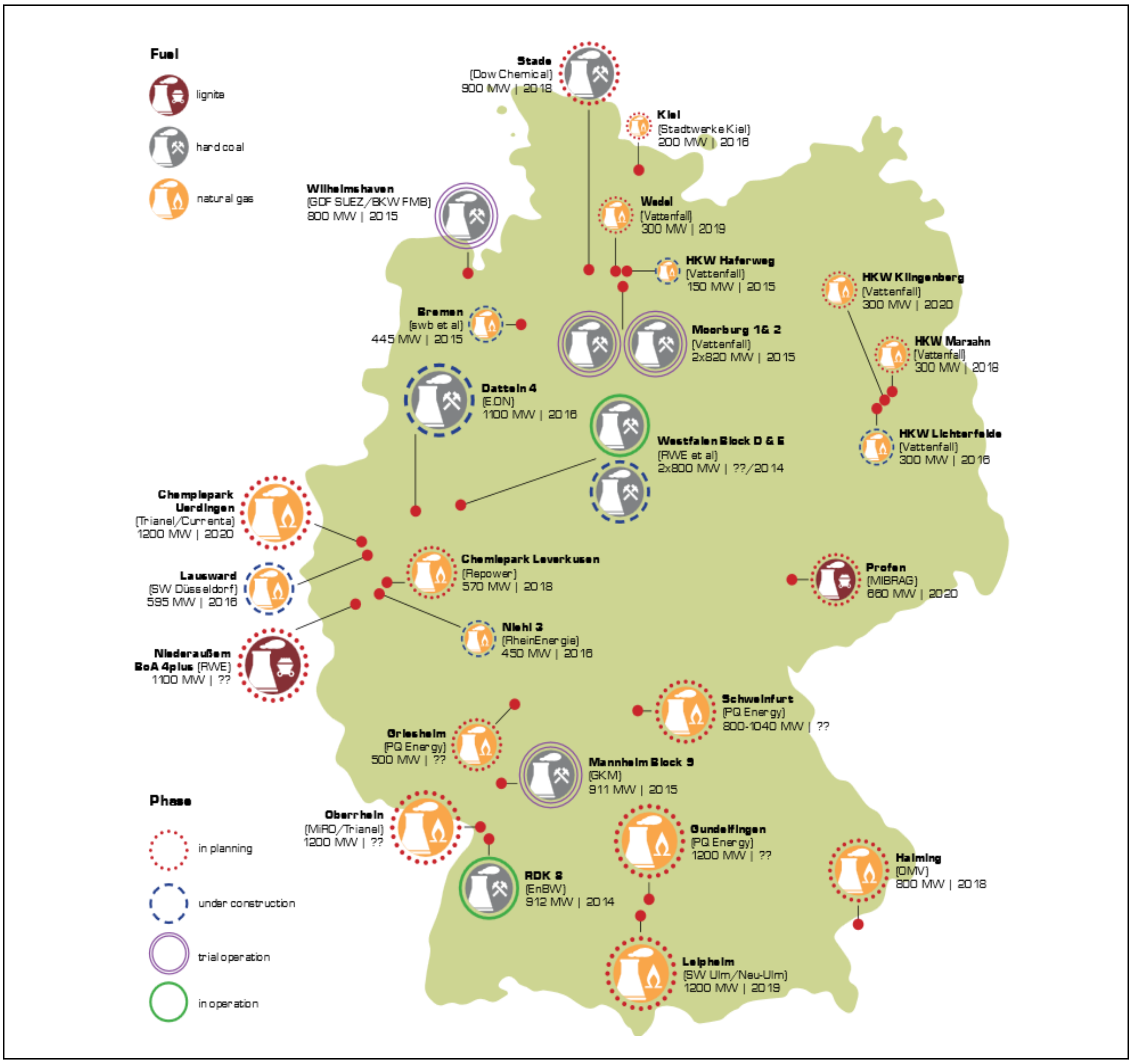
Source: elaborated from (Statista, 2014)

FIGURE 10. Jänschwalde power plant

Source: (FAZ, 2010)

It is important to note that Germany is also building several fossil fuel plants of over 100 MW in different locations in the country.

FIGURE 11. New fossil fuel plants of over 100 MW



Source: (Kraftwerke Invest, 2015)

New generation from hard-coal thermal power plants began in 2013, with the commissioning of the Dortmund plant (750 MW). At that time, completion of 10 new hard coal plants was scheduled for the next two years, giving a total of 7,985 MW. This would increase Germany's hard coal capacity by 30% (Pei, 2013).

If we take into account the low CO_2 emissions trading prices in the European Trade System, coal is currently more cost-effective than gas, marking an incentive for the use of lignite, despite the fact that it has higher CO_2 emissions. Germany's lignite capacity is approximately 20 GWe, taking into account the addition of new plants with higher efficiency in 2011 (about 3 GWe). Power producers in Germany planned to install 5.3 GWe of coal capacity by 2013, according to statistics from the federal distribution agency (BNetzA).

Coal capacity currently being built and due to be connected to the grid in 2016, includes: RWE-Hamm Westphalia 750-800 MW; RWE, EnBW & MVV Energie-Mannhem 900 MW, Vattenfall-Hamburg Moorburg 1640 MW; E.ON-Datteln 1000-1100 MW. RWE y E.ON also have 2650 MW of power in the Netherlands.

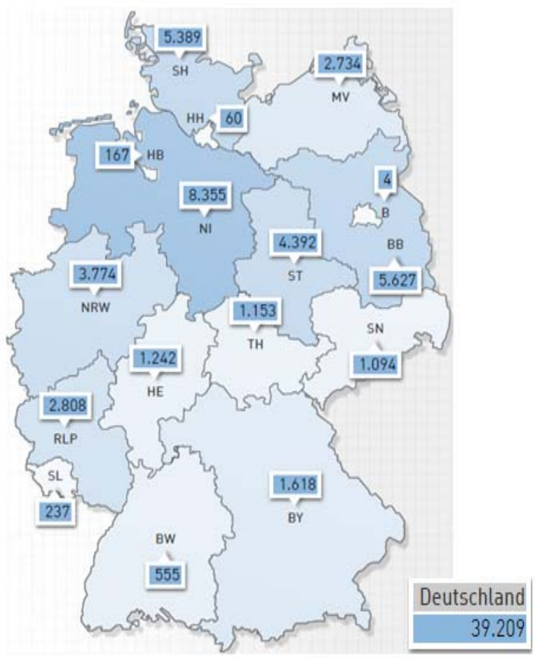
Between 2011 and 2015 10.7 GW of capacity from new coal plants was connected to the grid, largely as a result of plans developed before March 2011, rather than as a reaction to the phasing-out of nuclear power generation.

In July 2015, after months of intense negotiations, the government announced that its proposal to close coal plants would not be revisited, but about 2.7 GW of lignite generation (representing approximately 13% of total installed lignite capacity) would be gradually transferred to reserve capacity between 2016 and 2020, under a deal negotiated between RWE (1.5 GWe), Vattenfall (1.0 GWe) and Mibrag (World Nuclear Association, 2016).

These new projects can be seen as part of the process for renewing coal plants with new technologies offering better efficiency and performance.

As for wind generation, the figure below shows the distribution of wind farms, which together make up 39,209 MW of installed capacity. Wind determines the wind generation, so the onshore farms are placed mainly in the windiest locations of Germany, in the North.

FIGURE 12. Location of installed wind power in Germany (MW)

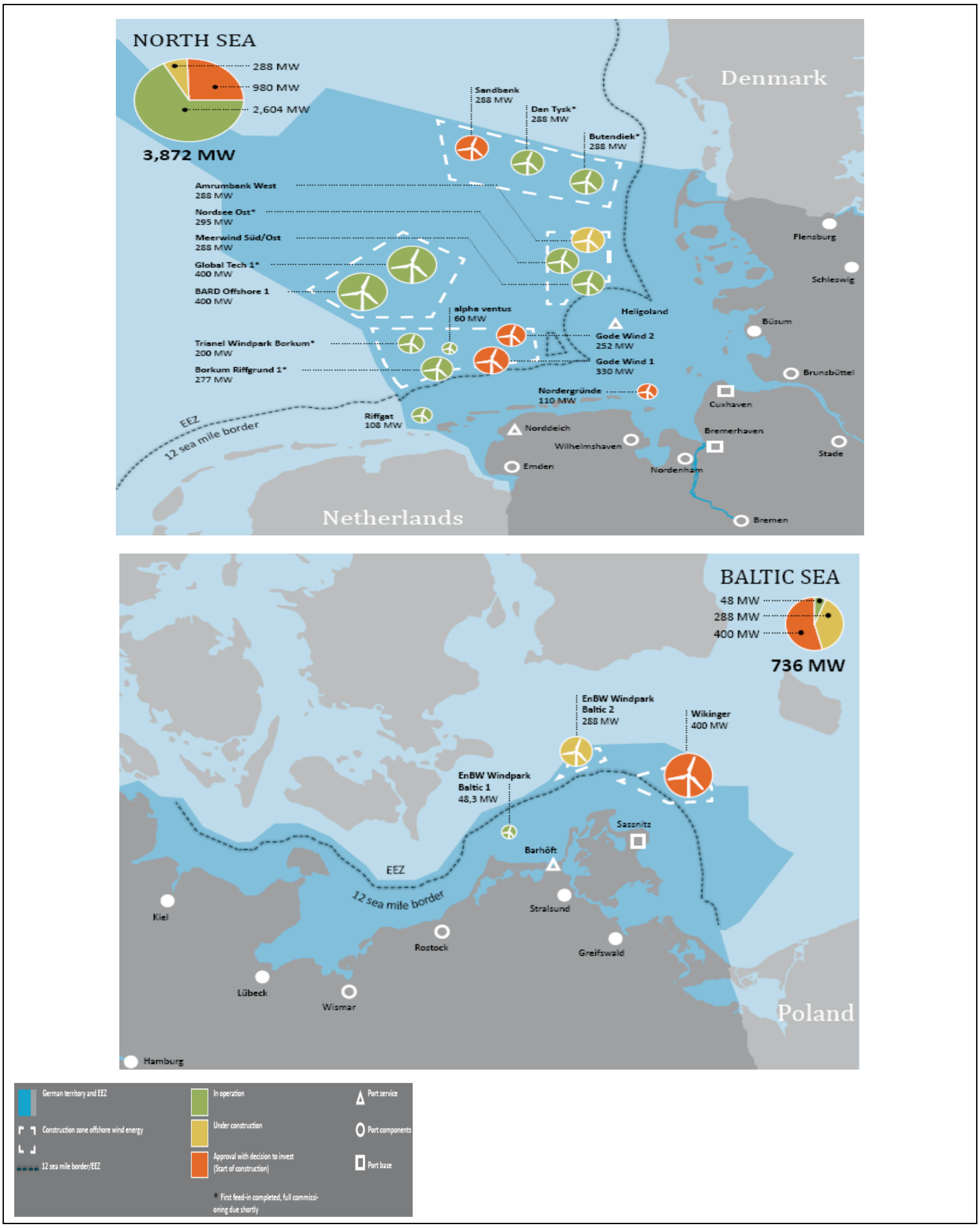


Principal wind-power states (MW)
Lower Saxony (NI): 8,355
Brandenburg (BB): 5,627
Schleswig-Holstein (SH): 5,389
North Rhine-Westphalia (NRW): 3,774
Rhineland-Palatinate (RLP): 2,808
Mecklenburg-Vorpommern (MV): 2,734

Source: (Agentur für Erneuerbare Energien e.V., 2015) and own elaboration.

Another example of offshore wind generation, based on which great acceleration and expansion can be expected in the near future, is shown in the figure below.

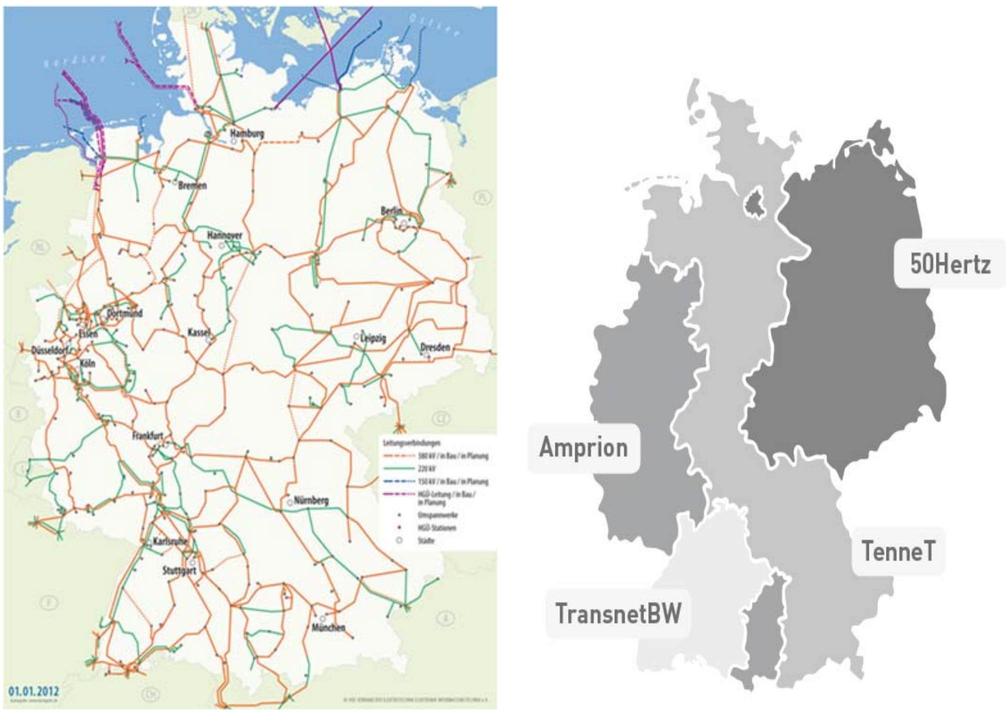
FIGURE 13. Location of offshore wind turbines in Germany



Source: (BWE, 2015)

The make-up of the generation system is intrinsically linked to the infrastructure of the power grid, which is a result of historical development and is dependent on the location of power plants and areas of large consumption, as shown in the figure below.

FIGURE 14. Germany's power grid and transmission system operators, by areas of control



Source: (NETZ, 2012)

The peculiar history of Germany during the second half of the 20th century, which was conditioned by the division of its territory, is reflected in the configuration of the transmission grid operation. Four transmission system operators (TSOs), currently divide the grid into different regions: Amprion, 50Hertz, TransnetBW and TenneT. Key characteristics of the four are shown in the table below.

TABLE 7. Transmission system operators

	Line length	Area covered	Consumers in area	Headquarters	Number of employees
Amprion	11,000 km	73,100 km^2	27 million	Dortmund	1,000
TenneT	10,700 km	140,000 km^2	20 million	Bayreuth	1,000
50Hertz	9,750 km	109,360 km^2	18 million	Berlin	800
TransnetBW	3,200 km	34,600 km^2	170.9	Stuttgart	340

Source: Own elaboration from (NETZ, 2012)

Of the four operators, the largest by line length and number of consumers in its area of operation is Amprion, followed by TenneT, 50Hertz and TransnetBW. One important point of differentiation is that 50Hertz operates 40% of German wind power (Netz Entwicklungs Plan, 2012), giving it an essential role due to its weight in Baltic Sea operations.

The entire transmission grid operated by the four TSOs comprises over 34,650 kilometres, but this is not the longest sector in the total grid. The greatest length is found in low voltage lines, followed by medium voltage and high voltage lines and finally the transmission grid; as the table below shows. In all, there are approximately 1.79 million kilometres of grid, operating at a frequency of 50 hertz, the same as in other European countries (Peter et al., 2015).

TABLE 8. List of German power grids by voltage

Grid	Voltage	Total length
Transmission voltage	220 – 380 kV	34,979 km
High voltage	110 kV	96,308 km
Medium voltage	10 – 30 kV	509,866 km
Low voltage	230/400 V	1,797,938 km

Source: Own elaboration based on (Peter et al., 2015)

This structure makes the German power grid the most complex in Europe. Part of the distribution grid is operated by over 800 different entities (DSOs or Distribution System Operators), which supply power directly to 20,000 municipalities. Among them, about 700 are known as *stadtwerke* (explained further on in this section in the detailed description of the companies), whilst more than three-quarters of DSOs supply to less than 30,000 consumption points. The four largest generation companies (E.ON, Vattenfall, RWE and EnBW), also studied in this chapter, have an important share of the distribution system, since concession contracts for operating municipal grids can have a term of 20 years. Under the Energy Industry Act of 2005 (see Chapter 6) these contracts must be reviewed to ensure non-discriminatory conditions. This might lead to the cancellation of some concessions, favouring smaller distributors such as the *stadtwerke* (Agora Energiewende, 2015d). The DSOs therefore play an essential role in the development of the decentralized distribution pursued by the *Energiewende* as a power model.

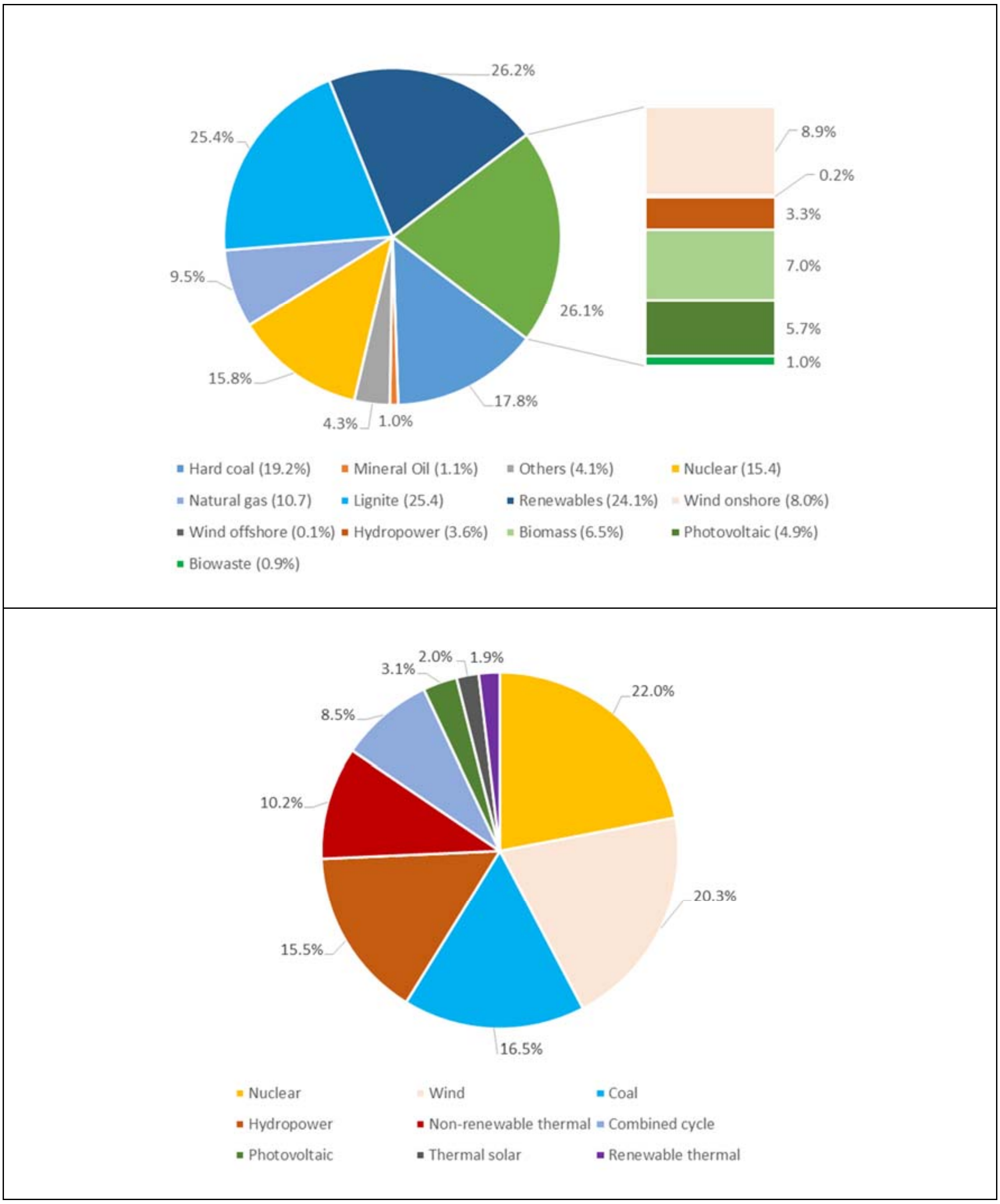
The four largest companies in the area of generation and distribution also have a large share in marketing power to the final consumer – 45.5% in 2012. These are large consumers and given Germany's high degree of industrialization, in 2013 they accounted for 48% of consumers, as compared to domestic consumers (which although the most numerous, accounted for just 27%) and industry and the small business sector (25%) (Agora Energiewende, 2015d).

Given that this grid requires adaptations and enlargement, as explained in Block I, the generation system will also need important modifications, both in terms of the removal of lignite, hard coal and nuclear plants and in terms of introducing new systems.

Power and production. Current situation and historic development

Capacity (see previous section) came to 614 TWh generation (Agora Energiewende, 2015c), as shown in the graph below.

GRAPH 17. Coverage of power demand in Germany (above) and Spain (below) in 2014



Note: data in parentheses in the figure above, are for 2013.

Source: elaborated from (Appunn, 2015; Red Eléctrica, 2015)

As regards power generation, in 2014 renewable energy sources contributed 26.2% (157 TWh) [48] to the German power grid,[49] and 41% had no CO_2 emissions (including nuclear power). By comparison, Spain has a large installed capacity of renewables,

[48] In 1980 it was thought that for technical reasons, the power system could not accommodate more than 4% of renewables (Von Hirschhausen, 2014).

[49] (Agora Energiewende, 2015c) (DENA, 2015)

covering 42.8% of power demand in 2014 (mainly wind and hydro), and 66.5% is carbon-free (including nuclear power) (see former graph). Generation from renewables is forecast[50] to be 176 TWh for 2016.

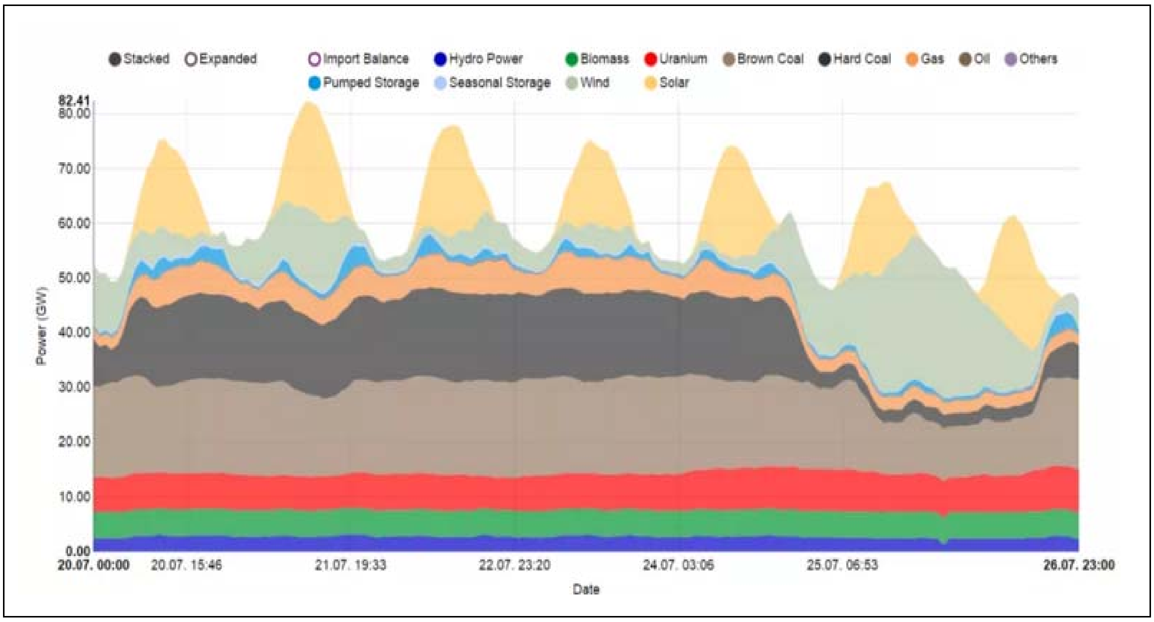
Historically, renewable generation remained "stuck" at 20 TWh until 1990, and grew only slightly in the decade between 1990 and 2000 (see Graph 20).

In 2013 wind energy accounted for most renewable power generated in Germany (35%), followed by photovoltaic (PV) (20%). In meteorological terms, southern Germany is the region best suited to PV energy, although average solar irradiation is still only comparable to Alaska.[51]

Weekly development, dispatch priority and variation in wind and solar output can be seen in the graph below, which reflects the dramatic reduction in hard coal and gas to accommodate wind and solar power.[52]

On 27 July 2015,[53] an unusual combination of sunny weather in the south and strong winds in the north enabled the country to attain record levels of renewable output, with 78% (47.9 GW) of internal power demand being met by renewable sources for several hours.

GRAPH 18. Power situation in Germany in the 30th week of 2015 (GW)



Source: (Fraunhofer ISE, 2015a)

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[50] (NETZ- TRANSPARENZ.DE, 2015)

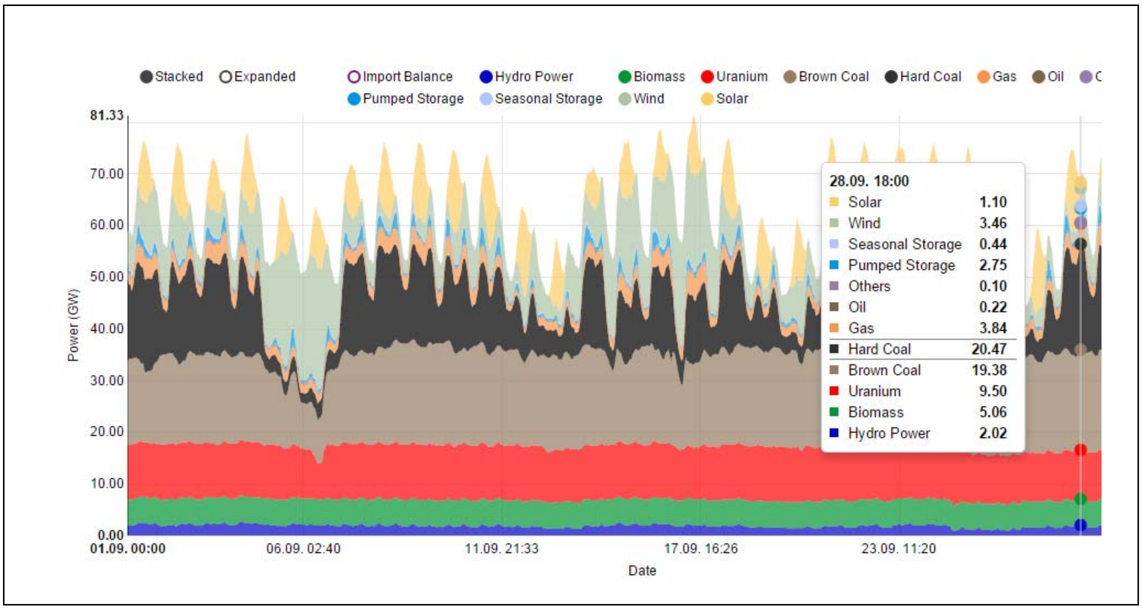
[51] Annual GHI (global horizontal irradiance) is particularly important in any assessment of the potential of photovoltaic energy. Germany has between 951 and 1,257 kWh/m^2/year (with an average of 1,055 kWh/m^2/year). This situation means that the performance of photovoltaic panels is currently characterized by losses of 15% in efficiency (depending on external temperature) and a range of between 536 and 1,014 full-load hours (with an average of 912 hours) in 2012 (Peter et al., 2015).

[52] Two issues are not analysed: prices and the fact that solar and wind energies enjoy FiT and enter the market at price zero.

[53] (Roca, 2015)

This variation and accommodation of hard coal (and also lignite) production can also be seen in the graph below, for September 2015.

GRAPH 19. Power situation in Germany in September 2015 (GW)



Note: data in the table shown in the graph indicates the composition of power production on 28 September 2015 at 18.00.

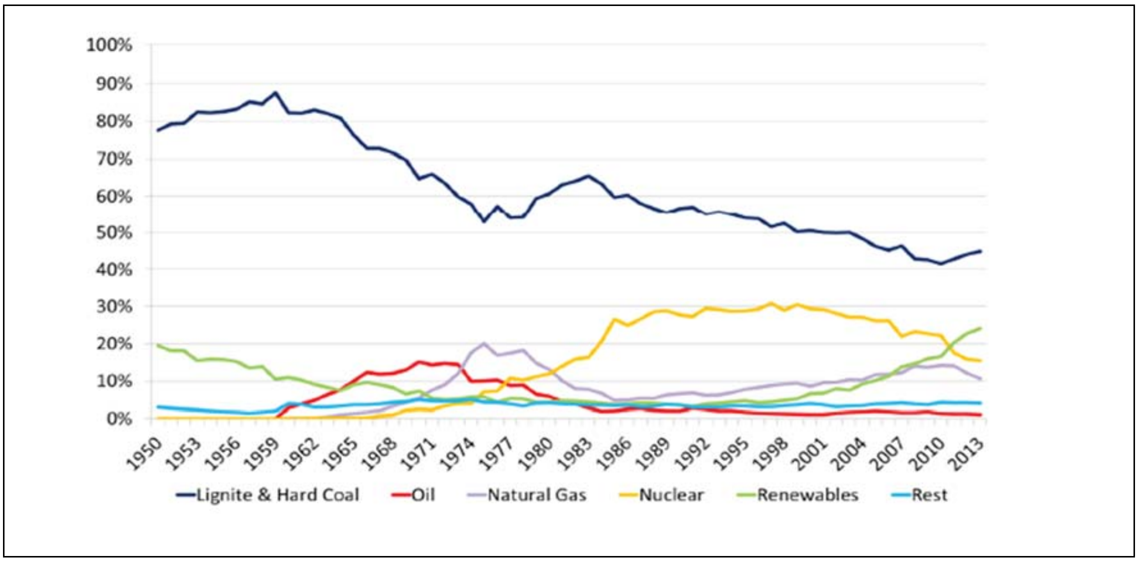
Source: (Fraunhofer ISE, 2015a)

Even this figure was recently exceeded, with a new record of 81% being set on 26 December 2015.

Historical development

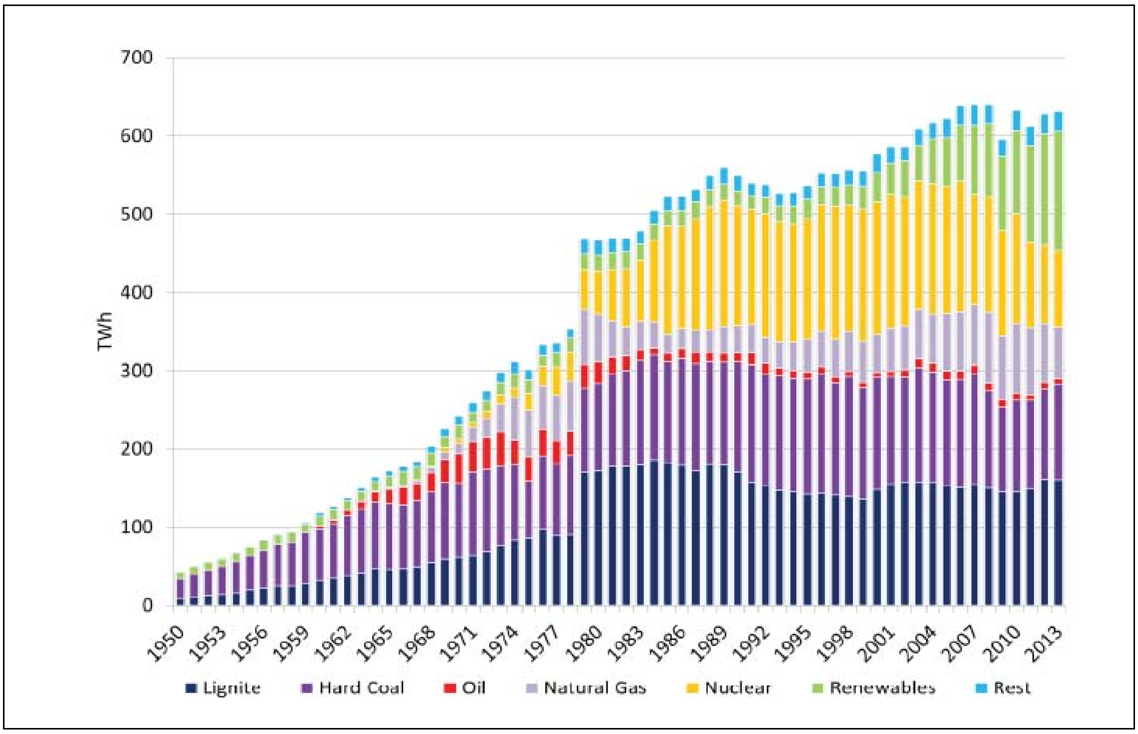
Graph 20 shows the historical variation in the power mix. As in the case of primary energy, the importance of RE increases when the coal share is reduced. Coal played an important role until the introduction of nuclear generation in the 1980s, reaching peaks of 30%, while renewables began to become more intense at the beginning of the 2000s.

GRAPH 20. Development of the German power mix since 1950 (%)



Source: (Rutten, 2014)

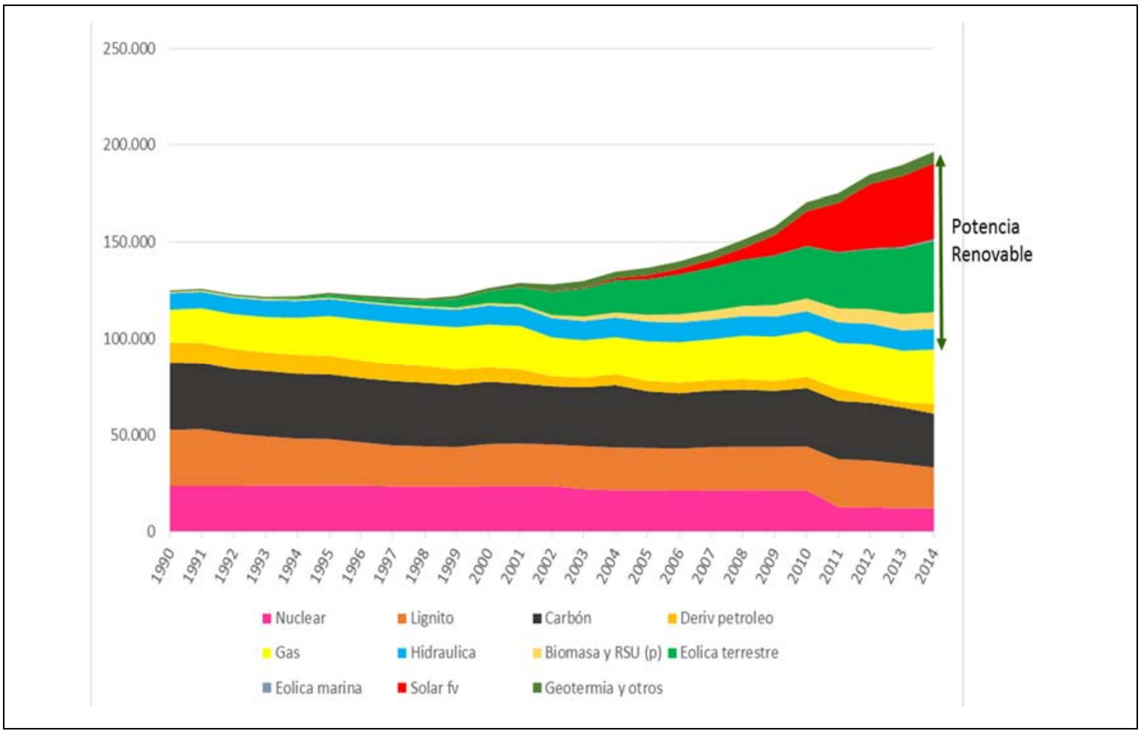
GRAPH 21. Development of power generation in Germany since 1950



Source: (Rutten, 2014)

Graph 22 shows developments in the German power mix in terms of installed capacity.

GRAPH 22. Development of installed capacity (MW)[54]



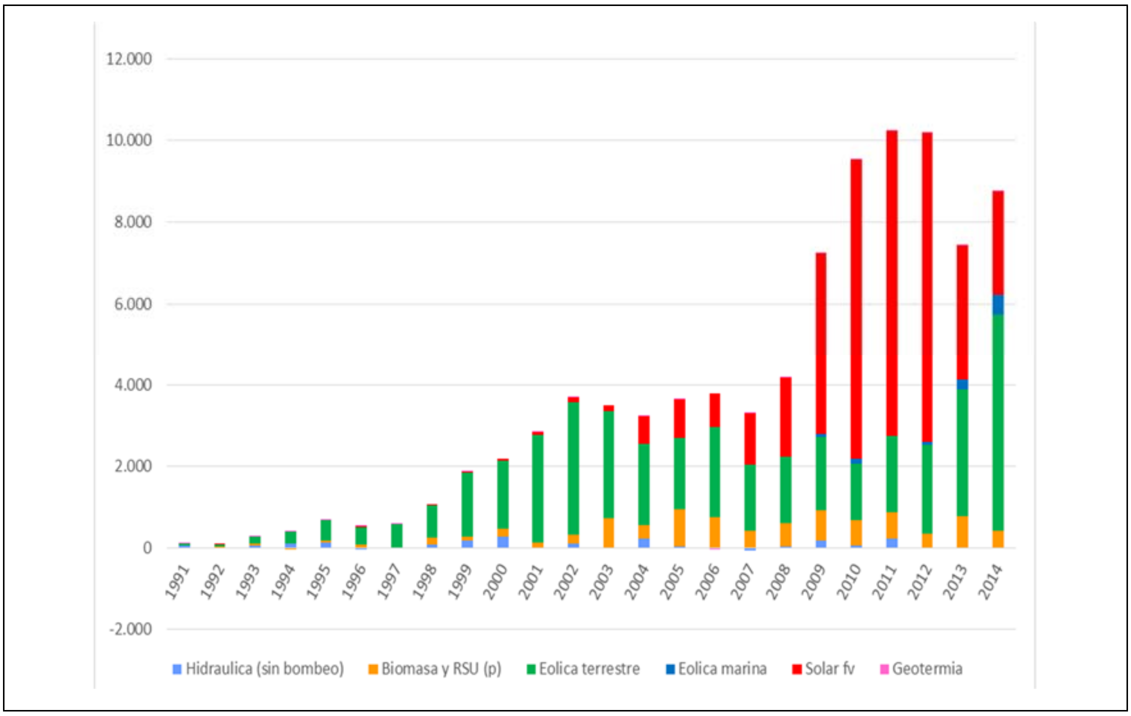
Source: BMWi in (Corrales, 2015)

At the end of the 1990s, wind energy started to become more important, topping 1,000 MW in 1995, 10,000 MW in 2002 and 30,000 MW in 2012. The first offshore wind farms were installed in 2009 and by 2015 they were producing 1,000 MW.

Solar photovoltaic energy capacity reached 1,000 MW in 2004 and between 2009 and 2012 it was growing at a rate of more than 7,000 MW per year. Nearly 38,000 MW was installed in 2014, exceeding wind energy power and making it the generation technology – conventional or unconventional – with the largest installed capacity in Germany.

[54] The current situation of coal plants and new projects is examined in Section 4.4 *Coal*.

GRAPH 23. Development in annually installed renewable energy capacity (GW)



Source: BMWi in (Corrales, 2015)

In addition, as the table below shows, installed capacity from fossil fuels has also increased since 1995, while installed capacity from nuclear energy has fallen.

TABLE 9. Development in installed capacity (GW)

	1995	2000	2005	2010	2012	2013
Fossil fuels	83.4	80.8	76.4	85.8	89.6	91.4
Nuclear energy	22.8	22.4	20.4	20.5	12.1	12.1
Hydroelectric energy	8.9	9.5	10.9	11.2	11.3	11.2
Wind energy	1.1	6.1	18.4	27.2	31.3	34.7
Solar photovoltaic energy	----	0.1	2.1	17.6	32.6	36.3
Other	----	----	0.6	0.4	0.4	0.4
Total	116.2	118.9	128.6	162.7	177.3	186.1

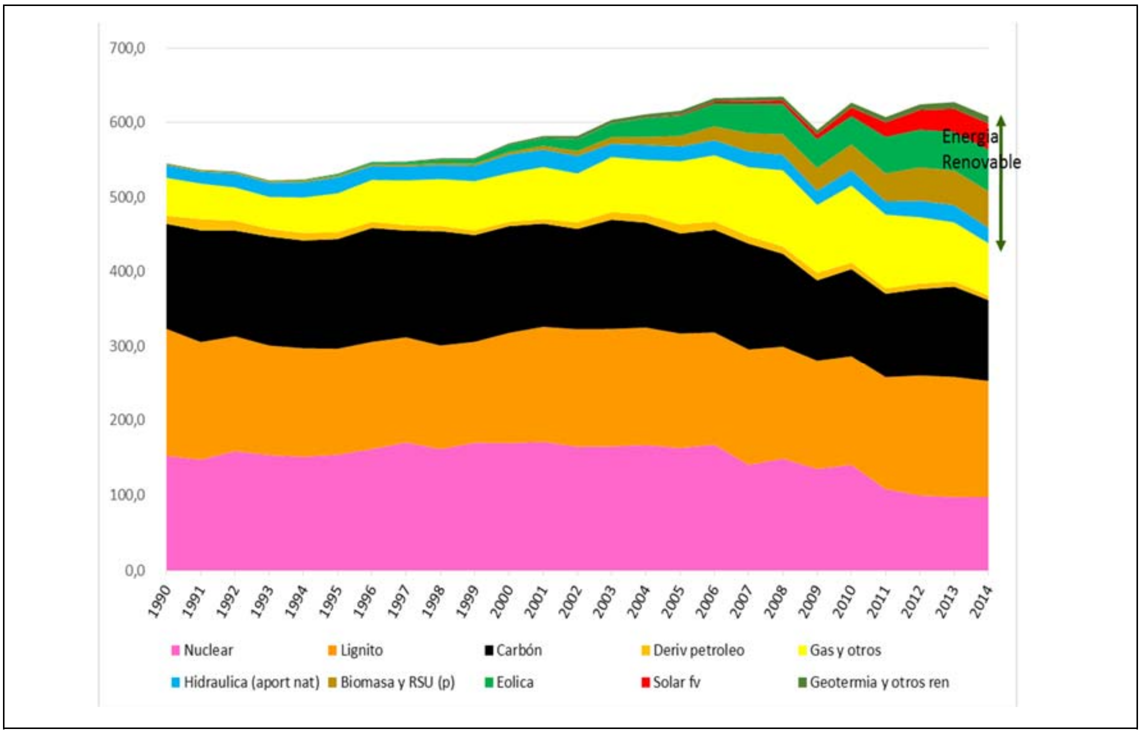
Source: Own elaboration from (European Commission, 2015)

The graph provides a more detailed picture of the development of power generation since 1990. Coal and nuclear energy continue to account for a considerable share. Renewables first began to be introduced on a large scale in the 2000s. In 1990, they accounted for just 3.4% and 6.2% in 2000. By 2005 the figure had risen to 10%, 17% in 2010 and 27.4% in 2014 (BMWi, 2015a).

However, these energies represented 50% of installed capacity, as explained above. This is logical, given that most solar sites barely exceed 1,300 equivalent hours, so that 38 GW of photovoltaic had barely 920 equivalent hours of full operation (10.6% of the load factor) in 2014. The ratios for wind energy were little better - 1,500 hours for onshore and 1,900 for offshore, even though the latter will not be competitive until it reaches 3,000 working hours, due to the high installation and running costs (Corrales, 2015).

Germany produced 548 TWh in 1990, of which 20 TWh (3.5%) came from renewables (mostly hydro power). This figure was not surpassed until 1996 (553 TWh), since the intermediate years were marked by German reunification and adaptation of East German industry.

GRAPH 24. Development in power generation (TWh)



Source: BMWi in (Corrales, 2015)

Maximum production in 2007 reached 641 TWh. Due to the global and European economic crisis and improvements in efficiency, this production level has not been matched since.

At the same time, it is important to note that Germany is still consuming coal. One of the reasons for this is the competitiveness of the coal price and also the low price of CO_2 emission rights. The price of CO_2 emissions (EU allowances or EUAs) was estimated at €25 per tonne and yet the price in September 2015[55] was €7.87 per tonne.[56] This has led to a rise in coal consumption compared to natural gas, which despite experiencing a reduction in price, is still less competitive than coal.

Germany produced 99.71 TWh in 2010 from anthracite and 130.43 TWh from lignite, rising to 107.73 TWh and 140.43 TWh respectively in 2014.

[55] (EEX, 2015)
[56] (Stilwell de Andrade, 2015)

TABLE 10. Development of power generation (TWh)

	1995	2000	2005	2010	2012	2013
Solid fuels	289.1	296.7	288.1	262.9	277.1	282.6
Oil and products	9	4.8	12	8.7	7.6	7.2
Natural gas	50.4	60	83.6	100.9	87.5	79.5
Nuclear energy	153.1	169.6	163.1	140.6	99.5	97.3
Renewable energies	30.4	39.7	69.3	111.2	149.6	158.2
Non-renewable wastes	5.3	5.8	3.3	6.4	6.6	6.6
Total	537.3	576.5	622.6	633	629.8	633.2

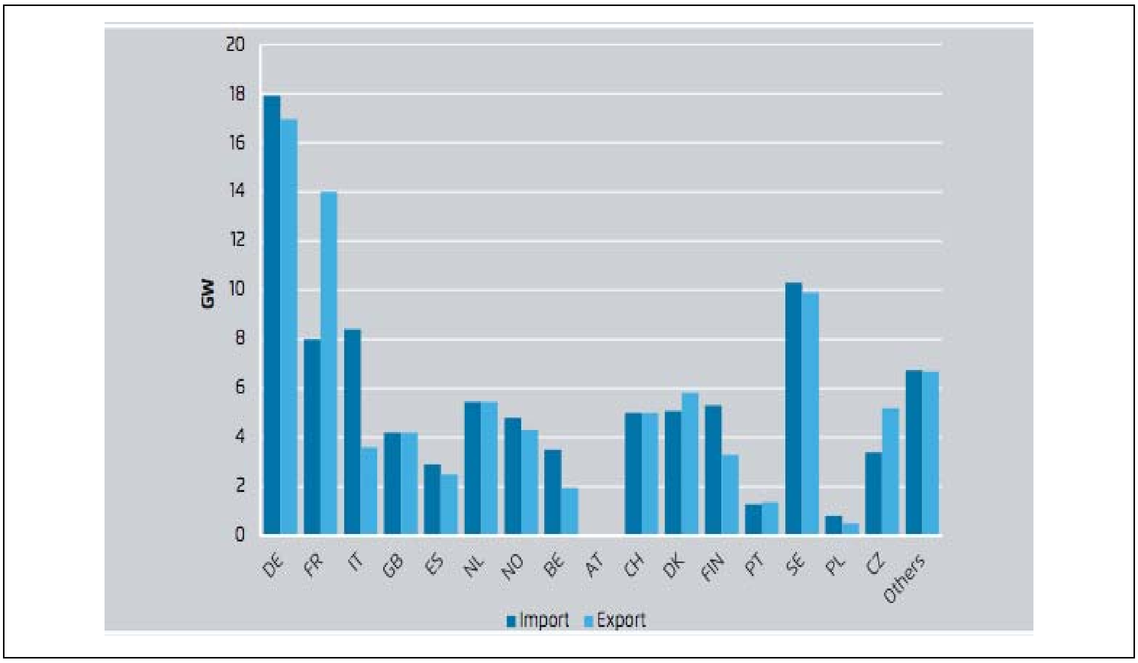
Source: Own elaboration from (European Commission, 2015)

Germany has seen the incorporation of new energy sources, such as coal, oil, gas and nuclear energy. As Graph 24 shows, power generation has risen significantly in the last few decades. In addition, since the 1990s, an increase in demand has been met by an increase in renewables.

Imports and exports

In 2012 Germany had one of the largest interconnection capacities in Europe, including interconnections with ten countries (Agora Energiewende, 2012).

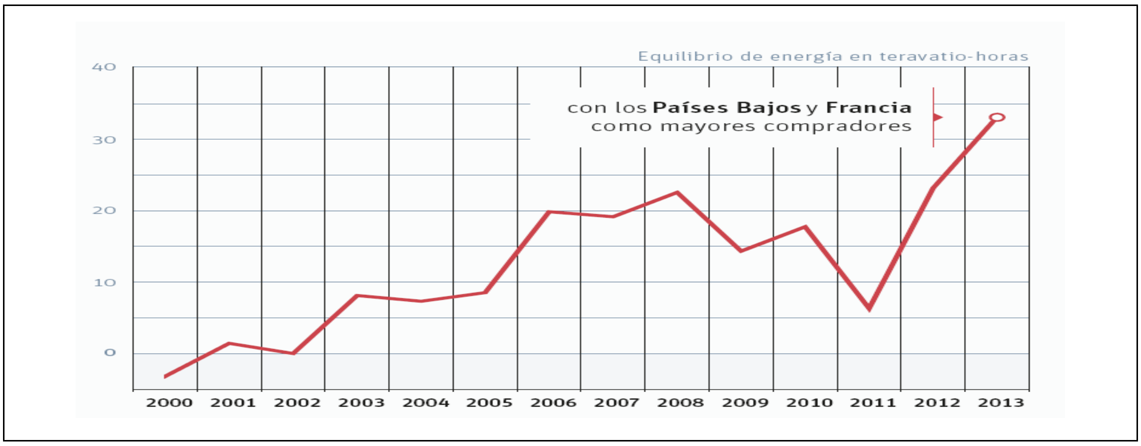
GRAPH 25. Capacity for power import and export by country (GW)



Source: (Agora Energiewende, 2015a)

As the graph below shows, the Heinrich Böll Foundation think-tank has found that Germany continues to be a net power exporter.[57]

GRAPH 26. Net power exports in Germany from 2000 and 2013 (TWh)



Source: Agora Energiewende and AGEB in (Morris & Pehnt, 2012)

In 2013, the German Institute for Applied Ecology published a report[58] on energy flows between Germany and its neighbouring countries. The report appeared at a time when Poland and the Czech Republic were complaining about German use of their grids to transmit its renewable power from the north to the south of the country.[59]

Switzerland also complained about the inability of its conventional power plants to generate all their potential power due to usage of its grids by German renewable energy. However, the Netherlands, which was in the same situation with regard to its gas turbines and German renewable energy, did not register a complaint.

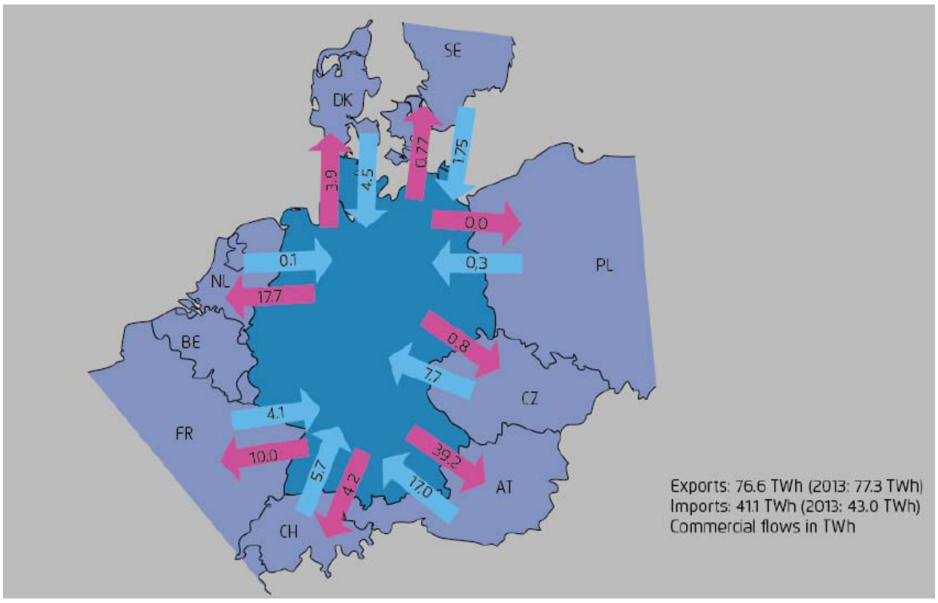
In the report, researchers argued that if flows are high, so too are prices. Thus, due to the design of the market, even if power can be purchased from neighbouring countries at lower prices, the electricity enters a grid that is often congested and has to be redistributed. This often happens with wind and photovoltaic energy production. As a result, market price and design are the causes of the flow loops and complaints from Switzerland, Poland and the Czech Republic.

57 A negative value of net imports of power energy, calculated as power usage minus production, indicates that the country is a net exporter.

58 (Loreck, Hermann, Matthes, Emele, & Rausch, 2013)

59 Indeed, the Czech national power system operator, CEPS, announced investment of more than €72m for transformers at its border with Germany by 2016, in order to protect the Czech Republic from grid failures.

FIGURE 15. Energy flows in Germany in 2014 (TWh)

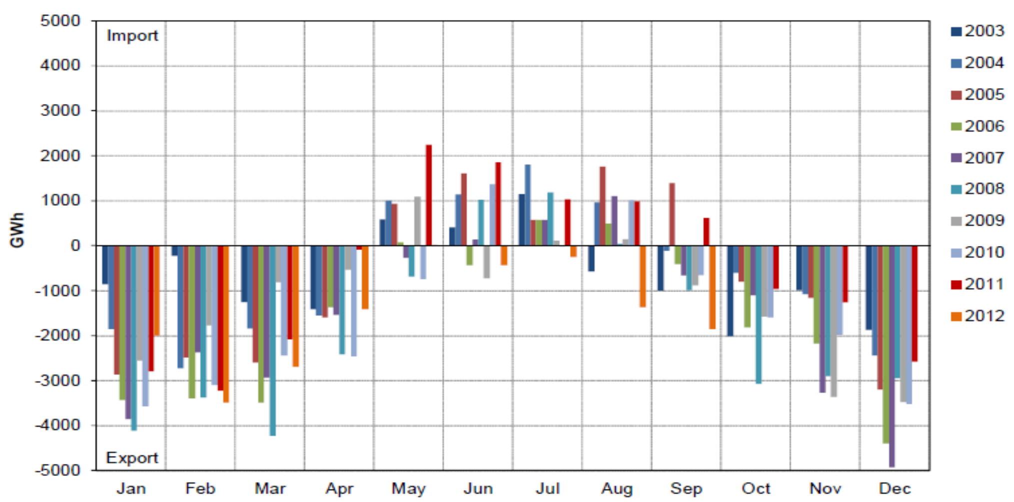


Source: (Agora Energiewende, 2015b)

Germany is a large importer of power from the Czech Republic and a net exporter to Poland. The report found that Germany not only sends electricity from north to south through Polish and Czech grids, but also sends electricity to Austria through these two countries.

One of the conclusions of the study was that Germany imports energy during the summer months and exports it during the winter months, as the graph below shows.

GRAPH 27. Monthly imports and exports in Germany between 2003 and September 2012 (GWh)



Source: (Loreck et al., 2013)

Researchers found that demand in France had a greater influence on energy flow than German requirements, due to the low degree of flexibility in nuclear plants.

This means that at times of low demand in both France and Germany, two countries with a similar load profile, it is generally France that exports power to Germany. The option of reducing output in nuclear plants is not suitable for reactors. When demand rises in France and Germany, it is Germany that exports to France. Germany has a power capacity that exceeds its demand peak.[60]

According to the Öko-Institut, Germany has higher physical transmission capacity than other countries such as France (the former has 52% as compared to 40% in the case of the latter); however, this is not translated into commercial capacity (32% for the German case and 60% for the French case).

France, three-quarters of whose power supply comes from nuclear energy, is a flexible commercial partner for Germany. Likewise, France uses German grids to export power to Switzerland and Italy and only 2.4 TWh of the 20 TWh that was physically imported from France to Germany was sold to Germany. This may also be one of the reasons why the German grid is congested.

As we shall see in the next chapter on regional cooperation and former issues, in 2015 Sigmar Gabriel took a step towards improving German and EU energy security.[61] The Minister and eleven counterparts from European neighbour countries signed a political declaration to guarantee a secure and reliable power supply between the countries. This regional cooperation programme is called "12 electrical neighbours".

Under this programme, energy security is seen as a European, issue, rather than an exclusively domestic problem. The intention is to focus on a single energy market in order to offer this security. This entails neighbour states' expressing trust in the other countries, although harmonizing different energy policies is a difficult task.

The Federal Ministry for Economic Affairs and Energy (BMWi) underlined the key points of the declaration. Firstly, the neighbour countries have agreed to make supply and demand more flexible by using market signals and price peaks and avoiding the use of legal limits on prices. At the same time, the neighbour states committed to reinforcing the grids and not restricting the boundaries of electricity interchange, even at times of power shortage. Additionally, neighbour states will pay special attention to assessing their development as a group and therefore being able to develop a common perspective.

[60] The winter of 2011-2012 is very illustrative: an intense wave of cold swept across Europe sparking record energy consumption in France (over 100,000 GW), partly explained by the use of electric heating. At one specific moment, France was importing between 4 and 5 GW, the equivalent of the output of almost four nuclear plants. Nonetheless, there was no energy shortage in Germany, which at the same time came close to its own maximum demand levels.

[61] (Kilisek, 2015)

This agreement is fundamental for Germany as it has to deal with an important excess of generation capacity, a consequence of an increase in renewable power production while it maintains conventional grid-connected power plants.

From the point of view of the German power market, this represents greater European integration. But this is even more true from the perspective of the country's supply security, since Germany is going to lose major base-load capacity due to nuclear disconnection. Given the nature of renewable energy, which depends on climate conditions, they therefore also need to support base load capacity in the Czech Republic and France (both nuclear-based).

Germany's objective is to avoid the need for a national capacity market through European integration. However, governments and policies can change and Germany is therefore assuming a great risk in outsourcing its future energy security. The wisest option would therefore be to combine integration of the European energy markets with a capacity reserve in a national capacity market.

Companies: RWE, E.ON, EnBW and Vattenfall[62]

In this section, we shall analyse the situation of the main power companies in Germany, as well as their situation in the country's current energy transition, with data from Appunn, K et al.[63]

The four main power companies in Germany are RWE, E.ON, EnBW and Vattenfall. These companies are involved in energy production, sales and distribution. In 2013, they jointly held a 67% share of the conventional energy market in Germany.

Although there are many smaller energy providers on the market that often offer lower consumption prices than RWE, E.ON, EnBW and Vattenfall, German consumers do not tend to switch provider and these utilities maintain a dominant market position.

Now, however, as a consequence of the *Energiewende*, they face very important challenges as Germany embarks on an energy transition that is far removed from their core business (energy production and distribution from fossil fuels and nuclear energy) and moves towards a low-carbon economy based on generation from renewables, a sector in which they are falling behind. We shall make a brief reference to the strategies of these companies in this transition.

RWE was the largest energy provider in the country with 6.6 million clients in Germany in 2013 and 24% of market share of sales to final clients and distributors. RWE operates nearly 330,000 kilometres of the power distribution grid. It also

[62] In this section we try to show the most relevant issues of the *Energiewende* as they affect business groups. The reader should bear in mind that this is not a detailed study of the issue and therefore, references to a given company may be to one of its subsidiaries or other companies in the same group – in a strict or legal sense.
[63] (Appunn & Russell, 2015)

operates lignite mines in the Rhineland (Hambach) with 40-45 MT/year, Garzweiler with 35- 40 Mt/year and Inden with 22 Mt/year.

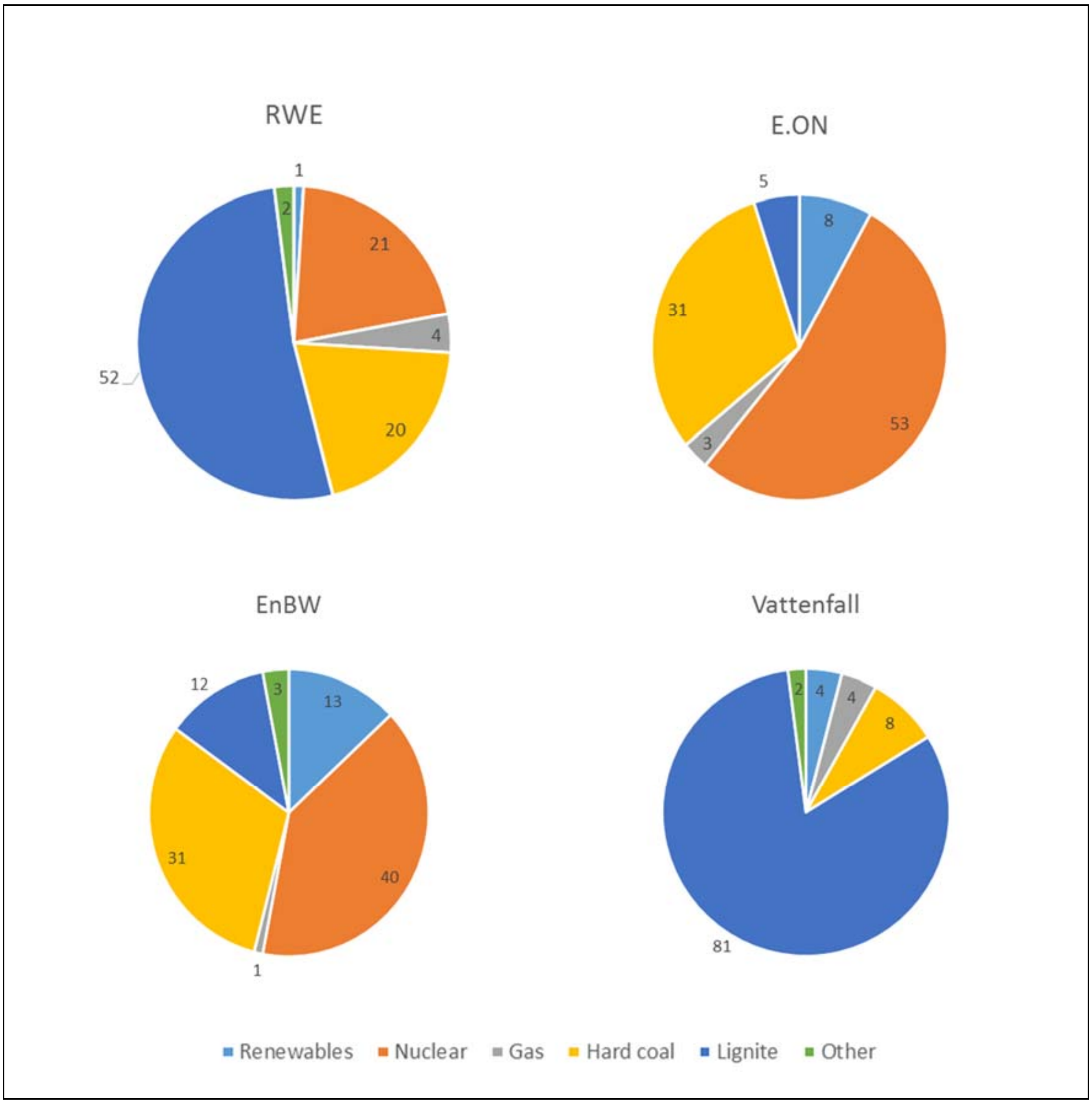
In 2013 RWE produced 145.9 Twh in Germany. As Graph 31 shows, more than half came from coal (52% from lignite and 20% from hard coal). Nuclear energy accounted for 21% of this figure, but renewables represented only 1% of RWE's power generation in Germany.

In 2013, E.ON supplied energy to 5.26 million customers in Germany. The company operated 352,000 kilometres or 19% of the distribution grid and produced 146.7 TWh of electricity in Germany. As Graph 28 shows, its generation is basically nuclear (53%), while renewable energies, mainly hydro, made up 8%.

Both RWE and E.ON (the main generation companies in Germany) have reported important losses – 3.2 billion euros in 2014 in the case of E.ON, due to write-downs in its thermal plants, and 2,800 in its coal assets. The strategy of both companies is to switch to large-scale renewables, distributed generation energy storage and micro grids. However, the two companies have set their sights on the introduction of what are known as "capacity markets" in Germany, in order to use conventional generation as backup to offset the intermittence of renewables. However, the German Government is unenthusiastic (Roca, 2015).

These two companies are currently in the process of restructuring their assets. RWE divested itself of its own coal assets in 2014 and preserves two of its independent subsidiaries: RWE Supply & Trading, which is in charge of power marketing (gas, coal and oil) in Germany, and RWE Innogy, which is devoted to renewable energy production (La Vanguardia, 2015).

GRAPH 28. Energy sources used for power generation by the companies studied in 2013 (%)



Source: elaborated from (Appunn & Russell, 2015)

EnBW produced 58.55 TWh in 2013 in Germany, of which 40% came from nuclear plants, 31% from hard coal, 12% from lignite, 12.8% from renewable energy sources (hydroelectric energy) and 1.3% from natural gas.

EnBW also operates the transmission and distribution grid, with 155,000 kilometres through its subsidiaries in Baden-Wüttemberg, where it has 99% of market share.

Vattenfall, which is owned by the Swedish State, is the fourth-largest energy provider in Germany with 2.9 million clients in 2013 and 12,254 employees. It owns and operates the power grids of Hamburg and Berlin. Vattelfall is also the sole operator of five open pit lignite mines in the German region of Lusatia (Brandenburg and Saxony), which had a combined output of 63.6 Mt in 2013.

Vattenfall generated 70.8 TWh in 2013. As shown in the graph above, 81% of that output came from lignite, 8% from hard coal, 5% from oil and 4% from hydro power.

Following the *Atomausstieg* in 2011, these power companies had to close several of their nuclear plants and will have to close the rest before 31 December 2022,[64] as shown in the table below.

TABLE 11. Nuclear plants owned by the main power companies in Germany

Operator	Reactors and net-capacity in MW (2010-2014)	Date of closure
E.ON	Unterweser: 1,345 MW	6 August 2011
	Isar/Ohu 1: 878 MW	6 August 2011
	Isar/Ohu 2: 1,410 MW	31 December 2022
	Brokdorf: 1,410 MW	31 December 2021
	Grohnde: 1,360 MW	31 December 2021
	Grafenrheinfeld: 1,275 MW	May 2015
EnBW	Philipsburg 1: 890 MW	6 August 2011
	Neckarwestheim 1: 785 MW	6 August 2011
	Philipsburg 2: 1,402 MW	31 December 2019
	Neckarwestheim 2: 1,310 MW	31 December 2022
RWE	Biblis B: 1,240 MW	6 August 2011
	Biblis A: 1,167 MW	6 August 2011
	Emsland: 1,329 MW	31 December 2022
	Grundremmingen C: 1,288 MW	31 December 2021
	Grundremmingen B: 1,284 MW	31 December 2017
Vattenfall	Krümmel: 1,346 MW	6 August 2011
	Brunsnüttel: 771 MW	6 August 2011

Source: elaborated from (Appunn & Russell, 2015)

Depending on the proportion of nuclear energy in the generation mix, in some cases this has meant a major reduction in the company's profits and serious employment cuts. E.ON suffered a €1.9m loss after reporting €6.3m in profits the previous year. Power plant owners have reacted to the situation by taking legal proceedings against the German Government. Vattenfall demanded financial compensation for damages, taking its case to the International Centre for Settlement of Investment Disputes (ICSID). For their part, E.ON and RWE brought their suit to the German Constitutional Court. In the case of EnBW, proceedings were brought against the German Government and the state of Baden-Wüttemberg in the Bonn district court.

Nuclear plant operators are also obliged by law to meet the cost of dismantling the nuclear plants and removing waste, thus increasing the economic impact of the *Atomausstieg* on those companies.

Following a stress test performed by the auditing firm Warth & Klein Grant Thornton AG, which assessed the costs of decommissioning nuclear plants and removing waste, Minister Sigmar Gabriel[65] said that "companies will be able to afford the costs".

[64] This was the case of Vattenfall in 2011; this is why nuclear power is not shown in the graph above.
[65] (BMWi, 2015c)

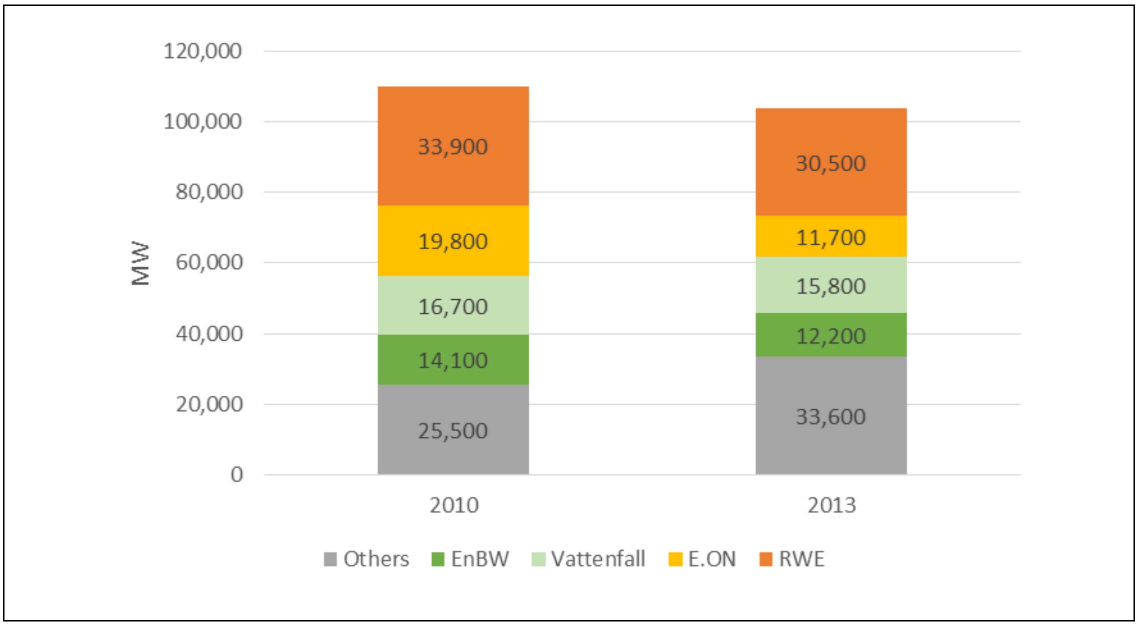
The experts who conducted the test anticipated that the total cost would come to €38.3 billion and the budget provided for the purpose was estimated at between €29 billion and €77 billion, while the companies have net assets of around €83 billion.

Apart from waste removal, the country's transition towards renewable energy sources, driven by the Renewable Energies Act (Erneuerbare Energien Gesetz, EEG), has also directly influenced the balance sheets of the large utilities. As discussed above, a greater increase in renewables has been achieved and in 2012 E.ON's CEO, Johannes Teyssen, said in an interview: "I am convinced that our market share in Germany will have to be reduced. It is not possible to maintain the same market share in a decentralized energy world". E.ON's power production fell by 38% between 2010 and 2013.

Since 2010 the aggregated market share of the four largest conventional power companies (RWE, E.ON, EnBW and Vattenfall) has fallen six percentage points, the overall market volume of conventional energy has fallen by 9% and the quantity of energy produced by the "big four" has fallen 16%.

As the graph below shows, large German power companies have lost weight in installed capacity.

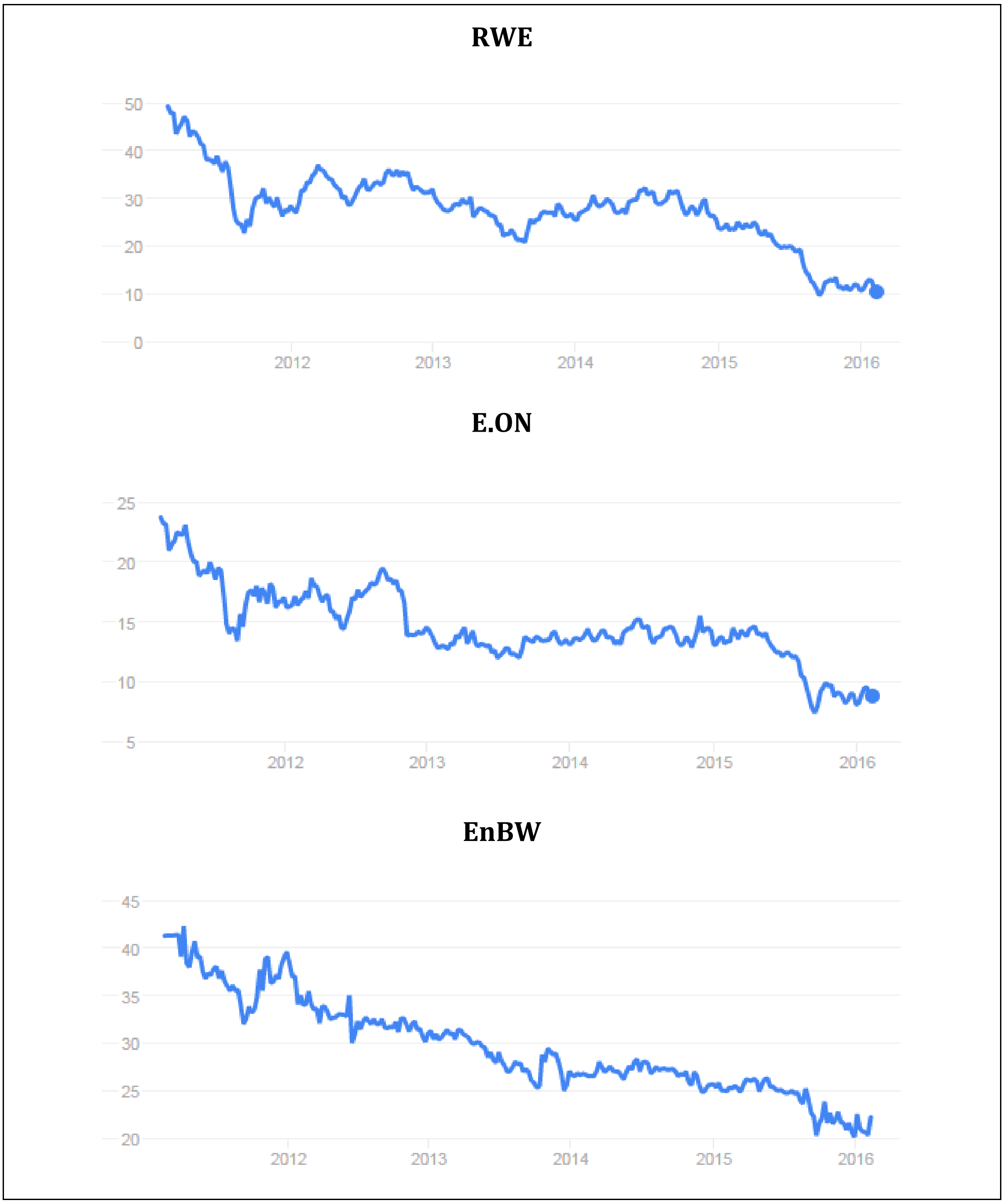
GRAPH 29. Installed capacity of the main utilities in Germany between 2010 and 2013 (MW)



Source: elaborated from (Appunn & Russell, 2015)

The progressive closure of nuclear plants and the effect on conventional fossil energy assets of the *Energiewende* has affected the price of these companies' stock, as the graph below shows.

GRAPH 30. Historical share price of RWE, E.ON and EnBW in the last five years (€)

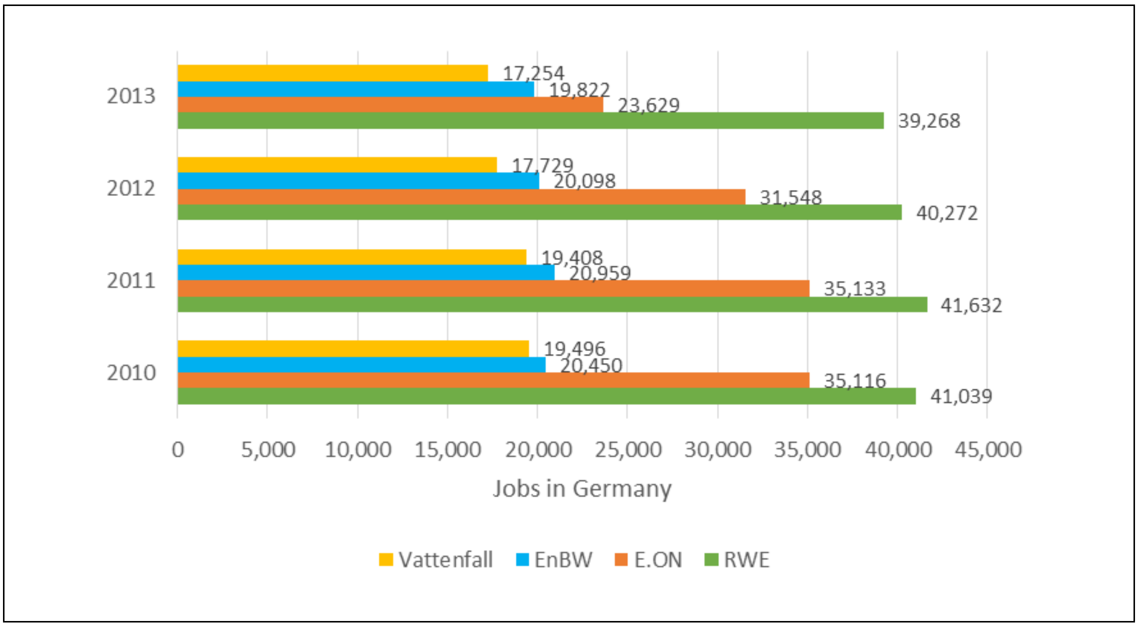


Source: (Google Finance, 2015)

In 2013 the trade union Verdi claimed that about 20,000 jobs in the energy industry were at risk. Following closure of the first nuclear plants, RWE, E.ON, EnBW and Vattenfall announced job cuts amounting to over 15,000 employees. In November 2014 the four largest utilities had 16,128 fewer employees in Germany than in 2010.

The largest cuts have been in E.ON[66] (11,487 jobs) with the smallest impact in EnBW (628 jobs).

GRAPH 31. Employee numbers at principal German power companies



Source: (Appunn & Russell, 2015)

On the other hand, as previously mentioned, following the closure of the Grafenrheinfeld plant in June 2015, E.ON said that despite the progressive nuclear disconnection, it sees opportunities in the *Energiewende*. Indeed, on 1 December 2014, E.ON announced that from 2016 on, it will begin divesting itself of its fossil fuel and nuclear operations to focus on renewable energies and distribution, a task which is made harder by the complexity of the conventional distributors.

In 2013, EnBW too announced its intention to increase its share of renewable energy by nearly 40% in 2020 to concentrate on wind and hydro energy.[67]

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[66] E.ON lay-offs in Germany between 2011 and 2013 were mainly due to closure of operations in Munich and sale of shares in other generation facilities such as Thüringer Energie, E.ON Westfalen Weser and E.ON Waste Energy, as well a new policy called E.ON 2.0, which focused on cost-cutting and improved efficiency in the company as a whole.

[67] Many municipally-owned public utilities (*stadtwerke*) had regional supply monopolies, amounting to 22.6 GW in 2013 with renewables and cogeneration. These were privatized during the 1990s. Some are owned by the four main utilities. However, following introduction of subsidies for green energy, some utilities have been renationalized as many councils and citizens decided not to renew their agreements with private companies. As a result, 72 new *stadtwerke* were founded between 2005 and 2013.
Due to distributed generation in renewable energy and cogeneration, the *stadtwerke* have some advantages if they are compared to the structures that belongs to RWE, E.ON, EnBW and Vattenfall.

5. OBJECTIVES. VIEW AND IMPLICATIONS

In this chapter we shall analyse the objectives and development of the *Energiewende*. We shall go on to focus on the vision for 2050 and examine the key topics recently (2014) identified by the German Ministry for Economic Affairs and Energy.

5.1. Basic objectives

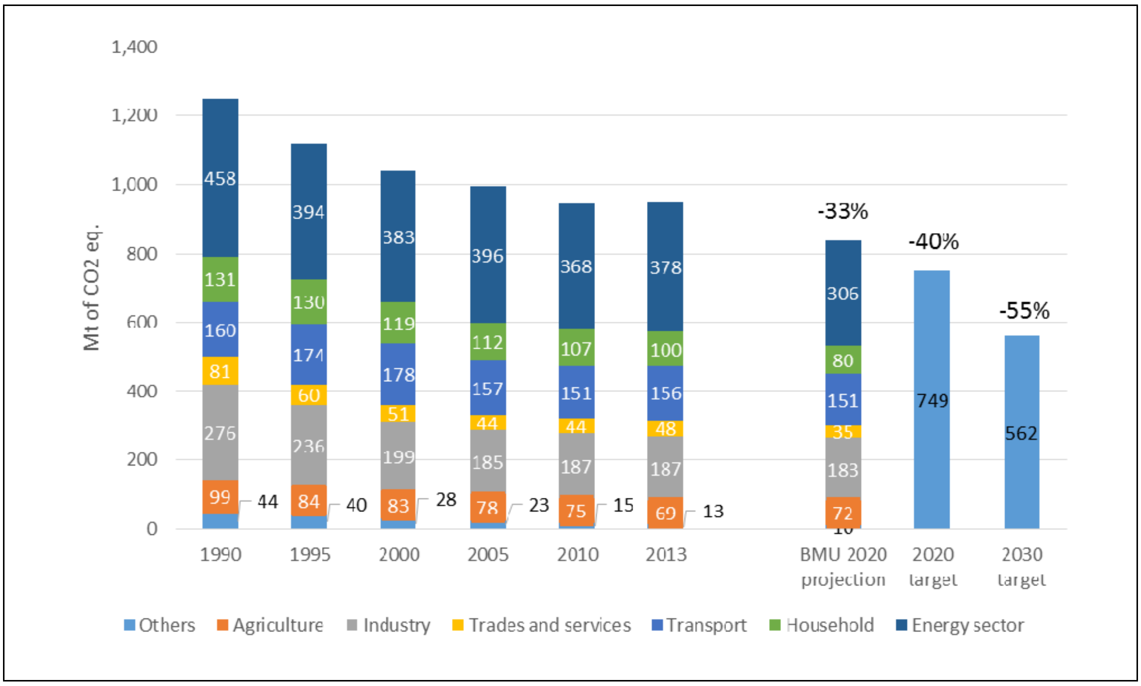
The basic targets of the *Energiewende*[68] for 2020 and 2030, as established by the German Government, are set out below.

Two basic objectives might be considered to be contradictory: reduction in GHG emissions and dismantling of nuclear power.[69] For the first of these, renewable energy and energy efficiency are fundamental tools.

GHG emissions

The first target consists of reducing GHG emissions (compared to a 1990 baseline) by 40% by 2020, 55% by 2030, 70% by 2040 and 80-95% by 2050.

GRAPH 32. GHG emissions by sector (in million tons of CO_2 equivalent)



Source: (Bayer, 2015; Rutten, 2014)

[68] (Von Hirschhausen, 2014)(Fundación Focus-Abengoa, 2015)(Galetovic & Muñoz, 2014)(Centro Mario Molina & Embajada República Federal de Alemania Ciudad de México, 2014)(Rutten, 2014)

[69] The German Government initially prioritized all targets equally. However, given the large number and the fact that many are contradictory, following a proposal by the Commission of Experts on Energy (Löschel, 2016) the *Energiewende* was limited to these two objectives.

The figure above shows trends and targets from 1990 to 2013, when a 25.5% reduction was achieved. Some authors (Bayer, 2015; Rutten, 2014) believed a target of 40% could not be achieved, but 33% was viable.

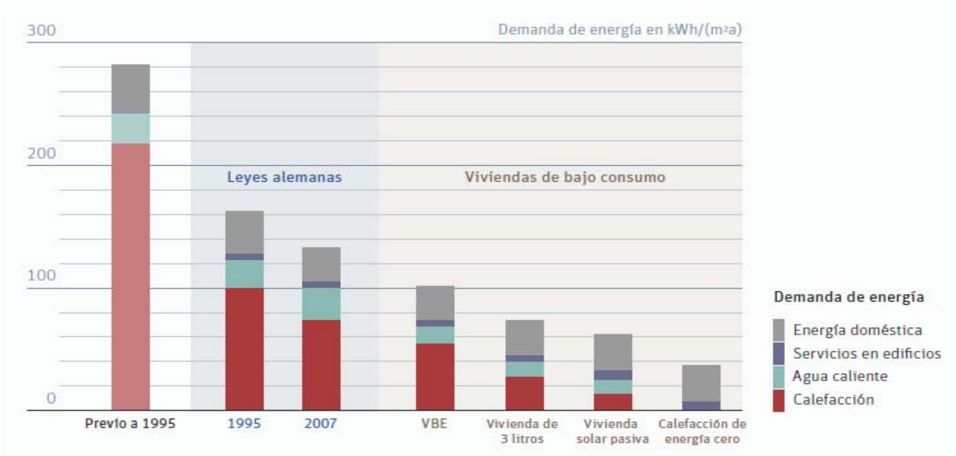
Approximately 146 million tonnes (Mt) of CO_2 equivalent was offset by renewable energy in Germany in 2012, of which 101 Mt came from the energy sector. Thus, CO_2 emissions in Germany were reduced in comparison to former years, although the figure is similar to 2009 emissions. This appears to indicate a relative levelling-off in CO_2 emissions[70] (Fortaleza, 2015).

Energy efficiency

The target is for annual improvements of 2.1% in energy intensity. Ambitious targets have also been set for improved energy efficiency: to reduce energy consumption in buildings from the 2008 baseline by 20% by 2020 and 80% by 2050; to reduce primary energy consumption by 20% by 2020 and by 50% by 2050; to reduce power consumption by 10% by 2020 and by 25% by 2050, and to reduce heating energy demand by 20% by 2020.

One of the main elements on which the energy transition focuses is an improvement in energy efficiency in buildings. This trend is shown in the graph below, in kWh/m^2-year, with the figures for low-consumption homes, demonstrating the huge long-term potential in this segment.

GRAPH 33. Energy demand in buildings (kWh/m^2-year)



Source: IFEU (2011) in (Morris & Pehnt, 2012)

[70] Indeed, Germany occupies one of the leading positions in the Climate Protection Index 2014 (Germanwatch, 2013), alongside Sweden and the UK. For many years, Germany has combined climate and environmental protection in the interest of a sustainable economy. The key of this model comes from an increase in energy efficiency and an extension of renewable energy and renewable raw materials (RRM).

It is important to consider the development of energy efficiency throughout the entire country. The table below gives trends in energy intensity[71] (EI) in Germany over recent years, showing a clear downward trend.

TABLE 12. EI development in Germany, 1995 - 2013 (toe/€m)

1995	2000	2005	2010	2012	2013
159	145	141	129	119	121

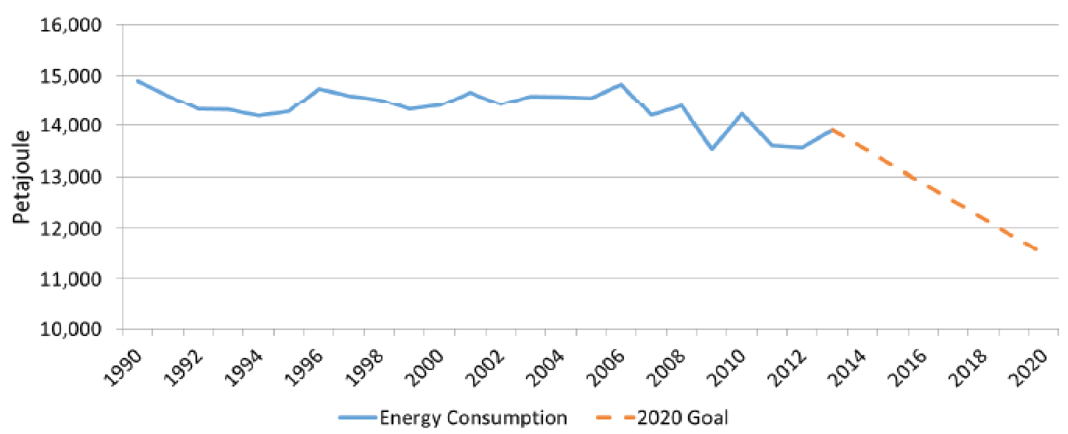
Note: for the purposes of measuring EI, €m are given at 2010 rates.

Source: Own elaboration from (European Commission, 2015)

Indeed, an efficiency study[72] conducted in 2014 by the American Council for an Energy-Efficient Economy (ACEEE) scored Germany highest among the 16 main economies analysed, because of its regulations for residential and commercial buildings. In the same ranking, Italy came 2nd, the European Union 3rd, China 4th, Spain 8th and the United States 13th.

The figure below shows trends in energy consumption in Germany and the forecast for the future towards the 2020 target.

GRAPH 34. Energy consumption in Germany (PJ[73])



Source: (Rutten, 2014)

However, efficiency trends are not as favourable as they need to be to meet the targets, according to Rutten (2014), and are not on course to reaching them.

[71] The usual means of measuring energy efficiency in macroeconomic terms is through energy intensity (EI). This indicator shows the relationship between energy consumption and the volume of economic activity and is calculated as a quotient between a country's primary/final energy and gross domestic product (GDP). Thus, high energy intensity indicates a high cost for transforming energy consumption into a given increase in GDP. Likewise, low energy intensity indicates that a large amount of wealth is obtained (GDP increase) with a low rate of effort (Ortiz & Alvarez, 2015).

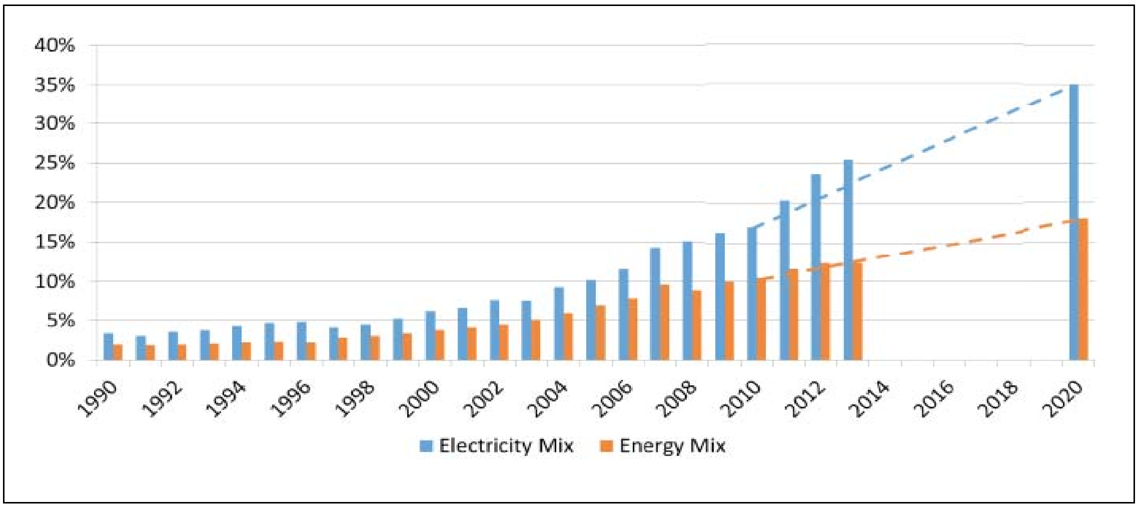
[72] (ACEEE, 2014)

[73] 1 PJ = 0.0238846 Mtoe

Renewable energies

As for the percentage of renewables, increases are targeted in both power generation (by a minimum of 35% by 2020, 50% by 2030, 65% by 2040 and 80% by 2050) and in final energy consumption (18% by 2010, 30% by 2030, 45% by 2040 and about 60% by 2050). See graph below.

GRAPH 35. Share of renewable energy in German power and energy mix with *Energiewende* targets (%)



Source: (Rutten, 2014)

This is the only target where good progress is being made both in final energy and power. The FiTs and the cost they entail are not unrelated to this trend, as we shall see.

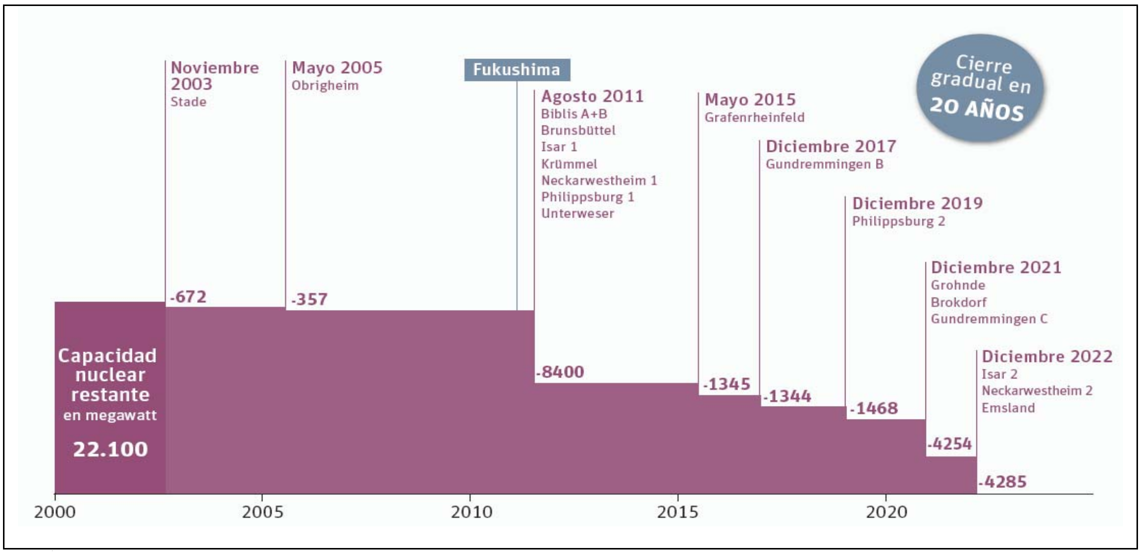
Nuclear energy

Another important factor is the progressive elimination of nuclear power, discussed in Chapter 3.

Following the announcement of the nuclear disconnection plan scheduled to be completed by 2022 and after completion of the first phase, with the closure of eight reactors in 2011, the next nuclear plant in the plan –Grafenheinfeld– was closed down in June 2015 (McKeating, 2015). Closure of the remaining eight is scheduled for between 2015 and 2022 (see graph below).

Among the plants still operating, the oldest is Gundedemmingen B, which began operating in April 1984. It was followed in 1985 by Gundremmingen C, both using boiling water reactors (BWRs). The other plants have pressure water reactors (PWRs). The plant with fewest years in service is Neckarwestheim 2, which was commissioned in April 1989; all plants still in operation were therefore built in the 1980s.

GRAPH 36. Scheduled reduction in nuclear energy capacity



Source: (Morris & Pehnt, 2012)

These closures will involve important costs in replacement by renewables and coal plants, estimated at around €1,000 billion (World Nuclear Association, 2016).

The table below shows the current situation of the nuclear plants, with the closure dates initially established and those agreed in 2010, and the results of the 2011 decisions.

TABLE 13. Nuclear plants affected by the *Energiewende*

Plant	Type	MWe (net)	Commercial operation	Operator	Provisional programmed shutdown of 2001	Agreed shutdown of 2010	Closure plan of 2011
Biblis A	PWR	1167	2/1975	RWE	2008	2016	Shut down
Neckarwestheim 1	PWR	785	12/1976	EnBW	2009	2017	Shut down
Brunsbüttel	BWR	771	2/1977	Vattenfall	2009	2018	Shut down
Biblis B	PWR	1240	1/1977	RWE	2011	2018	Shut down
Isar 1	BWR	878	3/1979	E.ON	2011	2019	Shut down
Unterweser	PWR	1345	9/1979	E.ON	2012	2020	Shut down
Phillipsburg 1	BWR	890	3/1980	EnBW	2012	2026	Shut down
Krümmel	BWR	1260	3/1984	Vattenfall	2016	2030	Shut down
Total shutdown (9)		9611					
Gundremmingen B	BWR	1284	4/1984	RWE	2016	2030	End of 2017
Gundremmingen C	BWR	1288	1/1985	RWE	2016	2030	2021
Grohnde	PWR	1360	2/1985	E.ON	2017	2031	2021
Phillipsburg 2	PWR	1392	4/1985	EnBW	2018	2032	2019
Brokdorf	PWR	1370	12/1986	E.ON	2019	2033	2021
Isar 2	PWR	1400	4/1988	E.ON	2020	2034	2022
Emsland	PWR	1329	6/1988	RWE	2021	2035	2022
Neckarwestheim 2	PWR	1305	4/1989	EnBW	2022	2036	2022
Total in operation (8)		10728					
Total (17)		20339					

Source: (NSA, 2016)

Summary of objectives

The German Government developed a method for monitoring progress in meeting the targets set, based on a series of annual monitoring reports and prospective reports to be published every three years. Following publication by the government, these reports are evaluated from a scientific perspective by an independent commission of energy experts, whose opinion is published each year (Löschel, 2016).

The table below shows the targets for greenhouse gases (GHG), renewable energy efficiency and nuclear plants, partly published in the Fourth "Energy Transition" Monitoring Report of 2015 (BMWi, 2015f).

TABLE 14. Summary of the main *Energiewende* targets

<table>
<tr><th colspan="2">Sector</th><th>Basis year</th><th>2014</th><th>2020</th><th>2030</th><th>2040</th><th>2050</th></tr>
<tr><td colspan="2">Greenhouse gases (GHG)</td><td>1990</td><td>-27%</td><td>-40%</td><td>-55%</td><td>-20%</td><td>[-80%, -95%]</td></tr>
<tr><td rowspan="4">Renewables</td><td>Power generation</td><td rowspan="2">-</td><td>27.4%</td><td>35%</td><td>50%</td><td>65%</td><td>80%</td></tr>
<tr><td>Final energy</td><td>13.5%</td><td>18%</td><td>30%</td><td>45%</td><td>60%</td></tr>
<tr><td>Heating</td><td>-</td><td>12%</td><td>14%</td><td colspan="3">-</td></tr>
<tr><td>Transport</td><td>-</td><td>5.6%</td><td colspan="4">-</td></tr>
<tr><td rowspan="6">Efficiency</td><td>Primary energy</td><td rowspan="4">2008</td><td>-8.7%</td><td>-20%</td><td colspan="2">-</td><td>-50%</td></tr>
<tr><td>Power</td><td>-4.6%</td><td>-10%</td><td colspan="2">-</td><td>-25%</td></tr>
<tr><td>Primary energy in buildings</td><td>-14.8%</td><td colspan="3">-</td><td>-80%</td></tr>
<tr><td>Heating in buildings</td><td>-12.4%</td><td>-20%</td><td colspan="3">-</td></tr>
<tr><td>Final energy productivity</td><td>2008-2050</td><td>1.6%/year</td><td colspan="4">2.1%/year</td></tr>
<tr><td>Final energy in transport</td><td>2005</td><td>1.7%</td><td>-10%</td><td colspan="2">-</td><td>-40%</td></tr>
<tr><td colspan="2">Nuclear</td><td>2000</td><td>12,761 MW</td><td>8,514 MW</td><td>0 MW</td><td colspan="2">-</td></tr>
</table>

NB: Negative efficiency target figures indicate the need to reduce consumption, i.e. to improve efficiency.

Source: Own elaboration based on (Paulos, 2013) (Morris &Pehnt, 2012) (Rutten, 2015) (BMWi, 2015f)

Following establishment of these targets, the *Energiewende* is now pursuing what is called the "Triangle of Energy Policy". This might also be termed a "Rectangle", since as well as three political objectives (environmental protection, affordability and supply security), it also takes into consideration the additional objective of social acceptance.

5.2. A vision for the future. Horizon 2050

We shall now examine in greater detail Germany's future energy structure, based on the objectives of the country's energy transition.[74]

[74] The Project *Energiesystem der Zukunft* (Energy Systems of the Future) is an initiative oriented towards providing specific answers on the energy system for 2050. It has been developed by the three German Academies (the National Academy of Science and Engineering [ACATECH], the Leopoldina National Academy of Sciences and the Union of the German Academies of Sciences and Humanities). The project has concluded that no technology lacks an alternative, meaning that there is always a possible substitution at a reasonable cost, provided the right path is established and the wrong locations avoided (ACATECH, 2016).

The graphs below show those possible future scenarios for final energy, installed capacity for conventional energy and power generation based on the objectives of the energy transition.

In the area of final energy, the vision is for a systematic and continuous fall in energy demand. The economic hypothesis for growth is -56%. There is a strong growth in penetration of geothermal and biomass, as well as wind and hydro power in final usage, with a hypothesis of +500%. Power demand is due to stop growing or fall.

These objectives can be achieved with greater or lesser success depending on the progress in energy efficiency and the reduction in energy consumption. Consequently, various more or less optimistic scenarios have been established, as shown in the graph below.

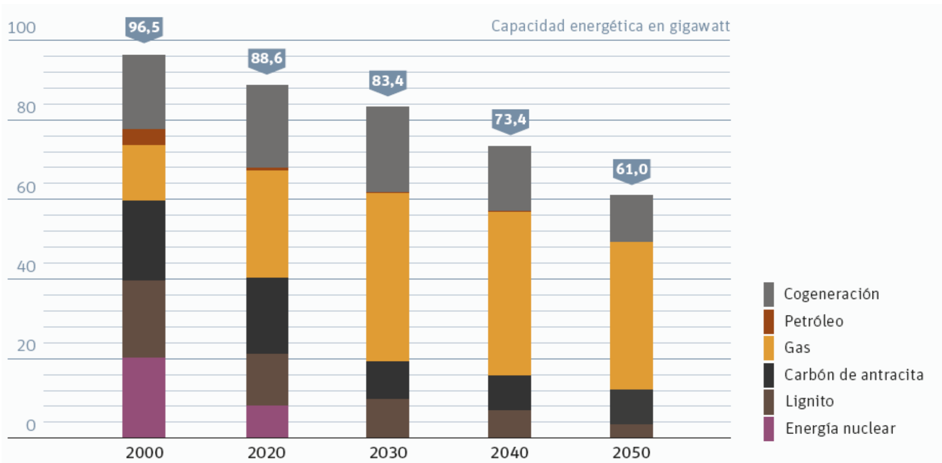
Starting from the reference scenario, established by the German government and consisting of a continuation of the current situation, various possibilities are developed, of which the most pessimistic is the business-as-usual (BAU) scenario, which reflects the reference situation with no progress in efficiency and an increase in energy consumption. The "*Efficiency Plus*" scenario allows for introduction of improvements under the European Efficiency Directive, whilst the "*Energy Concept*" scenario involves meeting German government targets. Finally, the "*WWF*" scenario is based on the targets set by the World Wildlife Fund (Prognos AG & AIEW, 2014).

GRAPH 37. Supply and demand scenario of final energy in Germany (PJ[75]/year) and (below) forecast development of electricity consumption in Germany in different efficiency scenarios (TWh)

Source: DLR Lead Study in (Morris & Pehnt, 2012) and (Prognos AG & IAEW, 2014)

As for power generation, the following graphs show installed capacity in different years between 2000 and 2050 and trends in production by technology for the same years.

GRAPH 38. Conventional energy. Installed capacity scenario in Germany (GW)

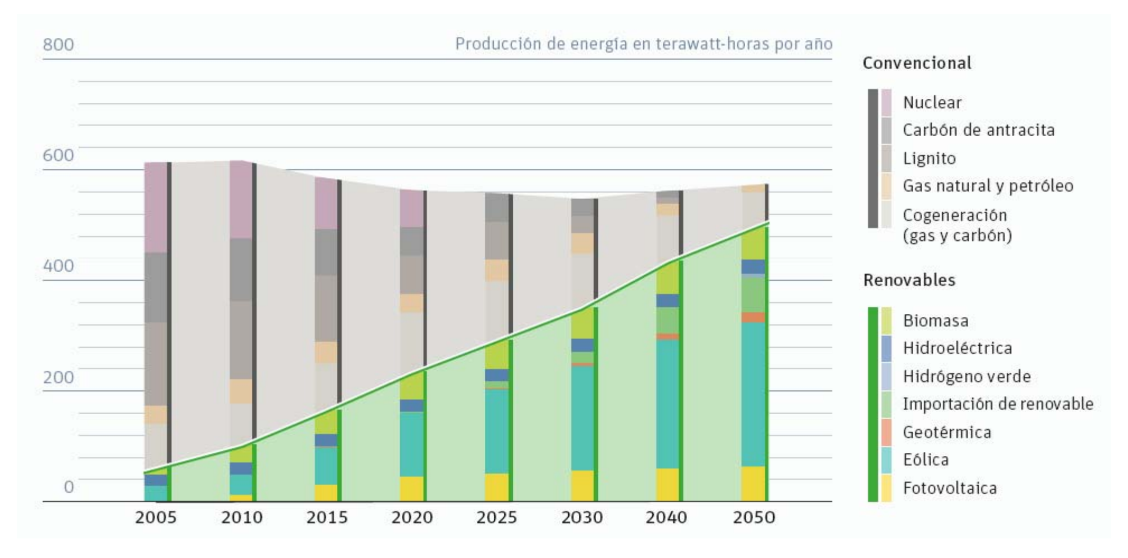


Source: Fraunhofer IWES in (Morris & Pehnt, 2012)

[75] 1 PJ = 0.0238846 Mtoe

We can see the mix of renewables, gas (40%) and coal (10%) in installed capacity. Amongst renewables, wind energy will dominate in power production.

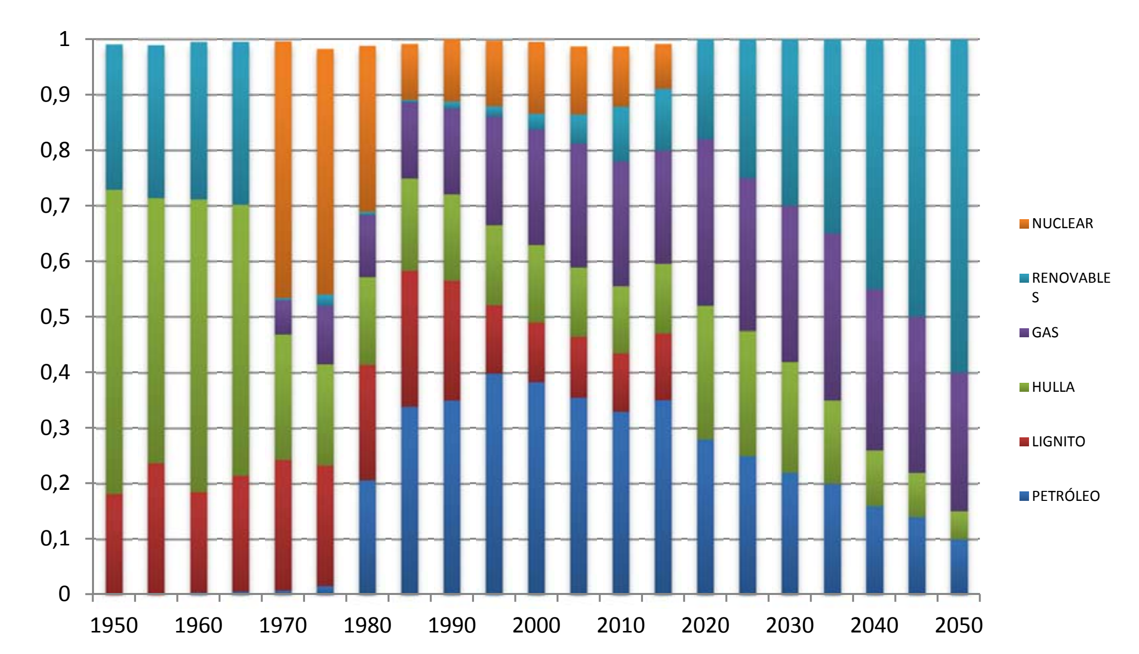
GRAPH 39. Power generation scenario in Germany (TWh/year)



Source: DLR y Fraunhofer IWES in (Morris & Pehnt, 2012)

It is interesting to see the final result in primary energy to the 2020 and 2050 horizons, as shown in the graph below.

GRAPH 40. Anticipated development of primary energy structure in Germany from 1950 to 2050 (for one unit of primary energy)



Source: Own elaboration from (BMWi, 2015a),(Morris & Pehnt, 2012),(Statistischer Bericht der Zentrallastverteilung für Elektrizität im BMWi, 1999), (Schröder-Burgdorf, 2015) and (Steblau et al., 2014)

The table below shows the percentages of each source by year. The column for 2025 deserves special attention, as it is the half-way point towards the 2050 horizon; oil and natural gas represent half of primary energy, whilst renewable energies account for 25% and coal almost 25%.

TABLE 15. Anticipated development of primary energy structure (%)

	1950	1975	2000	2025	2050
Lignite	18.2	21.7	10.8	-	-
Oil and products	-	1.6	38.2	25.0	10.0
Natural gas	-	10.5	20.7	27.5	25.0
Nuclear energy	-	44.2	12.9	-	-
Renewable energies	26.2	2.1	2.9	25.0	60.5
Hard coal	54.7	18.2	14.0	22.5	5

Source: Own elaboration

5.3. Key points for the *Energiewende*

This sections sets out key points of the *Energiewende*, giving the objectives, vision and implications.

The German Federal Ministry for Economic Affairs and Energy (BMWi) recently (in 2014) drew up an "energy agenda" identifying ten key legal questions[76] for the success of the *Energiewende*.

This section addresses aspects related to the *Energiewende* and enlarges on the "most specific" issues mentioned above. We shall analyse the issues or problems, partly linked or related to the basic objectives that arise.

Renewable energies

A programme for review of the law in 2016 which could lead to a change in the financing of renewable energies (all technologies) –established up to now by auction– based on the experience obtained following the January 2015 law regulating subsidies for photovoltaic installations.

2030 European Climate and Energy Framework and ETS Reform

Application before 2020 (starting in 2017) of the measures established by the European Council in October 2014 within the European Climate and Energy Framework, and the reform of the emissions trading system (ETS). In addition, it will be necessary to implement a global raft of directives for a post-2020 ETS.

Power market

The power market must be designed to: ensure efficient implementation of power plants based on a growing increase in renewable energies, maintaining energy security and meeting the national climate target for 2020, with the involvement of all sectors. Additionally it is important that financing for cogeneration or combined heat and power (CHP) fits within the future design of the power market.

[76] (BMWi, 2014a)

There have been several debates on the German Power Market Platform and a green paper has been submitted offering various options, with their respective advantages and disadvantages. There has also been a process of public consultation followed by the issuing of a white paper setting out specific measures.

Regional cooperation in the EU and internal market

The cooperation being built at the Pentalateral Energy Forum[77] is fundamental, as Germany has initiated talks with its neighbouring countries to enforce energy security and coordinate design of the energy market.

European power grids must be more integrated with interconnected markets. This would make the power system more efficient and reduce the need to maintain generation capacity, as it would allow energy security to be achieved at a reduced cost. This would facilitate the integration of renewable energies. Consequently, the German government is seeking to intensify cooperation with its neighbours and with the EU as a whole.[78]

Transmission grids

Expansion and extension of transmission grids is essential for the energy transition[79]. The Grid Development Plan for 2025, which is based on the Grid Development Plan 2015, will compare the need to enlarge transmission grids, not only with the extension corridors established by the 2014 Renewable Energies Act, but also by using various scenarios to show the German government's ambitious targets for mitigating climate change. This plan will be authorized by the Federal Grid Agency and presented to government in mid-2016.

Distribution grids

Distribution grids must also be introduced to satisfy energy transition, since a large part of power generation will be based on decentralized renewable energy sources.

A project for review of the Ordinance for Regulation by Incentives will be presented together with a raft of ordinances on smart grids, an ordinance on grid system fees and a review of the process for awarding licenses, relevant for distribution grids, which will come into force at the beginning of 2016.

Efficiency Strategy

Improved energy efficiency is highly important to the *Energiewende*. Consequently, both the National Energy Efficiency Action Plan (NAPE or *Nationaler Aktionsplan Energieeffizienz*) of 2014 and fulfilment of its basic requirements are considered

[77] The Pentalateral Energy Forum is the framework in which cooperation within Central and Western Europe is developed. The Forum was created in 2005 by the energy ministers of the Benelux countries, Austria, Germany and France (Switzerland was a permanent observer) with the purpose of driving collaboration in cross-border power interchanges (Europe Direct Salamanca, 2015).

[78] For example, the 2014 Renewable Energies Act has created the possibility of financing foreign power through auctions. Specific details are stipulated with rules and there is close coordination with interested partner countries.

[79] This can be seen in the earlier sections of this Block III, *Energiewende*.

essential. Various measures have already come into force and others are to be implemented soon.

Buildings

In the long term, there is a particular need to renovate existing buildings, an aspect covered in NAPE and of vital importance for achieving climate-neutral urban planning[80] by 2050. The general strategy for the construction sector is therefore to address aspects of power, heat and efficiency, as well as including the necessary measures to attain these goals. This will be achieved through a major development in the Law on Heat Generation using Renewable Energy and the Ordinance on Energy Saving.

Gas supply strategy

Natural gas represents approximately a quarter of primary energy consumption in Germany (as Graph 6 shows, approximately 20% of primary energy and nearly 20% of final energy). Therefore, a secure and affordable gas supply for industry and housing is crucial.

Attention will focus on the creation of the internal energy market, including improvements to interconnections between EU member states and access to liquefied natural gas (LNG) terminals, for example, through European common-interest projects. There will also be support for commercial projects whose purpose is to diversify supply countries and routes.

Energy transition monitoring / platforms

The process of monitoring the energy transition has three essential objectives: general information, assessment and perspectives. An annual report describes and evaluates the state of implementation of the energy transition.

It is also important to consider the role of society in the drafting of policies. This dialogue has already been established. Indeed, the German Federal Ministry for Economy Affairs and Energy (BMWi) has created five platforms for the energy transition: power market, efficiency, power grids, buildings, and research and innovation.

At the same time, the German Federal Ministry for Education and Research (BMBF) has initiated another platform for dialogue called the *Forschungsforum Energiewende* (Forum for Research for the *Energiewende*) which includes stakeholders from the energy industry and representatives from political and academic institutions, industry and civil society.

Although the summary that follows does not seek to address all the energy-related issues, we feel it may be helpful to examine various aspects of German energy policy

[80] Climate neutrality involves returning to pre-Industrial Revolution levels of contaminating emissions. The timescale established for achieving this goal by the Secretary of the United Nations Framework Convention on Climate Change (UNFCCC), Christiana Figueres, is the second half of the 21st Century (LIMA COP20 & CMP 10, 2014).

in the table below. For each topic we list aspects such as motivation for consideration, stated objectives in this area, main points of action and regulation, its place in the key aspects for the BMWi, trends in achievement of the targets and difficulties that have arisen.

TABLE 16. Main elements of German energy policy

Points	Motivations	Objectives	Action lines and regulation	Key points (BMWi)	Development	Difficulties
Emissions CO_2 eq.	To stop climate change and global warming.	To reduce GHG emissions in relation to 1990.	-1994→State's objective in the Fundamental Law. -1999→"Eco-tax". -2000→Renewable Energy Sources Act (EEG) (amended in 2004, 2009, 2012 and 2014) -2005→Environmentalist Directive. -2010→Special Fund for Energy and Climate.	-Measures by the European Council in October 2014 in the European Climate Framework. -Directives for the ETS post 2020.	-GHG reductions. -Agreement in COP21.	-Costs -Power system stability -Crisis in the power industry
Energy efficiency	To stop climate change, global warming and energy imports.	Consumption reductions in relation to 2008.	-2014→National Action Plan for Energy Efficiency (NAPE). -2002→ *Energieeffizienz* initiative and Energy Saving Ordinance, *Energieeinsparverordnung* (EnEV).	-National Action Plan for Energy Efficiency (NAPE) of 2014. -Law of Heat, Renewable Energies and the Energy Saving Ordinance.	Improvement in energy intensity (IE).	Measures are not effectively applied.
Renewable energies	To stop climate change, global warming and energy imports.	To increase the percentage of renewable energies.	-1990→Law of Non-Conventional Renewable Energies (NCRE). -1991→*Stromeinspeisungsgesetz* (StrEG). -2000→ Law on Renewable Energies (EEG) (amended in 2004, 2009, 2012 and 2014).	Revision of the Law for Renewable Energies (EEG).	-Reduced premiums. -Increase in capacity and consumption of renewables.	Energy storage systems are required.
Nuclear energy	To eliminate risks and protests.	Progressive elimination of nuclear energy.	-2011→ *Atomausstieg*.		The disconnection continues.	Difficulty in calculating when a secure long-term waste storage site will be found
Creation of industry and employment (cooperation and distributed generation)	-Economic reward for communities. -Job creation. -Control of energy poverty. -Promotion of ecological innovations and exports.		Distributed generation promoted through the Renewable Energy Sources Act (EEG) and feed-in tariffs (FiT).			There have been reverses in job creation.

Points	Motivations	Objectives	Action lines and regulation	Key points (BMWi)	Development	Difficulties
Energy security	Less dependency on other countries.			-Pentalateral Energy Forum. -Renewable Energy Sources Act (EEG). -Creation of an internal energy market with connections in Europe.		
Power grids		To build and optimize grids.	-2011→ *Netzausbaubeschleunigungsgesetz* (NABEG).	-Ordinances on distribution grids. -Plan of Grid Development for 2025.		Popular opposition.
Transport			-2009→National Plan for Eletromobility Development. -2011→Regulation on labelling for electric vehicles.			-The target of one million electric vehicles by 2020 seems unlikely to be met. -Limited contribution from the sector in reducing GHG emissions.
Power market			The current German Government wants to change energy policy, mainly in order to avoid a greater increase in the cost of electricity.	-To assure efficient implementation of power plants. -To match financing for cogeneration or combined heat and power (CHP) generation with design of the power market.		-For the moment, sustainable long-term design has not been found.
Gas market				A secure and affordable gas supply is crucial for industry and families: attention will focus on the creation of the internal energy market, including an improved physical connection with Europe.		Power prices leave little margin for gas and coal plants.

Source: Own elaboration

5.4. The cost of renewables

Supporters of the *Energiewende*, such as Von Hirschhausen (2014), believe that the high cost of renewables will fall in the future.

These forecasts are shown in the graphs below. The first depicts the anticipated trend in the cost of investing in renewables (€/kW) while the second shows the same trend in €/MWh. It should be noted that the hypothesised price of fossil fuels, and thus the price per kWh, grows continuously, which may not happen in this case.

The dynamic analysis[81] suggests that renewables have a considerable comparative advantage when cost reductions kick in. This means that thanks to technological innovation and economies of production, generation costs have fallen significantly for PV solar and wind energy (as already mentioned) and there are great expectations for the trend to 2050.

Indeed, most of the reduction in costs to date has occurred in PV solar energy, with the learning rate[82] increasing by 15-20%, leading to an expected reduction of 15-20% in the cost once installed capacity is doubled. As for onshore wind energy, the learning rate varies between 5 and 15% and a reduction in cost is anticipated, based on experiments on different types of turbine.

Nonetheless, even taking the trend shown in the graph below, an asymptotic trend can be seen, with the result that the greatest decreases do not seem to offer the same proportion of continuity.

Thus, according to the BWS (the German monitor for photovoltaic prices) the costs[83] in the photovoltaic solar energy market in 2012 were €3.62 per Wp[84] for systems installed with less than 100 kWp. As for components, the average price for thin sheet modules was under €2/Wp, while the price of crystalline silicon modules varied between €2.30 and €2.50 per Wp.

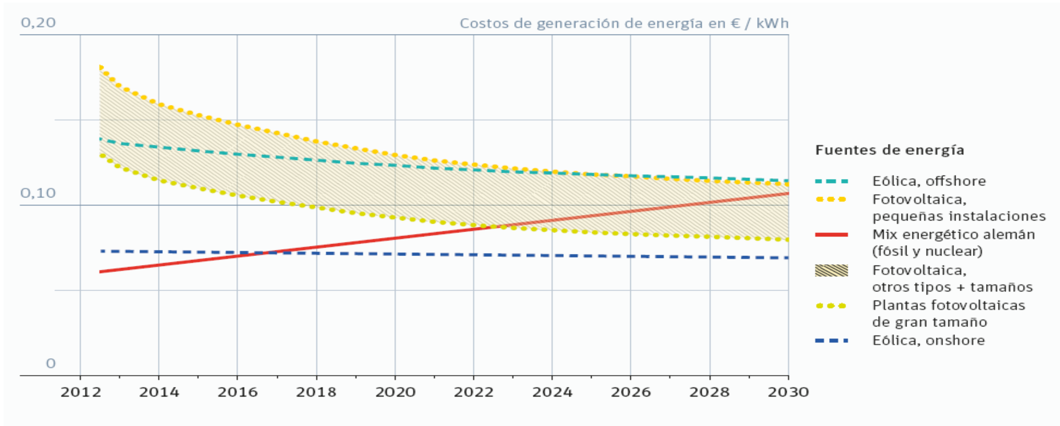
[81] (Von Hirschhausen, 2014)

[82] The learning rate refers to technological learning, which is the reduction in costs as technology manufacturers accumulate more experience. Most learning rates are based on non-energy technology studies or isolated results from a small number of energy studies (McDonald & Schrattenholzer, 2011).

[83] (BSW Solar, 2013) (Gorozarri Jiménez, 2012)

[84] The peak power of a photovoltaic element, measured in peak watts (Wp), is defined as the maximum electric power it can generate under the following standard measuring conditions: irradiance: 1000 W/m^2, temperature: 25 °C, AM: 1.5, where AM or Air Mass is a measure of the distance that the radiation traverses when it passes through the atmosphere. AM varies according to the angle of incidence, according to the following formula: AM= 1/cos(Θ), where θ is the angle of incidence of a ray of light in the vertical of the site.

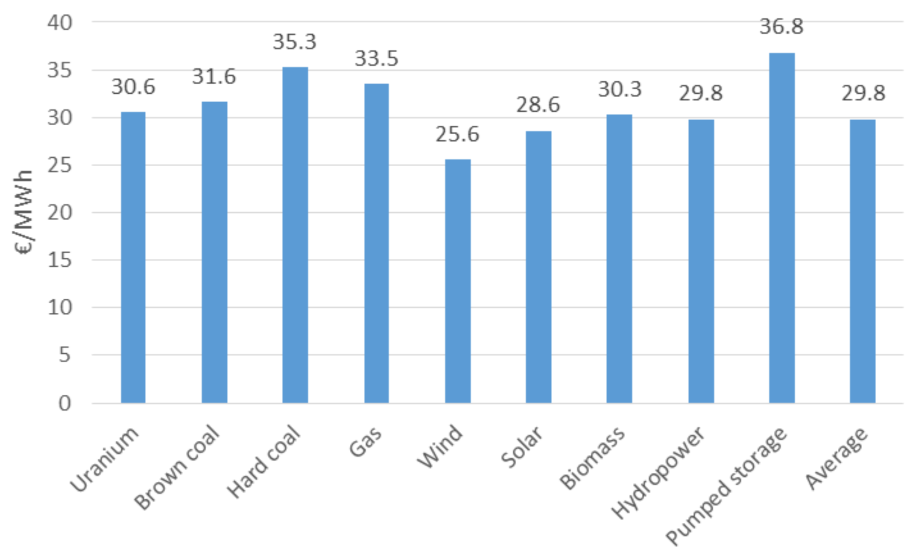
GRAPH 41. Expected cost for energy generation (€/kWh)



Source: Fraunhofer ISE in (Morris & Pehnt, 2012)

The graph below shows German daily market prices by energy sources in the first half of 2015, with the difference in price per MWh between lignite (€31.6) and hard coal (€35.3) on the one hand and wind (€25.6) and photovoltaic (€28.6) on the other.

GRAPH 42. Daily market price for the different energy sources in the first half of 2015 (€/MWh)



Source: elaborated from (Fraunhofer ISE, 2015b)

According to the German Energy Agency,[85] generation costs for photovoltaic energy in Germany in 2013 stood at between 8 and 14 cents/kWh, meaning that they were below the costs for 2012 (between 11 and 17 cents/kWh) (DENA, 2015). In the case of wind energy, generation costs vary by technology and in 2015 they ranged from 4.5 to 10.7 cents/kWh for onshore wind, between 11.9 and 19.4 cents/kWh for

[85] (DENA, 2015)

offshore wind and from 15 to 20 cents/kWh for small wind turbines for private use.[86] These numbers are similar to those shown in the following table.

TABLE 16. Costs of power generation in Germany

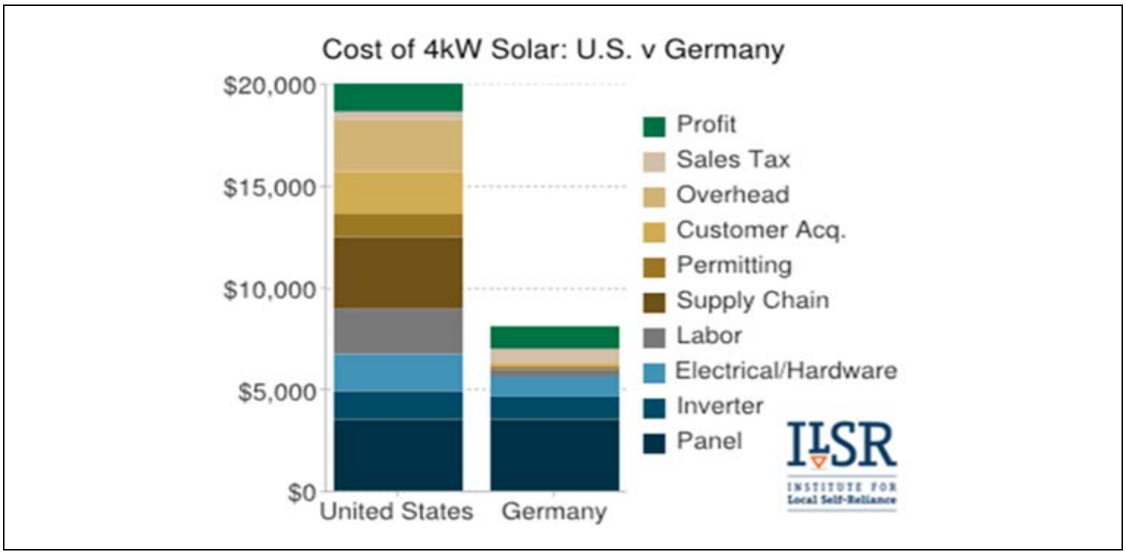
Source	Cents €/KWh	Equivalent full-load hours per year	Capacity factor (%)
Photovoltaic	7.8-14.2	1,000-1,200	11-14
Onshore wind	4.5-10.7	1,300-2,700	15-31
Offshore wind	11.9-19.4	2,800-4,000	32-46
Biogas	13.5-21.5	6,000-8,000	68-91
Lignite	3.8-5.3	6,600-7,600	75-87
Black coal	6.3-8.0	5,500-6,500	63-74
Natural gas combined cycles	7.5-9.8	3,000-4,000	34-46
Retail process for homes	28.9	-	-

Source: Fraunhofer Institute in (World Nuclear Association, 2016, 2016)

One aspect of the different amendments to German legislation for promoting renewable energies has been the inclusion of administrative changes to facilitate investment in renewables. This has meant that costs associated with administrative processing, location studies, environmental impact studies, the obtention of permits and taxes and fees, etc., fell considerably, mainly for small installations.

An example, of this competitive advantage in Germany in terms of costs is shown in the figure below, showing the relative costs for a 4 kW photovoltaic solar installation in the US and Germany.

GRAPH 43. Comparison of costs for a 4 kW solar installation in Germany and the US based on 2013 data ($)



Source: ILSR in (Corrales, 2015)

[86] The TSO has estimated average payments through the EEG to renewables for 2016 of 30.613 cents/kWh for photovoltaics, 24.389 cents/kWh for geothermal, 18.657 cents/kWh for biomass, 18.362 cents/kWh for offshore wind, 9.156 cents/kWh for onshore wind and 9.402 cents/kWh for hydro (NETZ- TRANSPARENZ.DE, 2015).

Whilst the price for panels is similar in the two countries (about $1,000/kW), other costs, mainly those associated with bureaucracy and regulation, are very much lower in Germany.[87] The end result is that in Germany a 4 kW solar installation can cost about $9,000, whereas in the United States the total cost can run to about $20,000.

[87] According to the latest data available from the Fraunhofer Institute at the time of writing, in the first quarter of 2015 the price of a photovoltaic installation was €1,300/kWh, with the panel accounting for 48% of the total cost (€624($712) per kWh). This proportion between the panel and the rest of the installation has remained at 50% in recent years (Fraunhofer ISE, 2016).

6. RELEVANT BASIC REGULATION

As well as the political context, it is also very important to examine the legal framework of the German energy sector in relation to the *Energiewende*. This chapter will address essential relevant legislation and the FiTs.

6.1. Chronology of the main regulatory measures

In order to understand the evolution of the *Energiewende*, it is essential to know the legal "legacy" and the measures on which it is based.

The figure below identifies[88] the main regulatory aspects that have enabled progress in the energy transition.

FIGURE 16. Timeline of the main measures for promoting the *Energiewende*

2014	▪ Amendment to the Renewable Energies Act (EEG)
2012	▪ Cogeneration agreements with industry ▪ Amendment to the Renewable Energies Act (EEG)
2011	▪ Financing by KfW bank for the first offshore wind farm ▪ Monitoring process for "The Energy of the Future" ▪ Environment, Climate and Renewable Energies Act ▪ Sixth Energy Research Programme ▪ Programme for progressive nuclear closure (*Atomausstieg*)
2010	▪ National Plan for Energy Action ▪ *Energy Concept* Plan ▪ Law on biofuel fees
2009	▪ Amendment to the Renewable Energies Act (EEG) ▪ Financing by KfW bank for renewable energies programme and energy efficiency and refurbishing programme (*Energieeffizient Sanieren*) ▪ Renewable Energy for Heating Act ▪ National Electric Transport Development Plan
2008	▪ Raft of laws for climate change and energy programme
2007	▪ Climate change and energy programme
2006	▪ *Klimazwei* research programme (Research on Climate Protection and Combatting Climate Impacts) ▪ Foundation of the solar energy development centre

Source: Own elaboration.

[88] For further information on the development of the legal framework for the energy transition in Germany, see Appendix 13.4.

FIGURE 17. Timeline of the main measures for promotion of the *Energiewende* (2nd part)

2005	▪ Energy in Industry Act (*Energiewirtschaftsgesetz*) ▪ Financing by KfW bank for the solar energy production programme ▪ Fifth Energy Research Programme
2004	▪ Amendment to the Renewable Energies Act (EEG) ▪ Solarthermie 2000Plus Programme
2002	▪ Combined Heat and Power Act ▪ Modification of EEG tariffs for renewable installation
2001	▪ Investment in "Future" programme
2000	▪ Extra law for heating and electricity ▪ Renewable Energies Act (EEG)
1999	▪ Preferential loan programmes offered by reconstruction loan corporation (KfW bank) ▪ Eco-Tax reform ▪ Market incentives programme ▪ "100,000 Solar Roofs" programme[89]
1998	▪ Baltic Energy Efficiency group
1997	▪ Federal construction codes for renewable energy production
1996	▪ Fourth Energy Research Programme ▪ "Green Energy" programme
1995	▪ "100 million" programme ▪ Ecological Subsidy ▪ Regulation on tariff lists for architects and engineers
1993	▪ Total cost fees
1991	▪ *Stromeinspeisungsgesetz* or Electric Act for *feed-in tariffs* (StrEG)
1990	· Act for Promotion of Non-Conventional Renewable Energies (NCRE) ▪ Environment and Energy Saving programme
1989	▪ "250 MW of Wind Energy" programme[90]
1985	▪ Support to federal states for renewable energy

Source: Own elaboration.

[89] This replaced and extended the 1998 *1,000 Solar Roofs* programme whereby 50% of installation costs were subsided, under which 5 MW had been installed on 2,500 roofs (2 kW per roof). The aim of the *100,000 Solar Roofs* programme was to install 300 MW in 100,000 roofs with an outlay of €562m (Corrales, 2015).

[90] This replaced and extended the 1998 *100 MW of Wind Energy programme* (Corrales, 2015).

6.2. Actions in the regulatory field

In this section, we shall examine the various regulations (summarized in the figure above) that Germany has been developing in order to progress towards meeting the energy transition targets set out in the *Energiewende*.

Renewable Energy

In 1990, the German Government approved the first Law on Promotion of Unconventional Renewable Energies (ERNC). This is a classification for solar, wind, tidal, geothermal, biomass and hydroelectric energy of less than 20 MW (IRENA, 2014).

As discussed below, the *Feed-in Tariffs* system was introduced for the first time in 1991 with the *Stromeinspeisungsgesetz* (StrEG). This law was meant to ensure that all electricity from renewable energy sources fed into the grid by producers would be purchased, thanks to the FiT.

The Renewable Energies Act (EEG) is a programme of market incentives created in 2000 and intended to consolidate the introduction of renewable energies. The programme is seen as the driver for the development of renewable sources with reduced impact on climate. Indeed, it is the EEG that establishes the ambitious goals for renewable energies mentioned in the targets of the *Energiewende*.

The EEG also specifies that renewable energies have priority of access to the grid and that investors must receive a high enough recompense through a form of tariff –the FiT (Feed-in Tariff)– to ensure that their investment is profitable, regardless of electricity prices on the energy market. It also made it possible to differentiate not only between technologies (solar, wind and biomass), but also between the size of the installations.

Despite successive amendments and modifications, the promotion of renewable energies and higher energy efficiency still stands at the heart of the EEG. In 2004, it was again extensively amended and FiTs were increased for biomass and offshore wind installations. In 2009 there was an attempt to bring growing output from renewable energies closer to the power market. The changes introduced in 2012 sought to promote the direct sale of renewable energy to final customers through a bonus to plant owners for the sale of their electricity.

Finally, the 2014 amendment to the law (the most recent) removes FiTs for new installations and introduces the competitive auction as the method for allocating remuneration for new installations. Thus only plants of under 100 kW coming into service after 2015 can receive a FiT. A fresh modification of the law is now being prepared (in 2016) that would mark a shift from the guaranteed FiT to the open competitive bid.

Ground-based photovoltaic is already being auctioned at a price of 8 cents/kWh (December 2015 auctions). From 2017 this price will also apply to onshore and offshore wind energy.[91] In the former case, the maximum price in the first bid will be 7 cents/kWh in the reference place; the maximum price will be in the range of 5.53 - 9.03 cents/kWh, depending on the wind resource at the location, with adjustment factors of 0.79 and 1.29 respectively (BMWi, 2016b).

Renewable energy for heating

The law on renewable energy sources for heating was the first legislation to deal explicitly with renewable heating; it required builders to use renewable heating systems while the owners of older buildings could obtain financial support for making renovations.

The law was passed in 2009 and its main target was for 14% of heat to come from renewables by 2020. Owners of new buildings are required to source part of their heating supply from renewables. They can decide how to comply with this requirement and those who do not want to use renewable energies can increase insulation or cover their heating requirements by connecting to zonal grids or CHP units.

Energy efficiency

In December 2014 the German Government launched its National Energy Efficiency plan (NAPE).[92] With this plan[93] Germany hopes to meet the efficiency targets set in the *Energiewende* to achieve a 20% reduction in primary energy consumption by 2020 and 50% by 2050 (compared to 2008 levels).

All measures in the NAPE are based on a single principle: information-support-demand. In the first place, large-scale provision of information and advice is required; secondly, investments and incentives are needed for efficiency measures; and finally, the contribution of the demand side, particularly industry, is required. By way of this national plan, the country also implemented the European Energy Efficiency Directive.

Energy conservation in buildings

In Germany, close to 40% of all energy is consumed in buildings, where it is mostly used in heating. It is therefore essential to make adjustments to constructions to improve the situation.

In 2002, Germany established the *Energieeffizienz* initiative which focuses on promoting efficiency for the final use in private residences and shops. The Energy Conservation Ordinance or *Energieeinsparverordnung* (EnEV) arose out of this initiative.

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[91] For the offshore case, to be launched between 2020 and 2024, a maximum price is expected for the first auction of 12 cents/kWh, with an adjustment of 0.05 cents/kWh for every 25 meters (or part thereof) of water depth.

[92] Energy efficiency, apart from helping to accomplish climate change targets, also helps to increase energy supply by reducing the quantity of energy required.

[93] (BMWi, 2015e)

In relation to the construction of new buildings, in 1990 the German energy transition initiated the development of the "high-efficiency passive home" but much work remains to be done to increase energy efficiency in buildings.

Germany can improve things by making its Ordinance for Energy Conservation (EnEV) stricter, especially due to a rise of energy prices and increasing renovation fees.

In addition, when solar roofs are added to passive homes, the result will be homes that produce more energy than they consume. These are known as *energy-plus* homes.

Cogeneration

The Cogeneration Act, passed in 2002, sought to improve the situation of CHP. Germany wants 25% of the energy supply to come from cogeneration units, which are more efficient than producing power and heat separately. The law provides for bonuses depending on the size of the system, regardless of generation levels.

The law was amended in 2012 to set the bonus as follows: for power under 50 kW of produced electricity, 5.41 cents/kWh; from 50 to 250 kW, 4 cents/kWh; up to 2 MW, 2.4 cents/kWh; and for power over 2 MW, 1.8 cents/kWh.

Distributed generation

Although there is no specific law on distribution, the *Energiewende* also fosters and promotes distributed power generation, principally through the Renewable Energies Act (EEG) and the feed-in tariffs (FiTs).

Distributed or decentralized energy generation systems are defined as being small power generation plants (between 3 kW and 10 kW)[94] that provide an alternative or support to traditional high-capacity generating plants.

The German energy transition is based on a model of energy policy in which large electrical firms coexist with decentralized generation owned by individuals and cooperatives. In 2012, 39.7% of installed renewable energy capacity was owned by individuals and 10.8% belonged to farmers (Weber, 2013). As well as the economic benefits mentioned above, distributed generation is a key element in meeting energy transition targets on efficiency and renewable generation and contributes to achieving favourable public consensus on the *Energiewende*.

Grid expansion

As we shall see, the energy transition will require an extended and adapted grid that can operate with more renewable energy. In 2011, the German Parliament approved a law to accelerate grid expansion, the *Netzausbaubeschleunigungsgesetz* (NABEG), in order to have a suitably operating infrastructure, adapted to future grid

[94] For distributed generation definitions, see Álvarez, E. y Castro, U. (2013), *Redes de distribución eléctrica del futuro. Un análisis para su desarrollo*, Orkestra.

requirements that will allow the quality of the power supply to be maintained and even improved.

Power transmission [95]

Transmission in Germany accounts for around 20% of total CO_2 emissions in the country, since 95% of the fuel used comes from fossil resources. This is therefore a sector that requires modifications in order to meet *Energiewende* targets.

One of the modifications required is an increase in the use of power transmission. The German Federal Government therefore approved the National Electric Transport Development Plan[96] in August 2009, with the German Federal Ministries for Economic Affairs and Energy (BMWi), Transport, Construction and Urban Development (BMVBS or *Bundesministerium für Verkehr, Bau und Stadtentwicklung*), Environment, Nature Protection, Construction and Nuclear Security (BMU) and Education and Research (BMBF or *Bundesministeriums für Bildung und Forschung*). Under the plan, it is hoped to have one million electric cars on the country's roads by 2020 (Germany Trade & Invest, 2014).

At the end of 2014, however, only 20,000 electric vehicles had been registered. Sales of electric vehicles increased by 56% between 2012 and 2013, a long way behind the neighbouring Netherlands (281%) and Norway (129%). These countries have preferred to introduce high subsidies and intelligent policies rather than attempting large-scale growth. Germany's policy, however, is based on tax incentives for owners, which limits growth and only attracts a certain group of buyers. For example, in 2011, the German government launched a labelling regulation for electric cars along the same lines as the National Development Plan, offering free parking. The German government's main objective must be to promote access to electric vehicles among a more diverse group of people, a policy that has been successful in countries with the greatest number of electric vehicles on the roads.

Germany predicts that in coming years, technological progress, including advances in electric batteries, will boost the EV market. The government is therefore promoting R&D projects related to sustainable transport. One example are the measures being taken to promote natural gas vehicles. Additionally, the government will collaborate with local governments to create the necessary public infrastructure to support electric transport.

The use of electric transport is one solution to the problems currently posed to the energy transition by the transport sector, since it will reduce fossil-fuel consumption and thus CO_2 emissions. It will also cut dependency on oil and oil products and increase the consumption of renewable energy.

The use of gas vehicles is also growing in Germany, albeit without *ad hoc* legal measures. This is mainly due to the incentive involved in having a reduced gas price

[95] (European Commission, 2009)(Dubon & Morris, 2015)(BMWi & BMU, 2010)
[96] (Die Bundesregierung, 2009)

and the fact that the automobile companies themselves are promoting this kind of vehicle. Germany has the second-largest fleet of compressed gas vehicles (NGV Global, 2016) in Europe, so this could be the next great penetration of fuels in transport. In any case, the fall in the price of crude oil means that, for the moment at least, the move towards EVs is proving slower and less feasible.

In addition, the same criteria might be applied to increase the use of biogas. The German ministry for food and agriculture (BMVEL or *Bundesministerium für Ernährung und Landwirtschaft*), together with the Worldwatch Institute, is developing a research project on the global potential of using biofuels for large-scale motorized transport.

Energy market

The current German government is attempting to change energy policy mainly in order to avoid a major increase in electricity prices.

The main reduction in cost has been brought about through photovoltaic energy. However Minister for the Economy and Energy, Sigmar Gabriel, says that changes in wind energy are also needed as the global objective is to avoid a rise in costs .

Another question to be considered is the capacity market, which is viewed as a medium-term project. As mentioned, renewable energy represents a greater proportion of supply and conventional plants operate fewer hours. Thus, to avoid the closure of too many conventional plants, it may be helpful to make payments by capacity, to ensure that they remain in reserve as a back-up supply.

Opinions differ as to the need for capacity markets. The Agora *Energiewende* research centre warns of a possible generation capacity deficit as a consequence of nuclear switch-off in 2022. The BDEW (*Der Bundesverband der Energie und Wasserwirtschaft e. V.* or German Association of Energy and Hydric Industries) also argues that a capacity market is required. On the other hand, however, the transmission system operator TenneT believes that an energy market will continue to guarantee supply security without the need for a capacity market.

Nature, ecology and the environment

The Federal Government actively promotes protection of the environment, climate-respectful development strategies and energy cooperation and frames its work in a global perspective.

Since 1994, nature protection has been established as a state objective in the Constitution[97]: “Article 20.a. (Amended 26/07/2002) [Protection of the natural foundations of life and animals]: Mindful also of its responsibility toward future generations, the state shall protect the natural foundations of life and animals by legislation and, in accordance with law and justice, by executive and judicial action, all within the framework of the constitutional order”.

[97] (Deutscher Bundestag, 2010)

Germany is the world's second-largest benefactor in financing climate protection. The country sets aside funds for promoting climate actions intended to mitigate climate change, by assuming measures that allow more efficiency, financing renewable energies, electric transport, etc.

In 1999, Germany introduced an "eco-tax" on the litre of petrol and the kWh of power generated from fossil fuels that increased annually. This was framed as a tax on activities that were environmentally harmful and important exemptions were provided to industry. The tax yielded €19 billion in 2003, which was set aside for reducing the charges on companies and workers for social obligations (Corrales, 2015).

One possible effect has been the fall in GHG emissions from transport; despite a considerable increase in the volume of traffic, in 2015 emission levels were below 1990 levels.

Nitrous oxide emissions have also been cut by about 50%. Desulfurization of combustion gases is also required by law and as a result, sulphur dioxide emissions have been reduced by 90% in soft coal and lignite plants (Wille, 2015).

However, income from environmental taxes[98] in Germany came to €57,852 million in 2013, 5.4% of total tax revenue, down on the figure for ten years ago, when it stood at €57,813 million and accounted for 6.9% of total tax revenue (Valera, 2015).

Another important tool for energy transition in the eco sphere is the Eco-design Directive, which is the main instrument for removing products with the worst environmental performance. This essential piece of legislation, implemented throughout Europe, is still one of the most important tools for reducing the demand for new grids and generation plants in Germany, and it is therefore a crucial aspect of the energy transition.

The 2005 Ecological Directive (known since 2009 as the Directive for Energy-Related Products or ErP) has its origins in Brussels and regulates the efficiency of energy-consuming products, with the exception of buildings and cars. The ErP Directive establishes minimum rules for different product categories. It also envisages life-cycle evaluations for certain products in order to determine their environmental impact and identify ways of improving them.

The directive does not only involve products used by energy producers and consumers but also products that affect consumption. The ErP Directive seeks to solve the absence of product-specific information on energy consumption so that consumers can see how much it will cost them if they buy a particular device, using the "efficiency label" based on European energy labelling standards. The ErP Directive thus limits low-efficiency products, while at the same time it seeks to guide

[98] The OECD and the International Energy Agency (IEA) define environmental taxes as being those whose tax base consists of a physical unit of a material that has a confirmed and specific negative impact on the environment (European Communities, 2001).

demand towards the highest efficiency levels by convincing consumers to buy the best products.

In 2010 Germany also created a Special Fund for Energy and Climate with National and International Initiatives for Climate Protection (now known as Climate Initiatives). Additionally, the country has an Umweltbank,[99] a bank specializing in environmental projects.

Gradual abandonment of nuclear energy. "Atomausstieg"

The gradual abandonment of nuclear energy or *Atomausstieg* is a pivotal element in the German energy transition.

In 2000, the Social Democrats and Green coalition government, under Chancellor Gerhard Schroeder, reached an agreement with the industry to close the country's nuclear plants after a 32-year life cycle. At that time, 19 nuclear plants were still operating in the country.

By 2010, the nuclear contribution to German energy supply had fallen from 30% (in 1999) to 23%, reflecting the gradual closure, with two of the 19 nuclear plants shut down.

Following the Fukushima accident in Japan on 11 March 2011, the German coalition government led by Angela Merkel resolved[100] to close eight nuclear reactors (located in seven nuclear plants) of the 17 in the country, and targeted a complete shutdown of nuclear power by 2022, by closing the remaining nine (12,060 MW).

It should be noted that Chancellor Merkel also included an exit clause, which would allow a return to *Atomausstieg* in the event of an energy crisis and she allowed two nuclear plants to be kept on stand-by (Sánchez, 2011).

6.3. Feed-in Tariffs (FiTs)

Feed-in tariff (FiT) systems involve the government setting the prices of tariffs, which vary depending on the type of renewable energy (solar, wind or other). The size of the generation plant and its location may also be taken into account.

One of the main characteristics in any FiT system is that there is a guarantee that all the electricity fed into the grid will be purchased. Furthermore, these prices are established for long periods, in some cases covering the entire life cycle of the installation (for example, 20 years).

[99] The institution, based in Nuremberg, invests exclusively in eco projects, such as the construction of eco houses and solar and wind energy projects. Since it was founded in 1997, it has financed 13,700 projects to a total amount of €1.37m, of which almost 50% were loans for solar energy projects (UmweltBank, 2015).

[100] This decision may have been motivated by regional elections that took place during the incidents at Fukushima, which were seen as a sort of referendum on nuclear energy and in which the Greens won a significant share of the vote.

Through these measures, the government intervenes in the price at which the power is purchased from the producer, thus guaranteeing the producer both the sale and the price, allowing them to recover their initial investment.

The International Energy Agency[101] sees FiTs as the best option for ensuring fast and effective development of renewable energy. German FiTs have helped boost the renewable energy industry, not only in Germany, but also in other countries, as we shall see.

German FiT system

Feed-in tariffs are a fundamental tool for the development of renewable energies, and therefore for the *Energiewende*.

As already discussed, at the beginning of 1990, Germany proposed a very simple policy to promote production of power from renewable energy sources through the *Stromeinspeisungsgesetz* (law on power take-up from renewable sources to the public grid) or Feed-in Tariffs Act (StrEG). As enacted in 1991, the law included wind, solar and small hydro generators. In 2000, with the passing of the Renewable Energies Act (EEG), FiTs were reviewed and increased. Since then, they have been reviewed every three or four years and the law amended.

The FiT establishes different tariffs for fed-in power for each kind of renewable plant, depending on plant size, location and type of energy produced. It was also guaranteed that these tariffs would be respected in the long term, with fixed periods of up to 20 years (depending on the type of renewable energy), as shown in the table below.

TABLE 17. FiT for different types of RE (years)

WIND	PHOTOVOLTAIC	HYDROELECTRIC	BIOMASS
20	20	15 – 30	20

Source: Own elaboration

The differentiation in tariffs is intended to prevent disproportional support for plants that do not need it, as this would represent inefficient usage of resources. For example, solar and geothermal energy enjoy a high tariff, but for hydroelectric energy it is lower.

The costs of establishing this special tariff are assumed by the consumers, as explained in Chapter 7. Thus, Germany has low prices for solar energy, not because it enjoys abundant sunlight, but because of investment certainty and market maturity resulting from its premiums policy thanks to FiT.

In the German system, another characteristic element of the FiT is the progressive reduction of fixed tariffs. This means that each year, tariffs for new plants coming on line that year are reduced by a given percentage compared to the rate originally set. For example, during the first year a plant comes into operation, it can access 100%

[101] (Gipe, 2013)

of the tariff because of the duration of that benefit (for example, 15 years); a plant coming on line in the second year can access 95% of the tariff in the rest of the period, and so on.

TABLE 18. Initial FiT structure defined in the EEG (2007)

SOURCE		POWER RANGE	FiT (euro cents/kWh)				REDUCTION
Solar			In buildings	Integrated in building fronts		Other systems	5% and 6.5% for other systems
		<30kW	49.2	54.2		38	
		30kW-100kW	46.8	51.8			
		>100kW	46.3	51.3			
Biomass			General	Renewable raw materials	Cogeneration	Timber waste	1.5%
		<150kW	11	17	13	11	
		150-500kW	9.5	15.5	11.5	11	
		500kW-5MW	8.5	12.5 (11 for wood)	10.5	8	
		5MW-20MW	8.0	80	10	8	
Hydro-electric	Large	<500kW	7.4				1%
		500kW-10MW	6.4				
		10-20MW	5.9				
		20-50MW	4.4				
		50-150MW	3.6				
	Small	500kW	9.7				
		5MW	6.6				
Geothermal		5MW	15				1%
		10MW	14				
		20MW	9				
		>20MW	7.2				
Wind	Offshore		Installed before 31/12/2010		Installed after 31/12/2010		2%
			9.1		6.2		
	Onshore		Until fifth year after installation		From fifth year after installation		
			8.2		5.2		
Landfill gas, sewage gas, mine gas			Traditional technology		Specific innovation technology		1.5%
		500kW	7.3		9.3		
		500kW-5MW	6.3		8.3		
		>5MW	Market price				

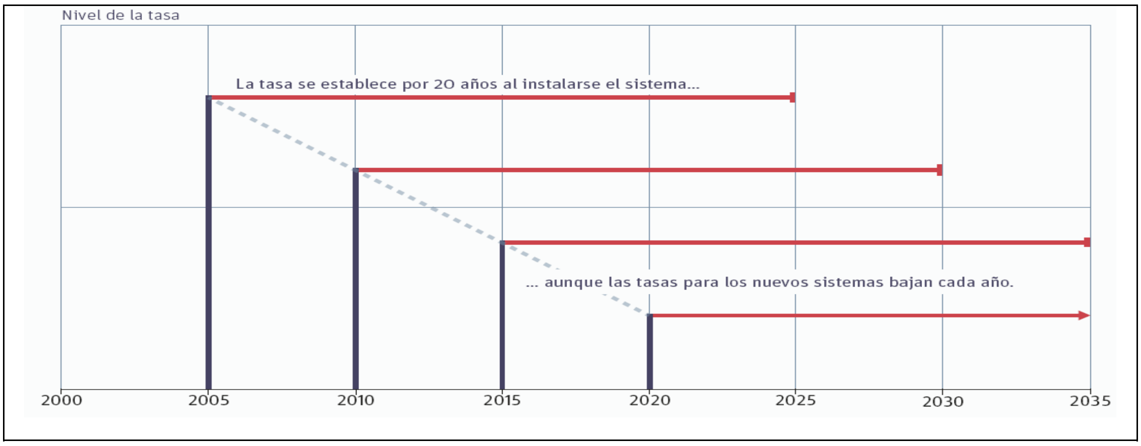
Source: Own elaboration from (Held et al., 2007)

The reduction varies depending on the type of technology. The purpose is to promote the development of less mature technologies with a progressively stronger reduction. In this way, companies that manufacture such technologies do not feel the pressure of other power companies to continue innovating.

As the former table shows, reductions in feed-in tariffs were programmed in the EEG (generally on an annual basis) in order to ensure that the price of renewable energies would continue to fall and that these energies would become more competitive.

These programmed reductions in FiT payments answer those critics who argued that these systems did not promote a cheaper type of renewable energy. In addition these reductions have been increased and updated on the basis of technological progress in NCRE.

GRAPH 44. Changes in FiT fees



Source: (Morris & Pehnt, 2012)

The table below gives details of the reductions established in the FiTs for solar photovoltaic and the repercussions of these developments.

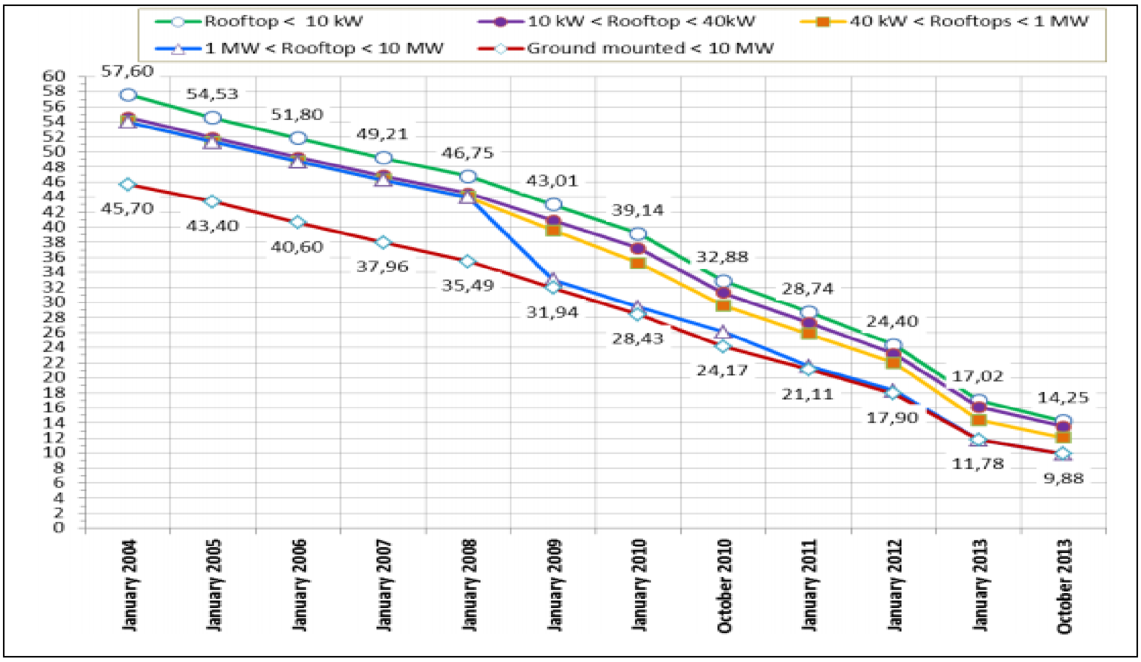
FIGURE 18. Development of the FiT system for photovoltaics to 2012

Policy changes	Variation	Effect
2000	• 51 cents/kWh remuneration for the first 20 years (regardless of installation size). • Annual programmed reduction by 5%.	• Increase in cost of photovoltaics from €19m (2000) to €37m (2001).
2003	• Reduction in pro-rata system of EEG for large power consumers by 0.05 cents/kWh. • Increase in remuneration for solar roofs to 54.7 cents/kWh.	• Reduction of the cost of the photovoltaic system from €6/Wp (2002) to €4.70/Wp. • Increase in cost of photovoltaics to €1.47 billion in 2007.
2009	• Reduction in remuneration by 8-10% to 2010 +/-1% per year in cases of installed capacity of >1500MW or <1000MW. • Option for own consumption at 25.01 cents/kWh or sale to third parties.	
2010	• Reduction in remuneration by 8-13% depending on size. • Additional one-off reduction of 10% in July and 3% in October.	
2011	• Adjustment of remunerations by 3, 6, 9, 12 or 15% depending on technology between March and May.	• Reduction in cost of the photovoltaic system from €4.3/Wp (2008) to €2.05/Wp. • Increase in cost of photovoltaics to €6.8 billion in 2011.
2012	• Adjustment of remuneration for own consumption to a maximum of 12.36 cents/kWh.	

Source: Own elaboration from (Hoppmann, Huenteler, & Girod, 2014)

The following graph complements the above table. It shows the variation in FiT in photovoltaic, depending on installation size.

GRAPH 45. FiT variation for photovoltaic energy (cents/kWh) to October 2013



Source: BNetzA in (Chabot, 2013)

For the case of wind energy, the FiT system in 2012 was as shown in the table below.

TABLE 19. FiT structure for wind energy to 2012

Type	Tariff	Reduction
Onshore	• 9.11 cents/kWh (initial) • 5.02 cents/kWh (basic)	1%
Onshore repowering	• 9.2 cents/kWh (initial) • 5.02 cents/kWh (basic)	1%
Offshore	• 13 cents/kWh (initial) • Bonus of 2 cents/kWh (for fast construction)	5%
Bonus	• 0.5 cents/kWh (new plants) • 0.7 cents/kWh (old plants)	

Note: tariffs for offshore plants depend on factors such as water depth and distance to coast, which are fixed at between 5 and 20 years.

Source: Own elaboration from BMU in (Gorozarri Jiménez, 2012)

Since the 2012 reform of the EEG, renewable installations have the option of receiving FiTs or going to market and receiving a complementary bonus.

One of these bonuses is the *Marktprämie*[102] or market bonus, established in May 2011 by the Federal Environment Minister, Norbert Röttgen, to achieve better integration of renewable energies in the market. The market bonus offers a cash reward to producers of electricity from renewable energy sources or gas who supply their power directly to a third party or to markets.

[102] (NETZ- TRANSPARENZ.DE, 2012)(BundesanzeigerVerlag, 2012)

In addition, as part of the market bonus, plant operators with reliable forecasts (on the amount of electricity they will produce) receive a management bonus (*Managementprämie)* or an additional fixed income. This is important, since in order to obtain an optimal price on the market for electricity from renewable sources, very precise predictions are required on renewable energy production with a prior knowledge of the reserves that will be needed or the energy to be bought. These additional bonuses brought the total to €2.2 billion in 2013 and €3.1 billion in 2014.

The following table summarizes the evolution of payments by type of EEG application.

TABLE 20. Value of management bonuses (cents/kWh)

Year	Onshore and offshore wind energy and solar energy	Hydro, landfill, sewage and mine gas, biomass and geothermal
2012	1.2	0.3
2013	0.65 - 0.75	0.275
2014	0.45 - 0.6	0.25
2015	0.3 - 0.5	0.225

Source: Own elaboration from (Buzer Systematische Normdokumentation, 2015)

Most wind technology installations have gone to market, mainly thanks to the bonus included in the EEG, while solar photovoltaic continues to avail of FiTs. There has been an increase in costs associated with the incorporation of photovoltaic technology, with 19,300 GWh in FiTs paying an average of €401/MWh.

However, Minister Sigmar Gabriel has said[103] that subsidies to renewables "are not sustainable". In 2014 he amended the Renewable Energies Act (EEG) on the grounds of the major investment it involved for Germany and the possible harm to common market compensation (investigated by the European Commission).

The reform,[104] approved by the *Bundestag* on 27 June of 2014 by 424 votes to 123, involved a reduction in subsidies to renewable energy products and in those energy targets. Although the minister indicated that the reform was "urgent" given the explosion in prices, the measure was criticized by the Greens and environmental associations. Green MPs accused him of "having finally supported traditional energy sources with this law".

[103] (EFE, 2014)
[104] (REVE, 2014b)

TABLE 21. Structure of FiT for different technologies from 2014

Type	Tariff (only for new installations)	Average (installations from 2000 to 2012)
Photovoltaics	9.9 – 14.3 cents/kWh	36.2 cents/kWh
Onshore	8.8 – 9.8 cents/kWh	9.3 cents/kWh
Offshore	15 – 19 cents/kWh	16 cents/kWh
Hydroelectric	3.4 – 12.6 cents/kWh	9.2 cents/kWh
Biomass	5.9 – 25 cents/kWh	18.2 cents/kWh
Geothermal	25 – 30 cents/kWh	21.8 cents/kWh

Note: tariffs for photovoltaics have programmed monthly reductions.

Source: Own elaboration from (Graichen, 2013)

It is important to remember that a new amendment to the law is being prepared for 2016 which could promote the switch from guaranteed FiT to open competitive bid.

The net result of all these developments has been to produce important outlays for the development of renewable energies. The table below shows the development of payments made as a consequence of application of the EEG between 2011 and 2014.

TABLE 22. Payments[105] by EEG application type between 2011 and 2014 (€m)

	Cost (€M)			
FiT	**2011**	**2012**	**2013**	**2014**
Hydroelectric	231	271	303	253
Onshore wind	4,164	1,344	688	661
Offshore wind	85	13	-	-
Photovoltaic	7,767	8,904	8,587	9,153
Biomass	4,476	4,872	4,059	2,645
Geothermal	4	6	16	13
Others	36	42	38	45
Total	**16,763**	**15,416**	**13,691**	**12,770**
MARKET	**2011**	**2012**	**2013**	**2014**
Hydroelectric	-	157	210	230
Onshore wind	-	3,585	4,179	4,800
Offshore wind	-	107	153	1,200
Photovoltaic	-	298	889	1,050
Biomass	-	1,389	2,725	3,400
Geothermal	-	0	3	4
Others	-	10	20	35
Total	**-**	**5,546**	**8,177**	**10,719**

Source: Own elaboration from BMWi y BNetzA in (Corrales, 2015)

Since 2000, the EEG supports the development of renewable energies in Germany and provides annual financing of €20 billion to the production of solar, wind, geothermal and hydroelectric energy. The most recent amendment is intended to strike a balance between prices for consumers and support for renewables. Thanks

[105] Photovoltaic energy data do not include self-consumption, through which 821 GWh were generated in 2013 and 2,788 GWh in 2014. The market energy system also includes management and market bonuses.

to the system of support to FiTs, up to 2013[106] 33,730 MW of renewable power had been installed.

Additionally, as reported in PV Magazine,[107] Minister Gabriel himself plans to replace FiT with an auction system by 2017 on recommendations from Brussels. Renewable energies would thus have to compete on the market as they would not have guaranteed purchase prices. The first changes will apply to photovoltaic energy.

Thus, from 2015 on, FiT will end for NCREs of over 500 kW, with the ceiling falling to 250 kW in 2016 and 100 kW in 2017 (Galetovic & Muñoz, 2014).

106 (Energía y sociedad, 2015)
107 (Enkhardt & Meza, 2014)

7. ELECTRICITY PRICES

One of the main criticisms levelled against the *Energiewende* is that it entails higher cost, given that the introduction of renewables currently requires major investment.[108]

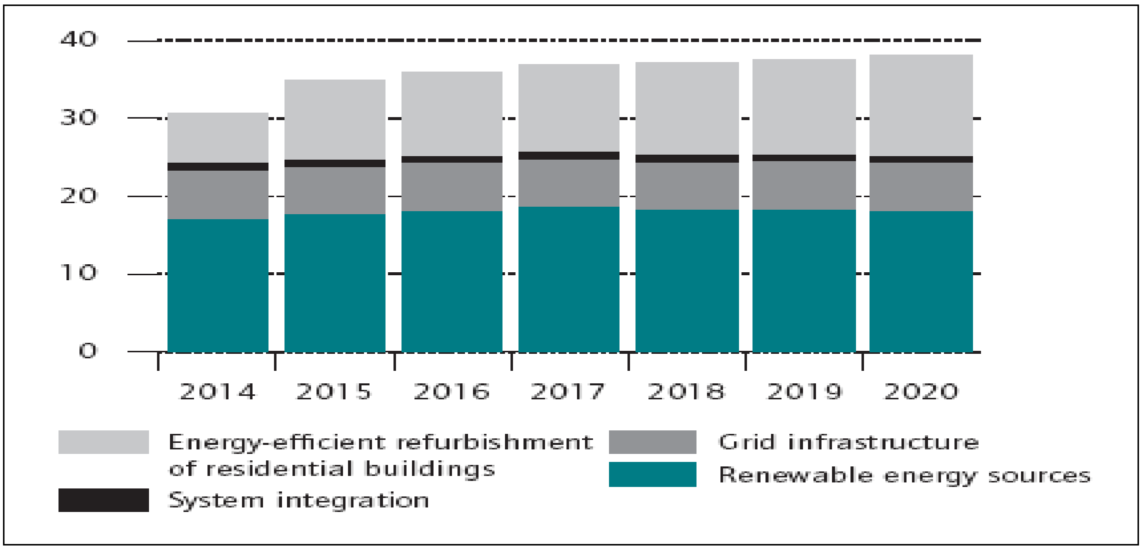
Indeed, investment in renewable power generation facilities in Germany over the last 25 years has come to over €200 billion, of which more than 70% has been made in the last 10 years (BMWi in [Corrales, 2015]).

Photovoltaic generation accounts for more than 50% of the investment (€110 bn), followed by wind generation (onshore and offshore) at 35% (about €70 bn) and smaller investments in biomass, hydroelectric and other renewable technologies (Corrales, 2015).

More than 25% of the investment has been made by German households, primarily through public bank financing. Another important part of the investment comes from public entities such as pension funds, collective investment associations, etc.

Continued investment is expected in coming years in new installations and energy infrastructures, as the graph below shows.

GRAPH 46. Expected investment from the *Energiewende* by activity (€bn)

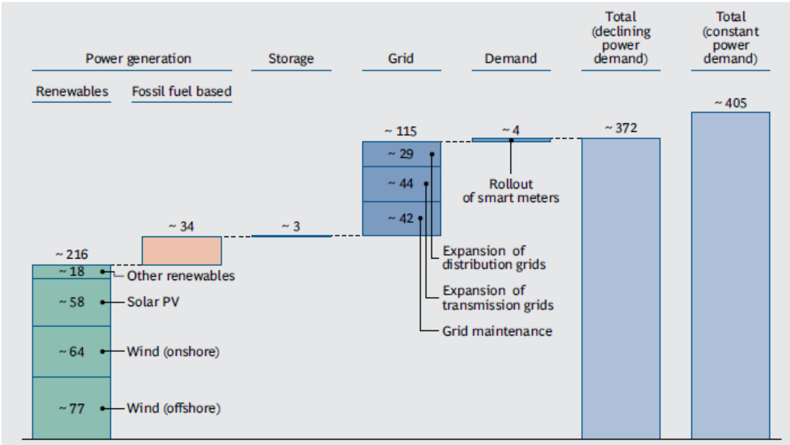


Source: (Blazejczak, 2013)

German consumers were forced to pay more than €20 bn in 2014 to subsidise electricity from solar, wind and biogas plants, when the real market value is no greater than €3 billion. However, the process is still underway and the transformation of the energy system –and the German system in particular– will require major investment both in generation and grid infrastructures.

[108] Those who defend the *Energiewende* consider that costs will remain low in this "first phase".

GRAPH 47. Accumulated investments required in future generation and grid structure (2010-2030) in billion euros



Note: based on the plan by the TSO, *Netzentwicklungsplàn.*

Source: (Heuskel, D.; 2013)

According to the Transmission System Operators (TSO),[109] for 2016 the figure[110] will be €23,066 million, 9.5% more than in 2015.

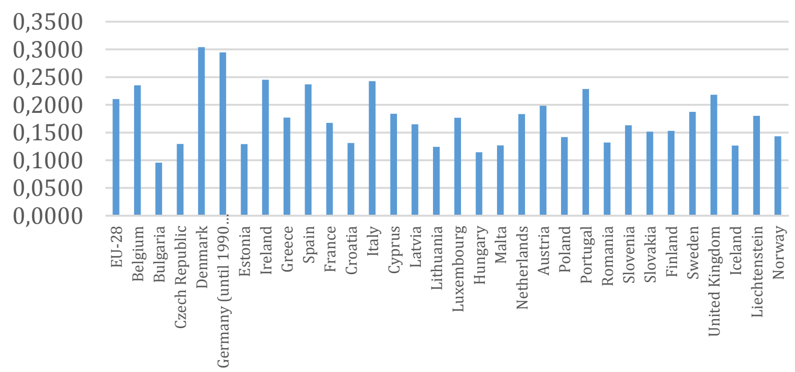
7.1. Electricity prices

With introduction of the *Energiewende*, Germany has one of the highest energy prices[111] for domestic consumers in Europe. As the graph below shows, it has the second highest[112] price (€0.295/kWh), just behind Denmark (€0.308/kWh). The price of electricity for domestic consumers in Germany is 42% above the European average (€0.208/kWh). Moreover, based on 2014 data, when power prices are compared to Purchasing Power Parity (PPP), Germany has the highest price (€0.282/kWh).

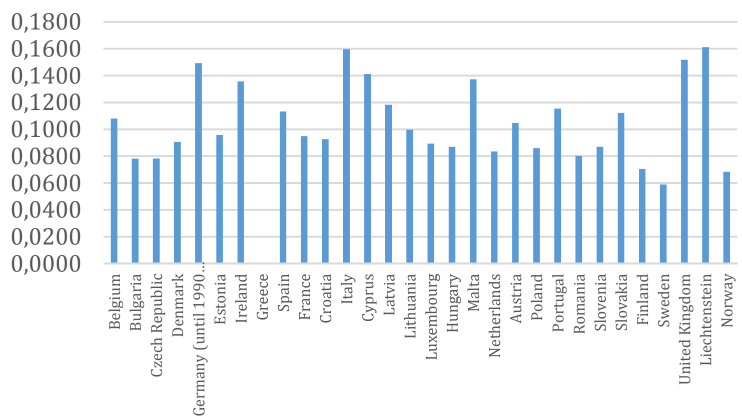
[109] (NETZ- TRANSPARENZ.DE, 2015)
[110] This amount basically consists of the transfer to the cost of renewables (€22,876 million in 2016), minus income from sale on the market, taking into account adjustments by the EEG resulting from divergence from estimations plus the liquidity reserve.
[111] Caution should be exercised when approaching any comparison between electricity prices –and especially their component parts– among EU Member States. The classification for the main energy cost components (energy, grids and taxes) has been found to vary from country to country. However, following a study by Eurelectric, it has been possible to present the differences between the different cost components presented by Eurostat (Eurelectric, 2014).
[112] (Eurostat, 2015)

GRAPH 48. Comparison of electricity price in the second quarter of 2015 in Europe(€/kWh)

DOMESTIC CONSUMERS



INDUSTRIAL CONSUMERS



Note 1: The electricity price for domestic consumers is defined from the national average price in €/kWh with taxes and other charges that can be applied for the second half of 2015 for domestic consumers with an annual consumption of between 2,500 and 5,000 kWh.

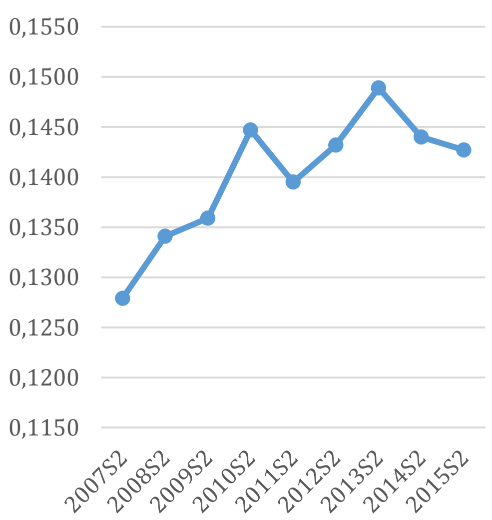
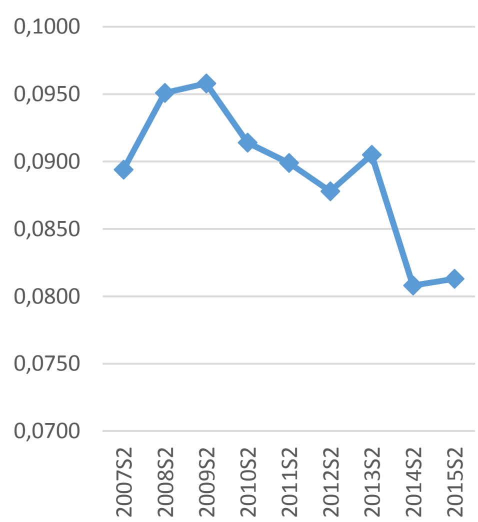
Note 2: The electricity price for domestic consumers is defined from the national average price in €/kWh with all costs included for the second half of 2015 for industrial consumers with an annual consumption of between 0.5 and 2 GWh.

Source: (Eurostat, 2015)

Germany is used to giving the rest of Europe lessons on competitiveness. However, German industry may face problems: according to official data from Eurostat it pays 40% more for energy than France or Holland, and its bills are 15% higher than the European average. Although the German intensive energy-use sector receives assistance in the form of reduced taxes, other sectors such as the chemical and steel industries are among the most seriously affected by the cost of the *Energiewende*, which comes to €740m/year.

German energy-intensive industry[113] accounts for a large percentage of the country's economy in comparison with the OECD average. The energy bill is therefore an important factor for competitiveness of the industrial sector and the German economy as a whole.

GRAPH 49. Electricity price before tax in Germany (€/kWh)

Domestic consumers	Industrial consumers
	

Note 1: for domestic consumers, the power price is defined by half-year and year after taxes for medium domestic consumers with an annual consumption of between 2,500 and 5,000 kWh.

Note 2: for industrial consumers, the power price is defined by half-year and year after taxes for medium industrial consumers with an annual consumption of between 0.5 and 2 GWh.

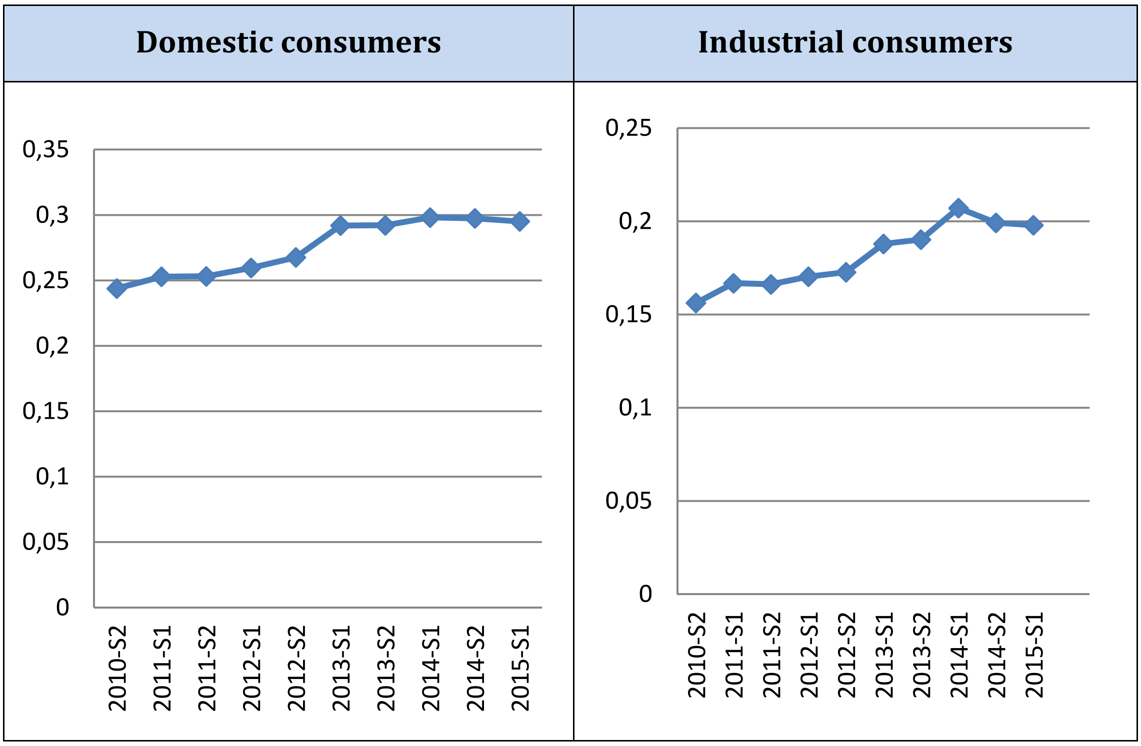
Source: Own elaboration from (Eurostat, 2015)

Based on 2015 data[114] the average electricity price before tax for a domestic consumer and an industrial consumer were very similar, at €0.15 /kWh and €0.08 €/kWh respectively; after taxes are taken into account, that difference widens considerably, with prices standing at €0.297 /kWh for domestic consumers and €0.15 /kWh for industrial consumers.

Taxes and rates make up about 52% of the electricity price for domestic consumers in Germany. In addition, the energy transition and the EEG have sparked debates on the increase in costs for the country's industrial consumers, for whom 46% of the energy price corresponded to taxes and other charges in 2015.

[113] Aluminium, chemical products, steel and glass.
[114] (Eurostat, 2015)

GRAPH 50. Electricity price in Germany (€/kWh)



Note 1: for domestic consumers, the power price is defined by half-year and year after taxes for medium domestic consumers with an annual consumption of between 2,500 and 5,000 kWh.

Note 2: for industrial consumers the power price is defined by half-year and year after taxes for medium industrial consumers with an annual consumption of between 0.5 and 2 GWh.

Source: Own elaboration from (Eurostat, 2015)

Although the increase has been similar (in both cases the price has doubled), domestic consumers have shouldered a higher burden than industrial consumers, as they do not enjoy the tax exemptions awarded to industry.

Thus, an average German domestic consumer spends €86.04 per month on power, representing 2.25% of the monthly wage.

TABLE 23. Power expenditure for an average German domestic consumer

CONCEPT	QUANTITY
Average annual salary (2014)	€45,952
Average monthly salary	€3,829
Average annual power consumption	3,500 kWh
Average monthly power consumption	291.67 kWh
Power price for domestic use (October 2015 – taxes included)	€0.295 /kWh
Average power expenditure per year	€1,032.50
Average power expenditure per month	€86.04
Power expenditure as a percentage of salary	2.25%

Note: A domestic consumer is an average three-person household.

Source: Own elaboration from (Expansión/Datos macro, 2014)(IndexMundi, 2014)

This figure is relevant, given that each year power supply is cut[115] to more than 300,000 German households for non-payment of bills. It is therefore important to bear in mind that a household of 3 people pays practically twice as much now as in 2000.

This is an important factor that might lead to a questioning of the energy transition programme and a decline in public support for it.

Indeed, more and more German people are now experiencing *Energiearmut*[116] or energy poverty, defined as having to spend more than 10% of one's income on energy.

As a result of a sharp increase in electricity prices compared to salaries, the proportion of German households suffering energy poverty increased from 13.8% to 17% between 2008 and 2011, an increase of 1.4 million households. There has also been an increase in the number of households whose supply has been cut off by the energy suppliers. Therefore, although support for the *Energiewende* remains high, in surveys the proportion who felt that the energy transition was "correct" fell from 63% to 56% between 2011 and 2013.

7.2. *Energiewende* surcharge

According to J.M. Martí Font,[117] this continued rise in electricity prices for consumers and companies is due to the surcharge set aside for financing the *Energiewende*, which has been developed through the Renewable Energy Sources Act (EEG) mentioned above (Section 6.1).

As discussed in the section on programmes and laws supporting the *Energiewende*, in order to provide support for the introduction of renewable energies, Germany promulgated the Renewable Energies Act (EEG).

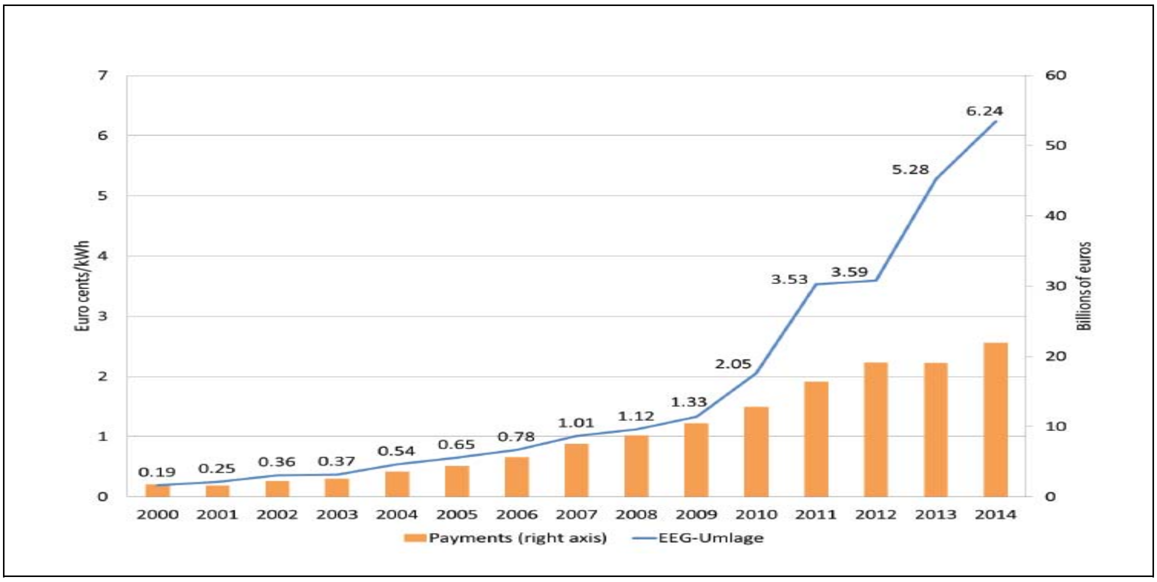
The EEG gives renewable energies priority access to the power grid and sets the feed-in price for a 20-year period.

In order to cover the costs resulting from this law, power consumers have to pay what is called the "EEG surcharge" or EEG-*Umlage*. As the graph below shows, the EEG-*Umlage* was 6.24 cents/kWh in 2014, or more than 20% of the cost of electricity for a 3-person household.

EEG-*Umlage* payments in 2014 are estimated to be about €22 billion and the total amount of payments for renewables since the scheme was introduced are estimated to come to €185 bn (Rutten, 2014).

[115] (Waterfield, 2014)
[116] (Rutten, 2014)
[117] (Martí Font, 2014)

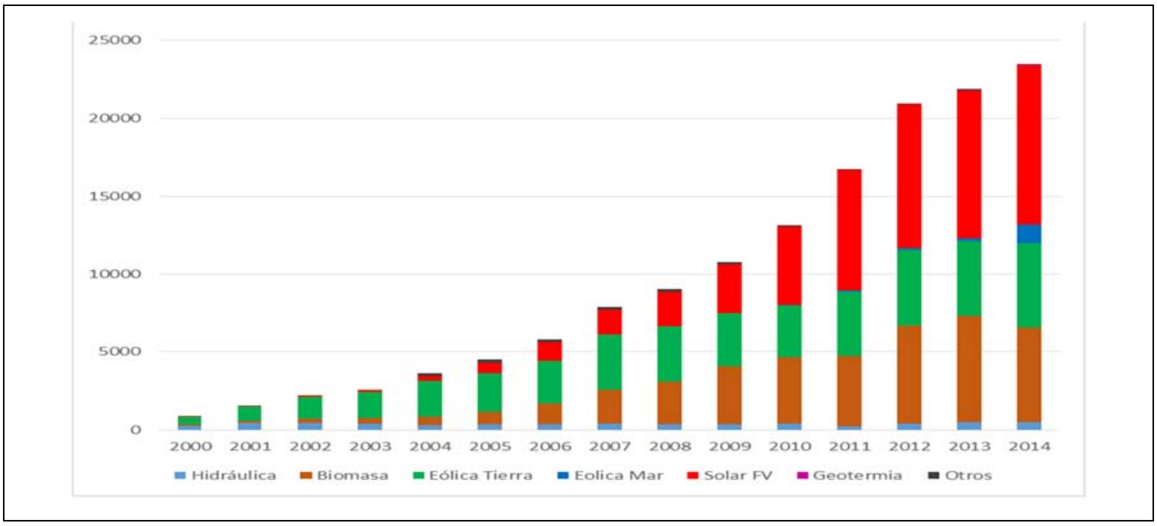
GRAPH 51. Development of the EEG-*Umlage* (cents/kWh) and payments to the EEG (€bn) from 2000 to 2014



Source: (Rutten, 2014)

This graph is complemented by the one below, showing development of EEG-related costs by technology.

GRAPH 52. Development of payments to the EEG from 2000 to 2014 (€m)



Source: BMWi in (Corrales, 2015)

As can be seen, the EEG-*Umlage* has risen steadily and it now seems essential to reverse this trend. In 2000, the cost came to less than €1 billion, in 2006 it was over €5 billion, in 2009 €10 billion and by 2012 €20 billion.

According to EnergyMarketPrice,[118] the EEG-*Umlage* is currently 310% higher than before the beginning of the *Energiewende* in 2010, clearly showing the latter's influence.

118 (Energy Market Price, 2015)

Since May 2014, the Government has approved a series of measures to try to limit this price increase, which would basically discourage the creation of new wind and solar farms.

The increase in costs has mainly been due to the fact that there has not been a simultaneous reaction to the changes in the costs of renewable technologies. For example, the cost of a photovoltaic module dropped significantly between 2010 and 2012 and yet tariffs remained significantly high, despite the fact that they had fallen (as analysed in the section on the FiT) in comparison to the real cost. This led to a 23 GW increase in the installed photovoltaic capacity in a three-year period, considerably increasing the total cost for the EEG.

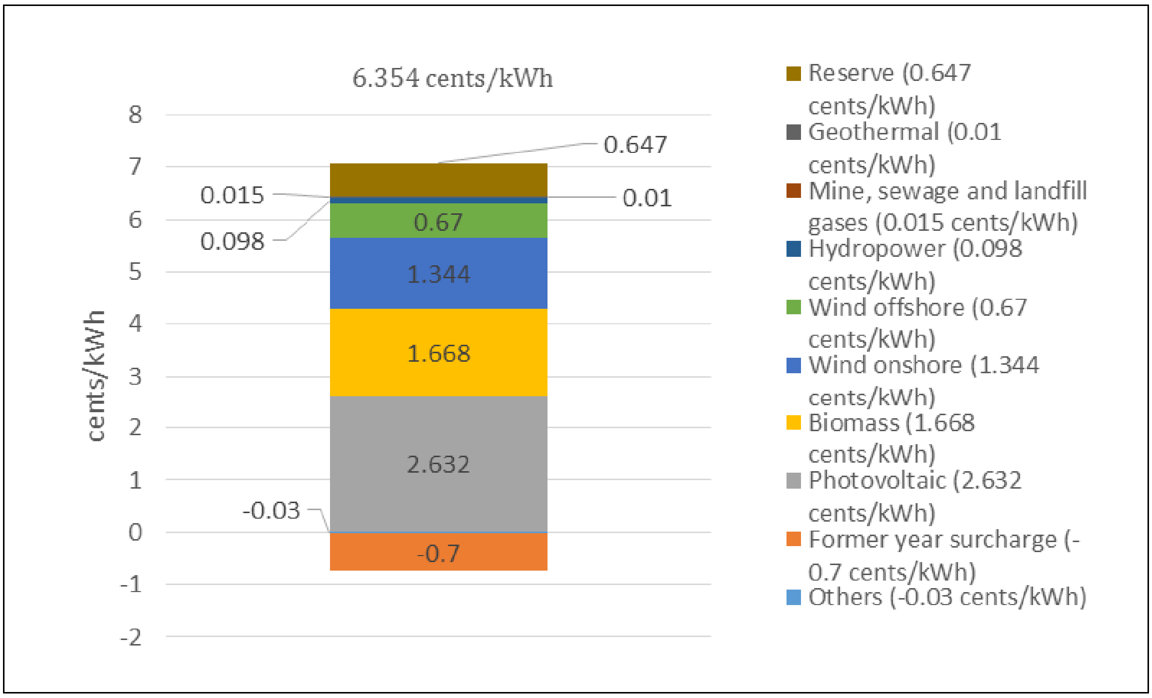
In order to prevent this happening in the future, in 2014 the German government introduced what are known as "extension corridors" in the EEG to establish specific caps on extension of capacity for each renewable technology. With this move, subsidies for renewables will be suspended and for the expansion of offshore wind energy they will be limited. Moreover, each year only 2.5 GW extra from wind and solar origin can be added, whilst offshore wind energy will have a limit of 6.5 GW in 2020. In addition, in January 2015, auctions for photovoltaic installations were regulated through an EEG ordinance.

One of the measures that will have the greatest influence on a reduction in costs is that from 2017 renewables will have to compete on the market, since suppliers will no longer have guaranteed purchase prices (as explained in the description of the FiT system in Section 6.3). As Social Democrat Sigmar Gabriel, Vice Chancellor and Minister of Economy and Energy puts it,[119] "These measures mean that we can no longer continue believing in the illusion that the energy transition can be achieved only by high-speed expansion in production from renewables; the expansion must also be secure and predictable".

However, on 15 October 2015, the four transmission system operators in Germany (50Hertz, Tennet, Amprion and TransnetBW) received confirmation that the allocation[120] for renewable energy promotion, the EEG-*Umlage*, would increase by 3% in 2016, rising rise from 6.17 cents/kWh (2015) to 6.354 cents/kWh. This is broken down by technology in the graph below.

[119] (Orth & Schayan, 2014)
[120] (STIMME.DE, 2015)

GRAPH 53. Breakdown of the EEG-*Umlage* (cents/kWh) of 2016



Note 1: The reserve is the one used for adjusting the differences between the estimated cost and that actually produced.

Note 2: The surcharge for the previous year is due to a surplus which led to a reduction in the EEG-*Umlage*.

Source: Own elaboration from (NETZ- TRANSPARENZ.DE, 2015)

This charge[121] had never been so high and German industry and the Greens blame the Federal Minister of Economy and Energy, Sigmar Gabriel (SPD) for these growing costs.

7.3. Exemptions

However, there are various exemptions from the EEG-*Umlage*. The most important is that awarded to industrial users with high energy consumption, but there are also other, less significant exemptions, including a green electricity bonus.

Users with high energy consumption (who make up an important part of the German manufacturing industry) have received partial exemptions from the EEG-*Umlage*, based on their annual power consumption and the percentage of their general costs going to energy.

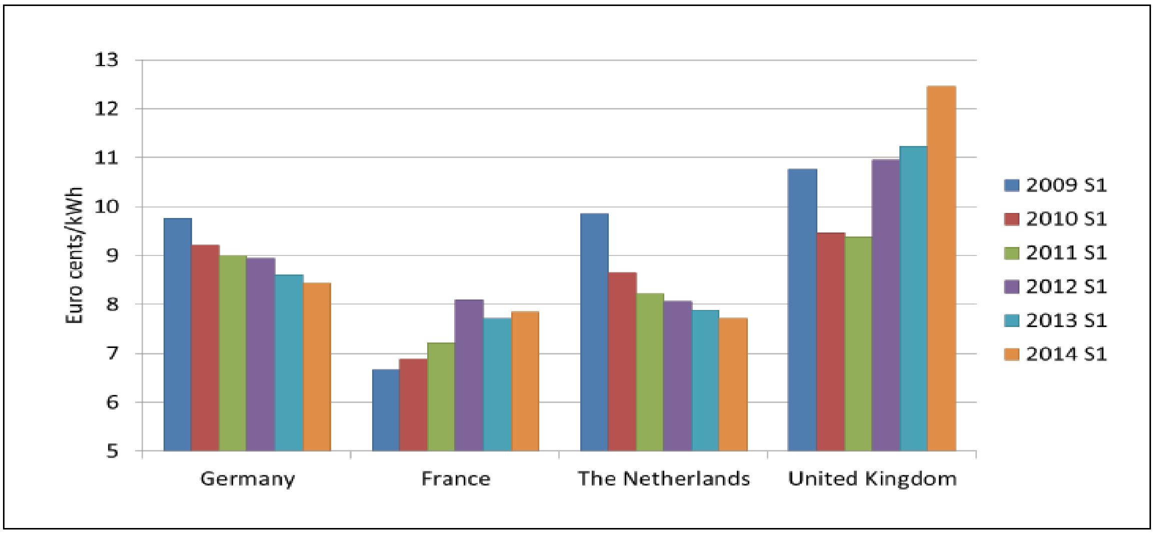
Thus, as indicated in the EEG,[122] industries with an annual power consumption of more than 1 GWh and for whom power costs account for 14% or more of gross value added (GVA) receive exemptions from the EEG-*Umlage*. These exemptions rise with consumption: those consuming between 1 and 10 GWh/year pay only 10% of the surcharge, between 10 and 100 GWh/year this falls to 1% and for consumption of

[121] The Greens' energy expert, Julia Verlinden, says that this increase could have been avoided "if Gabriel had managed to avoid the increase in coal-fired power on the market".
[122] Section 41 of the EEG (BMWi, 2014b)(Lang & Lang, 2013).

over 100 GWh they only have to pay 0.05 cents/kWh. Thus, the following industries are exempted due to consumption: chemicals, paper, pharmaceuticals, non-metallic minerals, iron and steel and non-ferrous metals.

As a result of a higher percentage of RE in the energy mix since the *Energiewende,* wholesale power prices have fallen for large consumers eligible for exemptions, whereas in France and the UK they have suffered increases.

GRAPH 54. Power prices for large industrial consumers (0.5 – 2 GWh/year) before taxes (cents/kWh)



Source: (Rutten, 2014)

These exemptions include one known as *Grünstromprivileg*[123] (green power privilege), introduced in 2000 by the BMU in the EEG, which remained in force until August 2014, when the EEG was amended. This privilege was an economic incentive for direct marketing of power from renewables, whereby power companies were exempted from paying the EEG-*Umlage* if 50% of the total base of supplied power came from domestically-generated RE.

Due to the use of this green power privilege, other expenditures would be chargeable to the remainder of energy consumers. As a result, the BMU limited the reduction of the tax obligation for companies using the green power privilege to €0.02 /kWh in the 2012 EEG. At the same time at least 20% of power must come from wind and photovoltaic systems.

In addition to these exemptions, there are also market and management bonuses in which the cost is economically rewarded, as previously explained, which therefore contribute to a reduction in costs.

Thanks to these exemptions, companies have been able to maintain their international competitiveness. However, as a result, other consumers pay a higher fee, since it is necessary to cover the total costs. This has caused protests not only

[123] (BSW Solar, 2014)(GrundGrün, 2015)(Schwarz, 2014)

inside Germany, but also abroad. In 2014 the European Commission (EC) opened investigations into the industrial exemptions of the 2012 EEG, to determine whether they constituted illegal state assistance.

However, due to their characteristics, the *Mittelstand*[124] (German SMEs) have not benefited from exemptions and are paying the high financing costs of the energy transition. This situation harms the country's international competitiveness and the German economy as a whole, given the importance of the *Mittelstand*.

As a result, many German companies have decided to produce their own power using fuels (whose price is currently less variable than electricity), thus protecting themselves against the EEG-*Umlage* and fulfilling the requisites to receive the subsidies set out in the *Energiewende* and reducing their power bill by 50%.

As for domestic consumers, those that are able to purchase solar panels can reduce their electricity bill, whilst the less fortunate pay a growing EEG-*Umlage* on their power consumption.

Analysis of exemptions to the EEG-*Umlage* therefore shows that it is the low-voltage clients, domestic and commercial consumers, who have borne most of these extra charges, since industry has been able to benefit from exemptions.

[124] The German economy included a large proportion of small and medium-sized enterprises (defined by the EU as firms with a maximum of 500 employees and a maximum balance of €40m). This section of the German economy is known as *Mittelstand* and covers more than 99% of German companies. In 2013 SMEs accounted for 52% of the country's total economic production, 37% of the total business volume of German companies and 19% of total exports by German companies. The *Mittelstand* employs approximately 15 million people, around 60% of all employees subject to social security contributions. In comparison to other countries, the German, *Mittelstand* firms are very active in the industrial sector (Rutten, 2014).

8. SOME IMPLICATIONS AND DIFFICULTIES

Implementation of the objectives of the energy transition has numerous implications, involves several challenges and is not free from difficulty.

New transmission lines

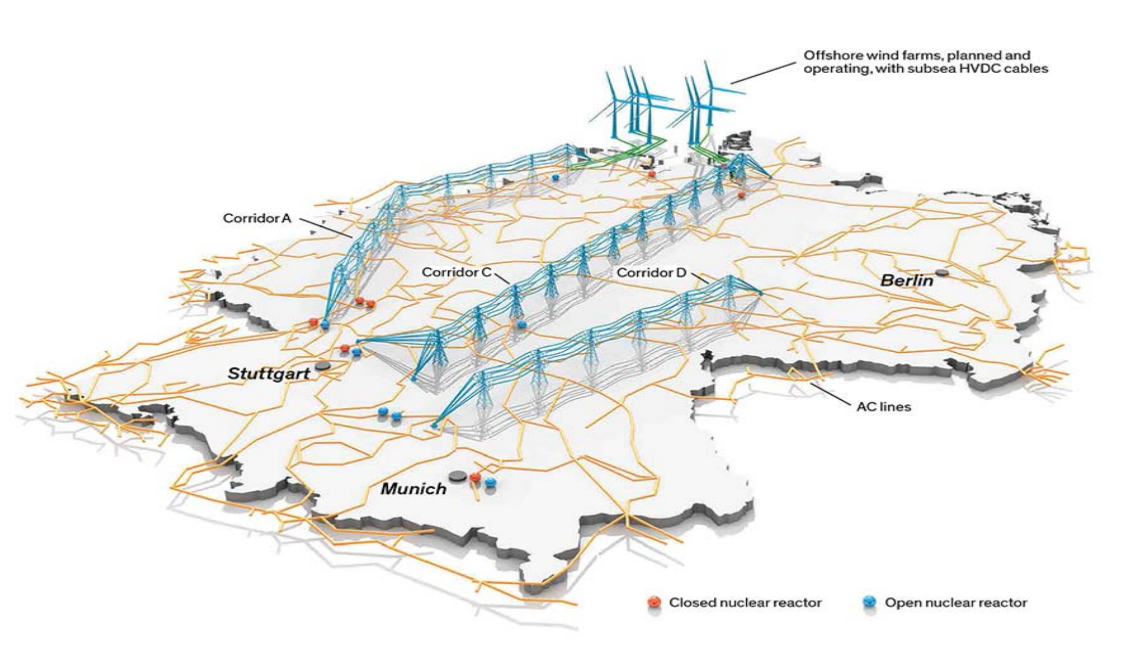
One of the key objectives for success of the *Energiewende* is to build more than 5,000 kilometres of new power grids by 2022. The reason is that the largest power consumers are concentrated in the south while most of the renewable energy is in the north, thus requiring construction of major North-South transmission lines. It is also planned to optimize 5,400 kilometres of lines.

In May 2012, the government announced five plans for improving and extending the transmission grid, in order to connect the new renewables and adjust to the changes involved in the nuclear closure.

In December that year, the Government decided to accelerate the program in order to build 2,800 kilometres of high voltage and to achieve it in four years, instead of ten. Other sources mention different lengths (3,800 kilometres of new lines and 4,400 of extensions and improvements), but in any case, the numbers give an idea of the important implications and difficulties.

Construction of “the great electric highway”, which is already underway, involves a corridor of 800 kilometres of extra-high voltage lines known as *SueLlink*. The project has a €13.5 billion budget which has been approved by the German government and is being managed by Social Democrat Vice Chancellor and Minister of Economy and Energy Sigmar Gabriel (Sánchez, 2014).

FIGURE 19. Planned enlargement of power grids in Germany

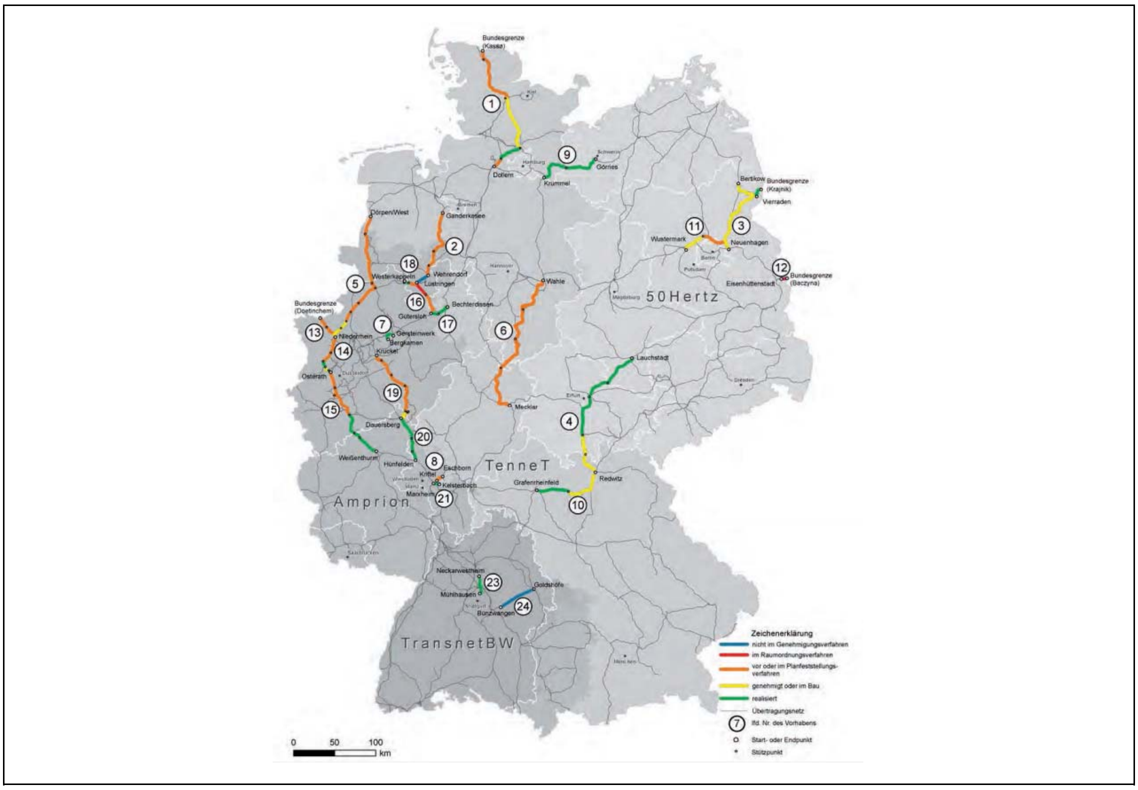


Source: ENTSO-E in (GENI, 2013)

As indicated, the project (explained above) to create new power lines linking the great industrial energy and power consumers in the South with renewable capacity in the coastal areas in the North (offshore wind energy) is of fundamental importance. However, this project is developing slowly as many German citizens are opposed to the idea of having high voltage lines close to their homes.

A number of protests have been organised against plans by the operator Amprion (involved in *SuedLink*), and TenneT has also encountered resistance to expansion of the grid in the state of Schleswig-Holstein. Indeed, Christian Democrat politician Heines Geissier suggested "submitting the project to a vote before continuing and assuming the risk of having to stop the project every 50 kilometres". However, the German government cannot afford a setback to the plan now that the budget for the project (€13.5 billion) has been approved (Sánchez, 2014).

FIGURE 20. Current state of the enlargement of the transmission grid at the end of 2015



Source: (Bundesnetzagentur, 2016)

Distribution and distributed generation

The distribution grid has gained in importance in recent years due to an increase in the quantity of low-voltage power generated by grid-connected photovoltaic energy. A bottleneck in this infrastructure could therefore limit possible development of the *Energiewende* (Rutten, 2014).

Furthermore, as mentioned, the *Energiewende* also includes a new energy policy paradigm, combining large scale generation by the large energy companies with a large share of decentralised generation, owned by individuals and cooperatives. Although this objective is not set out in any law, it forms the basis for achieving public consensus and ensuring the long-term success of the *Energiewende*.

An iconic example for the *Energiewende* in distributed generation is the *Solarsiedlung* neighbourhood of Vauban in Freiburg[125] (see next figure), which is shown in the figure below. In this neighbourhood, a) houses are built with low energy consumption criteria using wood, a low-contaminating material; b) houses have photovoltaic panels that produce energy which is sold to the grid if not consumed; c) the use of shared cars, bicycles and public transport is promoted in the neighbourhood, thus reducing the number of cars by 35%; d) there is a CHP plant producing the necessary energy for homes from wood chips and photovoltaic

[125] (Perezdans, 2014)

panels, thus cutting CO_2 emissions by 60%. Sixty-five percent of the energy produced in this plant comes from renewables.

FIGURE 21. Houses in Vauban neighbourhood (Freiburg, Germany)

Source: (Mejorarq, 2015)

Another project is *Ökocity*, a German/Japanese scientific partnership which plans to establish an ecological urban planning code in the industrial metropolis of Kitakyushu (Japan), where construction of a residential area of 30 to 50 houses began in 2006 (Academic, 2015).

Supply security

As regards supply security, the German power system has traditionally worked with high security margins, including both a large surplus of generation supply and enough grid capacity. If this was not maintained, the *Energiewende* would be in danger.

Preliminary evidence suggests that neither the adequacy of resources nor the stability of grids have so far been affected by the *Energiewende*. In any case, if there is sufficient political willpower to allow the capacity of neighbouring countries to be viewed as secure for Germany, the *Energiewende* can overcome this hurdle and progress without maintaining conventional margins.

In their article, Kunz and Weigt[126] show that even the process of nuclear dismantling, due to be completed by 2022, will not cause a shortage provided capacity is contracted with neighbouring countries for security (Austria and Switzerland) and that the regulator, the German Federal Grid Agency (BNetzA or *Bundesnetzagentur*) maintains a conservative stance.

[126] (Kunz & Weigt, 2014)

It is also important to note that the *Energiewende* will be effectively satisfactory if its costs can be affordable and if the power supply is not put at risk, as Von Hirschhausen explains in his article *The German Energiewende-An Introduction.*[127]

Energy efficiency

As for the targets on energy efficiency, Germany is running behind schedule in its plans, and as the energy efficiency ratio (EER) indicates, part of the problem lies with inefficiencies in the market (market failures, lack of information, irrational behaviour), mostly in energy efficiency in buildings where towns are not applying measures for improvement, despite the economic advantages they would offer.

In Germany the funds for promoting measures for improving insulation and energy efficiency are linked to revenue from auctions for emissions permits, but when the subsidies for these decrease, there is little margin for this area. This issue is discussed in the Fourth "Energy Transition" Monitoring Report of 2015 (BMWi, 2015f).

Reserve capacity and mass integration of renewables

Photovoltaic and wind energies are the main resources on which Germany is basing its energy transition in relation to the power industry.

In first place, the variability in renewable energy production makes storage systems necessary. As Norbert Röttgen –Minister for the Environment until 2012– has said, storage technologies will be of key importance for the success of the energy transition.

The government has earmarked about €200m of the R&D budget for storage systems, including different technologies (lithium batteries, heat pumps, decentralized storage systems, thermal heat and hydrogen storage). Dams are not considered as a storage option as there are few suitable sites for this kind of infrastructure in German topography. Moreover, the German public tends to oppose this kind of action on environmental grounds.

Another element that needs to be taken into account is therefore the reserve capacity. As mentioned, the electricity produced from renewable energy sources depends on climate conditions (wind and sunshine) and in order to prevent power cuts during days with little wind and/or sun, reserve capacity is needed.

Electricity prices currently leave little margin for gas plants (the typical kind of reserve plant) and therefore the private sector does not have enough economic incentive to facilitate an increase in this necessary reserve capacity.

Mass expansion of renewable energies such as photovoltaics and wind energy (which depend on seasons and climate conditions), therefore poses a challenge for the policy of incorporating more renewable energy into the energy system.

[127] (Von Hirschhausen, 2014)

It will also be necessary to apply smart solutions, expand the infrastructure through distribution and transmission grids, improve coordination with neighbouring countries and distribute equally the costs of the energy transformation.

The latest amendment to the EEG in 2014 seeks to ensure better control of the expansion objectives so that costs are better distributed and to contribute to the incorporation of renewable energies onto the market with greater efficiency through the obligation for direct marketing.

Social costs and benefits

Costs come from different "fronts"; the cost of the renewables themselves, of the transmission grids, of nuclear closure and of new coal plants. The amount involved varies depending on the sources, which view the situation with varying degrees of optimism; according to those who defend the transition and establish policy objectives, the costs are justified in the large term.

Energy costs can come to billions of euros every year. The Ministry of Environment bases its arguments on a comparison of the costs of the present power system with one based on renewables, which would be cheaper by 2025, as well as the work of Von Hirschhausen, C. (2014), which compares the periods before 2010, 2011-2020, 2021-2030 and 2031-2040.

Another issue is the sharing of energy costs. The interests of many stakeholders must be taken into account, including energy suppliers,[128] grid operators, the energy supply industry and investors, as well as the many energy consumers, including the large energy consumers who are protected through exemptions.[129]

Social benefits are considered as one of the main arguments in favour of RE. In 2012, the German Minister of Environment announced that 380,000 jobs had been created in the renewable energies sector. However, the real figure appears to be lower, at around 320,000.

Thus, the benefits appear to filter down into the renewables sector, in the form of job creation and an area of industry that will be addressed below (as will the increase in the cost of energy).

Nonetheless, an awareness of the cost of the German tariffs system (FiT) has driven the Government to reduce tariffs for solar production by 30%, which –combined with strong competition from Asian producers of solar panels– has led to a reversal of job creation.

A final consideration

To conclude this section, we can see that the first phase of the energy transition has developed strongly, although it is equally true that after this initial success, Germany

[128] As seen in Chapter 4, the economic impact on traditional companies has been devastating.
[129] As discussed, the German government's aim is for German industry –the fifth largest in the world– to continue to be competitive in the case of energy-intensive companies (DENA, 2014).

now needs to resolve several important issues. In 2012, Matthias Kurth, then President of the German Agency of Industrial Networks (*Bundesnetzagentur*) recognized[130] that it was "premature to celebrate the event". Therefore, we can conclude that the *Energiewende*, which might appear to be a temporary phenomenon, is a plan that is being consolidated and is working but whose development is not free from high costs and numerous difficulties.

[130] (Frankfurter Allgemeine, 2012)

IV. INDUSTRY

9. INDUSTRIAL POLICY

In her first television interview following her re-election in December 2011, Chancellor Merkel said[131] that for her "the most pressing problem is design of the energy revolution, which is highly important since the future of employment and of Germany as a business location, depends on it". This reflects Germany's concern to implement a well-designed industrial policy that will adapt to the country's energy transition.

For a better understanding of industrial policy in Germany, it needs to be examined in the context of the guidelines and proposals of European industrial policy. The first section of this block will therefore address this aspect, before moving on to a specific examination of the German situation.

9.1. The position of European industrial policy

Article 173 of the Treaty on the Functioning of the European Union (TFEU) establishes the juridical basis for European Union industrial policy, which seeks to improve the competitiveness of the European industry, mostly through the adoption of measures covering several sectors. The industrial policy is mainly a transversal one that affects many other policy areas, such as trade, the internal market, research and innovation, employment and environmental protection (BMWi, 2015b).

Since 2002, the European Commission has published a number of communications on European industrial policy, setting out key action lines and a specific working programme for this field. In its communication of January 2014, the Commission announced that it would focus on presenting the domestic market in a more attractive way and on promoting innovation.

At the same time, the European Commission also supports small and medium-sized enterprises, facilitating their access to financing. It has likewise committed to assisting European companies, mainly through the negotiation of a number of free trade areas (FTAs) with third countries and the promotion of international standards.

To judge by what has happened in industrial policy in recent years, one may conclude that the European industrial sector will only remain strong if responsible politicians, both at a European level and in the individual member states, implement a coherent overall strategy. And whenever political decisions are taken in other fields, such as energy or environmental policy, there must be an attempt to strengthen industrial competitiveness and avoid an excessive regulatory burden on industry. Key objectives therefore include better energy efficiency, environmentally-sustainable products and more efficient production processes.

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[131] (Waterfield, 2014)

In 2012, the European Commission presented a strategy for a sustainable economy in Europe, which pursues the promotion of a greater and more sustainable use of renewable resources. One of the main challenges in coming years will be the development of a sustainable energy strategy and an efficient industrial strategy in the use of resources, which does not involve an excessive burden for consumers or business (BMWi, 2015b).

The EU has set a target of a 20% contribution to GDP from industry by 2020. But beyond its contribution to GDP, the relevance of the industry can best be seen if one takes into account the fact that more than 80% of European exports and private RDI take place in this sector.

In order to lay the foundations for growth and modernization after the crisis, the European Commission, in one of the key messages of its Communication of January 2014, called on member states to recognize the importance of industry as a central element for job creation, growth and the incorporation of industrial competitiveness in all political fields.

The new initiative on industrial policy centres on specific measures for improving the application of industrial policy to the established priorities, in order to develop industrial transformation. Among the main priorities proposed, several are related to energy.

The first was an invitation by the Commission to the Council and the Parliament to adopt proposals on energy, transport, aerospace and digital communication networks, as well as applying and enforcing legislation for creating the internal market.[132]

Another proposal was that industrial modernization must be pursued through investment in innovation, efficiency resources, new technologies, skills and access to financing.

They also advocate the promotion of a Europe that is more focused on business, through actions that are designed to simplify the legislative framework and improve efficiency in the public administration at community, national and regional levels.

They also mention the updating of the Small Businesses Act and strengthening of the Entrepreneurship Action Plan and facilitation of access to third countries' markets through harmonization of international standards, open public contracting, patents protection and economic diplomacy.

[132] In 2006 the European Commission revealed the existence of irregularities violating the principles of the liberalization treaty for gas and power markets in Europe, and warned that sanctions might be applied (European Commission, 2007). This led in 2007 to the launch of the "third package" of EU energy policy measures, approved in 2009, which had important consequences for the vertically-integrated structures of energy companies in some countries.

Finally they consider smart specialisation as a means of guaranteeing better integration of industrial and regional policies.[133]

9.2. Industrial policy in Germany

After the Second World War, Germany became one of the main promoters of the free market economy in Europe. In Germany, the word that is used to refer to industrial policy is *Strukturpolitik*. However, for the 100 years before the war, Germany was a great interventionist and centralist state. State intervention and restrictions on free competition began in Bismarck's Germany and ended in 1930. The German Customs Union or *Zollverein*, established in 1834 under Prussian mandate began the process[134] and also enabled the construction of a strong industrial economy (Andreosso & Jacobson, 2005).

Until 1960, German industrial policy –the *Strukturpolitik*– was basically interventionist. Thereafter, the government played only a supporting role, whose main purpose was to increase productivity and promote innovation and technological development. This was made possible by a number of factors: a) the federal structure of the country, which gives the *Länder* the responsibility for education and professional formation; b) the politicians of the new *Länder* have pursued greater decentralization, increasing economic activity and promoting a more positive and active industrial policy aimed at rescuing the rest of the public companies; c) cooperation among the different partners (government, industry, research centres, universities, trade unions and large banks) in design and implementation of the policy. The role of the banking system in particular was crucial as efficiency in the bank system meant that financing assistance could be extended to many more industrial sectors, including nuclear plants, aeronautics, computing and shipbuilding. As a result of the German industries' predominance in technologically-oriented industries, a close relationship was forged between education and training on the one hand, and industry on the other.

The authors cited above see the *Strukturpolitik* as generally being more a *laissez-fair* than an interventionist stance, albeit with some relatively limited governmental assistance, which has sought to leave most of the decisions to market forces, with the exception of the social market (Andreosso & Jacobson, 2005).

The German Government is currently trying to make energy and industrial policies converge. In this way, it seeks to support the *Energiewende* with an industrial policy since, apart from the impact that these energy policy measures might have on the competitiveness of energy inputs in the industrial fabric, the change might consolidate advanced industrial sectors based on the development of energy technologies with high added value. As well as reinventing the industry associated

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[133] For an analysis of smart specialization and energy, industry and mining, see the article by Álvarez, E., *Energía, industria y minería: retos y estrategias territoriales* (2016).

[134] The *Zollverein* removed customs duties among members of German Confederation, except Austria.

with the energy sector, this would facilitate the necessary tools for preventing change from having a negative impact on the energy cost of the industry.

The German energy transition has been planned taking into account a business fabric that will support this process and to create suitable conditions to facilitate the competitiveness of an industry with an innovative sector as well as other more mature segments.

Within the highly-integrated German supply chains and industrial clusters, energy intensive companies and those that do not have high consumption are intrinsically connected, giving German industry a competitive advantage at an international level and guaranteeing high quality products. These characteristics make the *Energiewende* a very important development for the country's entire industrial sector, creating as many challenges as opportunities (Rutten, 2014).

The country's industry is located mainly in the south, throughout the *Länder* of Baden-Württemberg and Bavaria, as discussed above (9). About 29% of the German population live in this area and together the two states account for nearly 30% of total German energy consumption. At the same time, industry represents about 55% and 60% of the energy consumption of the states of Bavaria and Baden-Württemberg respectively. The chemical and pharmaceutical sectors are very important in Bavaria, while the automotive industry is located mainly in Baden-Württemberg.

Nuclear energy has traditionally been –and still is– an important source of electricity generation in the South. Of the eight[135] nuclear reactors still in operation in the country, five are located in these two southern states. The combined power generation of the two states meets about 40% of their total power consumption. Therefore, in the industrial heartland of Germany there will be no great consequences for supply security resulting from the *Atomausstieg* (nuclear energy switch-off) (Rutten, 2014).

German industry tends to focus more on quality than on price, a feature that is closely related to having had a strong currency. Historically, as a result of the strong international position of the Deutsche Mark, the German industrial sector was limited in its capacity to use devaluation to improve international competitiveness. German industry therefore had to focus on quality. With regard to the *Energiewende* and the rise in electricity prices, this means that increases in production costs, as a result of greater energy costs, are not necessarily leading to a reduction in demand for German products. This is the due to the fact that demand elasticity is generally lower in markets with a high margin and higher added value than in those with a low margin. Nevertheless, high-volume markets are examples of competitiveness and sales based on low prices (Rutten, 2014).

135 Although at the start of the *Atomausstieg* programme (nuclear energy abandonment) there were nine nuclear reactors in operation, at the time of writing this number had fallen to eight, with the Grafenrheinfeld plant closing in June 2015.

Most of the German automotive industry, known the world over for brands such as Mercedes-Benz, Audi, BMW and Porsche, does not receive exemptions from the EEG-*Umlage*. However, the industry uses many high-energy-consuming products, such as aluminium, so ultimately they reap the benefits of the exemptions received by the companies, as explained in the section above. The EEG-*Umlage* represents more than a third of the electricity bill of the German automotive industry. Its main concern regarding the *Energiewende* is international competitiveness, due to the fact that its sales share is higher abroad than inside the country. Despite high energy prices and the financial crisis, however, the German automotive industry has seen an increase in the value of exports in recent years. These companies focus on added value rather than prices, so having energy prices above the European average does not necessarily undermine their export capacity.

"Green" technology companies are also well represented amongst the *Mittelstand* and it is here that Germany's "green" industrial base can be found.

There is already a significant market for products that increase energy efficiency, an especially important feature according to a study by Roland Berger,[136] which found that the market for energy efficiency products will continue to grow, with volumes doubling between 2005 and 2020 to €450 billion. It is therefore not surprising that there is growing investment in the development of this sector, where German participation, at 20%, comes second only to the US (24%).

The high proportion of employment in high-tech management sectors is one of the characteristics of the German economy, which goes hand in hand with German government R&D budgets: 2.02% of total government spending in 2012. This is also reflected in the number of patent applications filed in Germany, which accounted for almost half of all patent applications in the EU-28 in 2012 (Rutten, 2014).

Germany stands as a global leader in renewable technologies and it would not have attained this position without its market policies and the support of the federal government. Indeed, it is a leader both in photovoltaic solar energy and wind energy, albeit the two cases differ.

The German solar photovoltaic industry increased rapidly in the last decade, but is now encountering strong competition in Asia, particularly in China. This has recently led to a trade dispute between the EU and China on exports of subsided solar panels and presumed dumping[137] practices, leading to the imposition of import duties in the EU on Chinese panels. Nevertheless, most photovoltaic production has been exported out of Germany. Most German companies currently involved in the photovoltaic business no longer produce modules, and are mainly fitters and suppliers. This may signal a shift from manufacturing to services and can

[136] (Roland Berger, 2011)

[137] Dumping can be defined, in this context, as the commercial practise of selling a product below its normal price or even below its production cost in order to eliminate competitors and take over the market.

be attributed to the high level of photovoltaic installed capacity in Germany. However, Germany is a global leader in photovoltaic equipment manufacture and in solar systems such as power inverters, rather than being an important producer of panels themselves. This is similar to the strengthening of the *Mittelstand* in electric engineering (Rutten, 2014).

The German wind power industry currently enjoys a strong position on the global stage; it is among the world's leading innovators and is expected to hold onto this position in coming years. Together with Denmark and the UK, Germany leads the offshore wind energy sector.

Current policies have led to an enlargement of installed capacity in wind energy and a recent emphasis on offshore projects. Nordensvärd, J et al.[138] argue that the current German wind energy policy faces two financing dilemmas: firstly it has to increase energy costs for the consumer, since feed-in tariffs are financed with a rise in electricity prices; and secondly, energy costs have decreased for energy intensive industries through exemptions.

Research involving in-depth interviews with wind-energy experts[139] concluded that while the share of wind energy has increased rapidly, feed-in tariffs and other policies and incentives for decarbonizing have not yet proved sufficient to achieve a socio-technological transition in Germany (Nordensvärd & Urban, 2015).

The study found that feed-in tariffs for wind turbine projects divert attention and financing from other necessary innovation projects, such as grid systems. The report therefore suggests that German wind energy policy needs to develop new financing and support methods and innovative incentives for the promotion of wind energy and a suitable grid structure for the future. It is also important that the consumer does not bear the brunt of the *Energiewende*; instead, the burden should be shared out more evenly among industries and the state.

Before the *Energiewende*, the power mix in Germany had already experienced other energy transitions. As is currently the case with the *Energiewende*, German industrial policy was decisive in this development, which was closely related to the country's energy policy. Thus one might say that Germany follows a trend of treating industrial and energy policies as one (Rutten, 2014).

When it comes to dealing with energy transitions, the German government clearly uses its powers to influence the possible results, taking into account different factors

[138] (Nordensvärd & Urban, 2015)

[139] These experts include energy companies, business associations, research organizations and the government: AREVA (energy company), BMU (German Federal Ministry for Environment, Nature Protection, Construction and Nuclear Security), BMWi (German Federal Ministry for Economy and Energy) Bosch Rexroth (wind components supply firm), CEwind (research organization) Enercon (wind energy company), EWE (energy company), ForWind (research organization), Greenpeace (NGO), IOEW (research organization), REpower (wind energy company), Vattenfall (energy company), Electric Systems VDMA (business association), Vensys (wind energy company) and Vestas (wind energy company).

such as energy independence, affordability and the nation's electorate. As with coal and nuclear energy, the government's support for renewable energies has two internal and external roots.

The start of the *Energiewende* coincided with that of the German green industry. One demonstration of the close relationship between German industry and the country's energy policy was the announcement by Siemens in 2011 that it was to totally abandon the nuclear industry. This was the same year that Chancellor Merkel decided to seep up the *Atomausstieg*. At the same time Siemens also created a separate division for its wind energy activities, Siemens Wind Power, which is now a European leader in the manufacture of offshore wind turbines. Therefore, in order to understand the causes of the *Energiewende*, one needs to see it within the framework of German industrial policy. And in predicting how it might develop, it is important to consider the country's various industrial interests (Rutten, 2014).

As regards employment, the increase in renewable energies has also led, directly or indirectly, to a loss in other sectors such as traditional public services and the coal and nuclear industry. The net effect on the country's employment cannot therefore be judged yet.

The same is true of the overall effect of the *Energiewende* on German industry. The German industrial basis is very diverse and the effects of the energy transition may take several different forms, benefiting some agents and harming others. What seems clear[140] is that Germany's industrial interests were taken into account when the *Energiewende* was launched and the emergence of green technology companies was strongly stimulated by the creation of a favourable investment framework.

Therefore the exemptions offered to energy-intensive industries, together with the strong German influence on new European Commission directives concerning public support for environmental protection and energy, reflect the close ties between German industrial and energy policies, and their influence in the EU.

One good example of this influence of German industrial policy is the creation of the International Renewable Energy Agency (IRENA). In 2011, this institution, promoted by the United Nations and particularly the European Union, chose to locate its Innovation and Technology Centre (IITC) in the German city of Bonn, an important achievement by the German government. IRENA manages important funds for renewable energy in developing countries,[141] giving some idea of the importance that Germany gives to its industry and the prospects of exporting technology and knowledge to other countries.

[140] (Rutten, 2014)

[141] According to IRENA, in order to double the share of renewable energies, it will be necessary for the international community to invest $770 billion per year to 2030. This effort, according the agency, would result in fifteen-times greater economic savings, as it would mean cuts in expenditure related to atmospheric pollution and climate change, as well as job creation (DW, 2016).

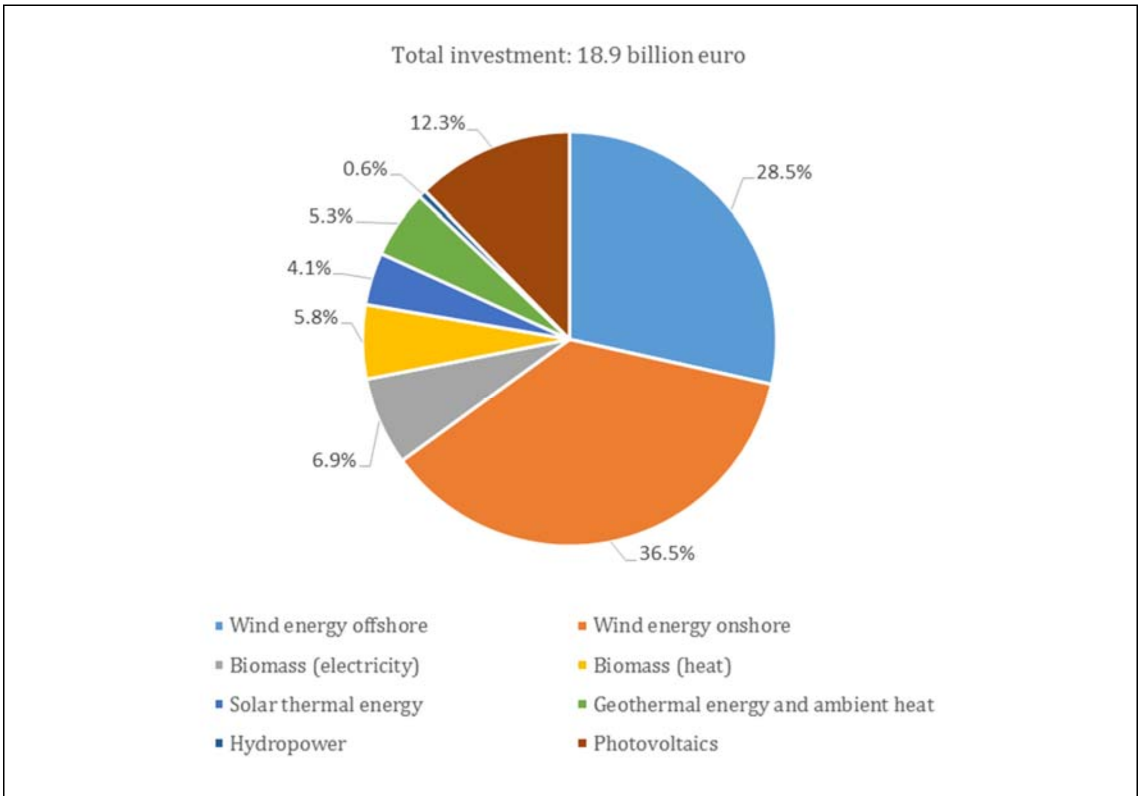
These links are not new; some parts of the German industrial sector already received preferential treatment when the country was facing previous energy transitions. Furthermore, in former periods of industrial development, the energy, coal and nuclear industries were a comprehensive part of the economic transformation.

10. THE RENEWABLES-RELATED INDUSTRY

Before going on to analyse Germany's business structure in the renewable energy sector, it is important to underline the strong investment made in the country to date in this kind of energy. As can be seen in the graph below, of the main EU countries, Germany is the one that has invested most[142] in solar photovoltaics and onshore and offshore wind energy (2014 figures).

Indeed, as the graph below shows, in 2014, it invested[143] €18.9 billion in building renewable energy plants or installations.

GRAPH 55. Investment in the building of renewable energy plants in 2014 in Germany (€bn)[144]



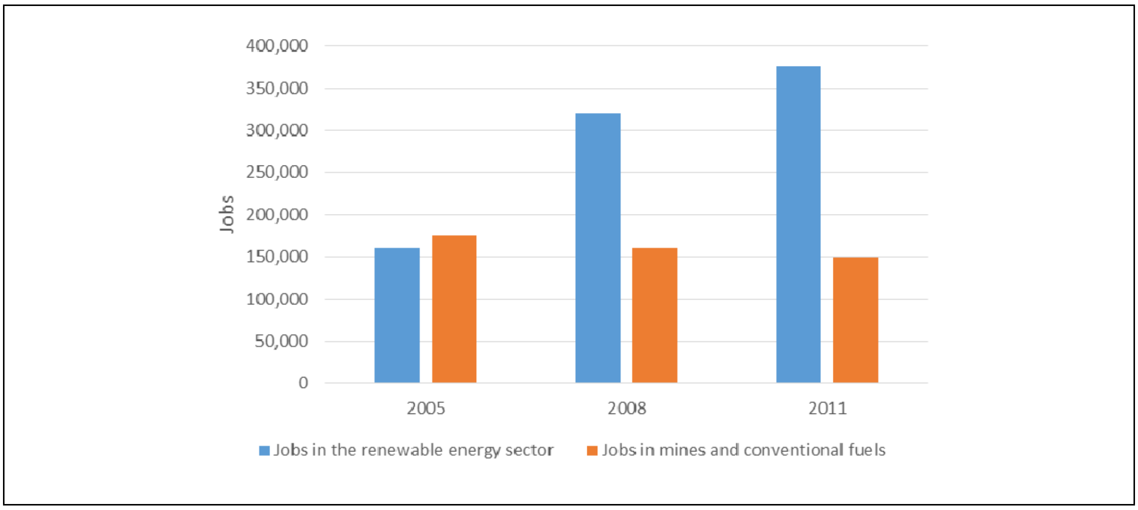
Source: (BMWi, 2015a)

With these investments, Germany has managed to increase its installed capacity[145] by nearly 60%, as discussed in Chapter 4.

Furthermore, as mentioned at the beginning of this document, the renewable energy sector had nearly 400,000 employees[146] at the end of 2014, with a major increase in employment since 2005, as the graph below shows.

[142] (Watts Up With That?, 2015)
[143] The economic figures used throughout this document should be taken as illustrative, given the shortage of official data on investment.
[144] Throughout this document, a billion (abbreviated as bn) is taken to mean 10^9 (1,000,000,000).
[145] (Rutten, 2014) (BMWi, 2015a)
[146] (DENA, 2014)

GRAPH 56. Jobs in Germany in energy sectors



Source: elaborated from BMU and BMWI in (Morris & Pehnt, 2012)

10.1. Wind energy

Wind energy plays a fundamental role in the transition of the energy system, as we have seen in Chapters 4 and 5.

In 2014, Germany had installed wind capacity of 36.5 GW,[147] making it the country with the highest installed wind capacity in Europe and putting it in third place worldwide, just behind China and the US (REVE, 2014a). In 2015 the figure reached 39.2 GW, with the country retaining its position in Europe and worldwide (Agentur für Erneuerbare Energien e.V., 2015).

The German Wind Energy Association (BWE) estimates that the industry currently exports between 65 and 70% of all components produced.

We will now examine the value chain and the main German wind-energy firms.

Value chain

The wind energy value chain[148] can be described as follows: a) companies that are installers or promoters of projects and installations for third partners[149]; b) manufacture of rotor blades, where the wind energy is converted into a rotating movement; c) manufacture of the shaft, responsible for transmitting the rotating movement; d) manufacture of the gear casing or multipliers, responsible for changing the spin frequency to another, lower or greater, depending on circumstances, in order to give the generator the right strength to work; e) manufacture of the generator, where the mechanical movement of the rotor is transformed into electrical energy; f) manufacture of other basic components that are required for proper and efficient functioning of the wind turbine, in accordance with the quality of the electricity service; g) manufacture of the electronic controller,

[147] Between 2013 and 2014, Germany increased its capacity by 1.8 GW (REVE, 2014a).
[148] (Gorozarri Jiménez, 2012)
[149] These include companies of very varying size and characteristics.

which allows the rotor blades to be oriented properly. It also halts the rotor in the event of any contingency such as excess wind speed or overheating of the wind turbine; h) manufacture of the refrigeration unit, responsible for keeping the generator within suitable temperature limits; i) manufacture of the anemometer and weather-vane, in order to calculate the wind speed and direction respectively; j) manufacture and assembly of the engine casing; k) manufacture of the tower; l) manufacture of the converter, for transforming the wind into electricity; m) foundation of the generator[150]; n) distribution and wholesale sale of equipment; o) importers of other kind of components.

The main German wind energy companies identified at the end of this section all have a very integrated manufacture process and perform almost all the tasks in the wind turbine value chain (design, rotor, blades, engine casing, tower, etc.) through other companies in the industry. They therefore cannot be classified according to the different processes in the value chain since they participate in most of them. As we can see in the next subsection, this is not the case in the photovoltaic energy sector.

Below, we list some German companies classified by elements or "position" in the value chain of the German wind power industry. As can be seen, the "elements" identified do not always coincide with the list of phases given above.

[150] In the case of offshore wind energy, the generator is moored using a base known as a "jacket", a lattice-like structure secured to the seabed (Losada, 2010).

TABLE 24. German companies in the wind energy value chain

VALUE CHAIN	COMPANY
Design development	EcofinConcept GmbH
	Energy GmbH
	GEO-NET Umweltconsulting GmbH
Rotor and blades	BayWa r.e. renewable energy
	Baju energy GmbH
	LTB Hochsauerland GmbH
Tower	cp. max Rotortechnik GmbH & Co. KG
	Hailo Wind Systems GmbH & Co. KG
	RENERTEC GmbH
	RoSch Industrieservice GmbH
Engine casing	AVANTIS Energy Group
	FWT energy GmbH & Co. KG
	Kenersys GmbH
	Vensys Energy AG
Converter and components	Availon GmbH
	psm GmbH & Co. KG
Foundation	Rotor Control GmbH
	Schütz GmbH & Co. KGaA
Connection	ZOPF Energieanlagen GmbH
Control, remote control and maintenance	ABO Wind AG
	Availon GmbH
	C&D Ölservice GmbH
	Deutsche Windtechnik AG
	Dirk Hansen Elektro- & Windtechnik GmbH
	EEG Service & Technik GmbH
	ENERTRAG Service GmbH
	Juwi AG
	MMM-Windtechnik GmbH
	N.T.E.S. GmbH WINDKRAFTSERVICE
	UTW-Dienstleistungs GmbH

Source: Own elaboration.

German manufacturers have extensive experience in all the different types of application mentioned above. This includes, for example, the manufacture and assembly of turnkey wind installations, as well as the production of individual components and devices, such as generators, gears and rotor blades, and also their spare parts (DENA, 2015).

Apart from manufacturers specializing in wind energy installations, many medium-sized traditional machinery constructors have created new business areas in the German wind industry. Tubular steel towers, concrete foundation and cast pieces are all required for building wind-energy installations, as well as location studies, authorisations and type tests. All the value creation is designed in Germany: from planning and project development to construction and operation of the facility.

In the case of offshore wind energy, German companies have extensive experience in the installation process, as well as the service, maintenance and occupational safety areas. One feature distinguishing Germany from other countries with a significant offshore capacity is that German offshore wind farms are installed at a large distance from the coast and at great depth.

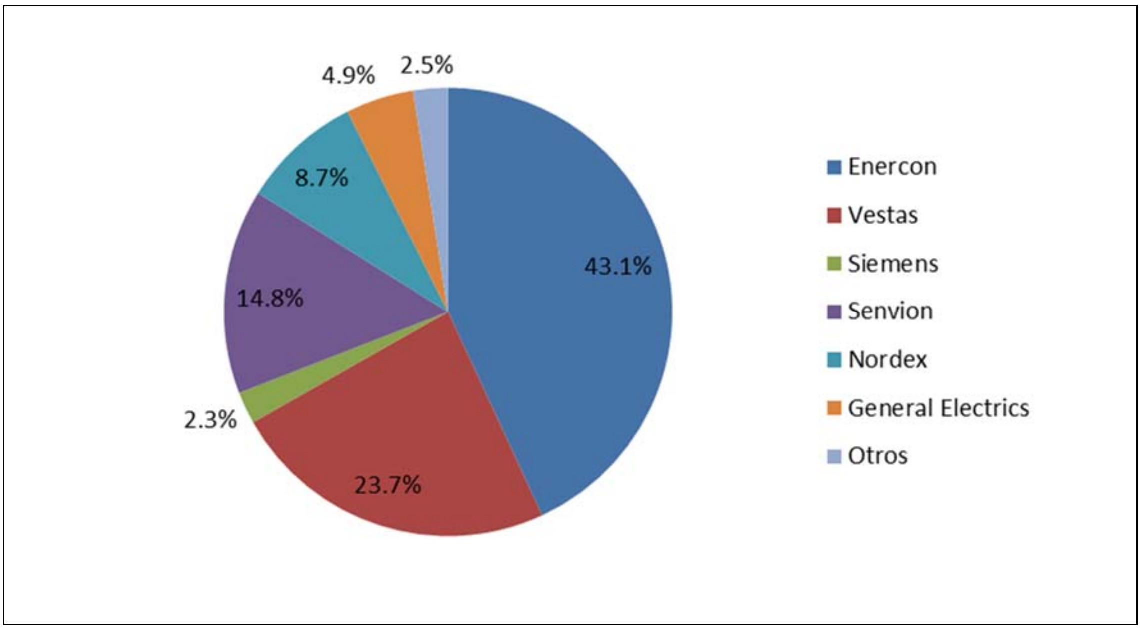
German manufacturers of small wind turbines have achieved growing production professionalization in recent years. Many types of facility built by German manufacturers –mainly in the range from 1 to 20 kWm– have gained an excellent position on the small wind turbines market (DENA, 2015).

It is important to note that the different processes in the wind energy value chain have a significant impact on the final price. For example, investment costs, including auxiliary expenses for foundations, grid connection, etc., have a 30% margin, so the final product price varies considerably (Gorozarri Jiménez, 2012).

Main German wind energy companies

German wind energy has created an *ad hoc* industry. Four German companies (Enercon, Senvion, Nordex and Siemens) control 68.9% of the German market, while Siemens has an almost 10% share of the global wind turbine market[151] and Enercon 7.8%.

GRAPH 57. Market share for wind energy in Germany (%)



Source: Own elaboration from (ENERCON, 2015)

The following table offers key information of interest on German wind energy companies.

[151] (ENERCON, 2015)

TABLE 25. Main German wind energy companies

Company name	Activity	Place (Germany)	Data
ENERCON	Manufacture, sale, installation and maintenance of wind turbines	Aurich	16,000 employees €4 bn turnover 32.9 GW installed / 22,000 wind turbines
Nordex SE	Manufacture of wind turbines	Hamburg	2500 employees €1.8 bn turnover 10.7 GW installed
Senvion SE	Manufacture of wind turbines	Hamburg	3500 employees €1.93 billion turnover 6.15 GW installed
Siemens AG	Manufacture of wind turbines Sectors: industrial, energy health, infrastructure, electrical appliances, etc.	Berlin, Munich and Erlangen	359.000 employees €71.92 billion turnover 23 GW installed

Source: Own elaboration

10.2. Solar photovoltaics

Germany is the world leader in solar energy, with 38.2 GW of installed capacity (2015 figures), ahead of China (28.2 GW) and Japan (23.3 GW) (Martíl, 2015).

The German Solar Association (BSW or *Bundesnetzagentur*) estimates that exports accounted for 60% of production by the German photovoltaic industry in 2012 (as compared to 14% in 2004) and the target is to reach 80% by 2020.

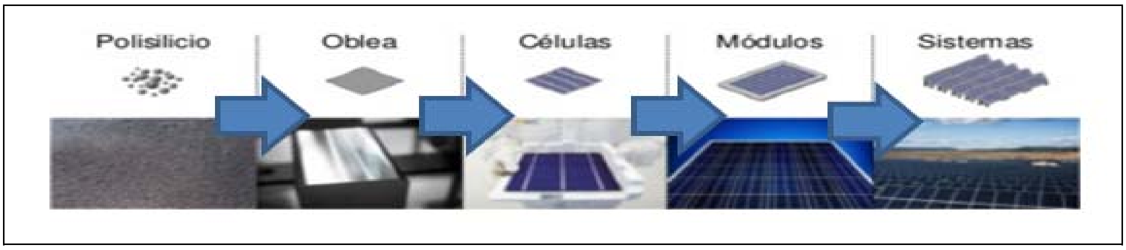
In the next section, we shall examine the value chain, followed by the principal German companies in the photovoltaic industry.

Value chain

The solar energy value chain[152] can be described as follows: a) transformation and production of raw material: extraction and transformation of silica sand; b) fitters or developers promoting third-party projects and installations[153]; c) production of wafers and ingots of solar grade polysilicon; d) manufacture of photovoltaic cells; e) manufacture of modules. Cells can be assembled in modules or manufactured directly; f) manufacture of other components such as cables, solar inverters, accumulators; g) distribution and wholesale marketing; h) imports of other products.

[152] (Gorozarri Jiménez, 2012)
[153] The companies vary greatly in size and characteristics.

FIGURE 22. Value chain of the solar photovoltaic sector



Source: Own elaboration from (Serrano, 2012)

The list below shows some of the German companies, classified according to the production process they perform in the value chain of the photovoltaic solar sector in Germany. Once again, it is worth noting that the classification in the table perfectly matches the breakdown given above.

TABLE 26. German companies in the value chain of the photovoltaic solar energy

VALUE CHAIN	COMPANY
Project development	IBC SOLAR AG
Silicon	Schmid Silicon Technology GmbH
	SolarWorld AG
Wafers	Mola Solaire Produktions GmbH
Cells	SCHOTT Solar AG
	Solland Solar Cells GmbH
	Systaic AG
Modules	Aleo solar AG
	AlfaSolar Vertriebsgesellschaft GmbH
	ALGATEC Solarwerke Brandenburg GmbH
	Arinna Energy GmbH
	asola Technnologies GmbH
	Centrosolar Group AG
	Heckert Solar GmbH
	Solar-Fabrik AG
	Solarnova Deutschland GmbH
	SOLARWATT AG
	Sunovation GmbH
	SunWare Solartechnik Produktions GmbH & Co. KG
	Webasto Solar GmbH
	Wulfmeier Solar GmbH
Total integration (wafers, cells and modules)	Bosch Solar Energy Services
	Conergy GmbH
	Renusol GmbH
	SolarWorld AG
Concentration photovoltaics (CPV)	Concentrix Solar GmbH
	Ritter Energie- und Umwelttechnik GmbH & Co. KG
	SolarTec International AG
Thin sheet solar cells	ANTEC Solar GmbH
	Avancis GmbH
	AZUR SPACE Solar Power GmbH
	Centrosolar Group AG
	CIS Solartechnik GmbH & Co. KG
	CTS Tandem Solar GmbH
	Masdar PV GmbH
	PVflex Solar GmbH Hersteller von Solarzellen und Solarmodulen
	Solarion AG
Photovoltaic technology and services (power inverters, batteries, etc.)	Deutsche Energieversorgung GmbH
	FENECON GmbH & Co. KG
	Grammer Solar GmbH
	Heliatek GmbH
	HelioSolar GmbH
	KOSTAL Solar Electric GmbH
	SMA Solar Technology AG
	Solarzentrum Allgäu e.K GmbH & Co. KG

Source: Own elaboration from (Pingarrón, 2011)

Crystalline and thin sheet panels and high efficiency inverters are together considered to be the flagship of the German photovoltaic industry. Facilities for producing silicon, wafers and cells also meet the strictest requirements and their products are available worldwide. German producers of software and measuring techniques, panel suppliers, system integrators, project designers and developers, providers of operating and maintenance services, as well as research institutes optimally extend the photovoltaic technology value chain (DENA, 2015).

According to DENA, 2015, German companies in the photovoltaic sector operate worldwide at different points in the value chain and enjoy an excellent reputation due to their extensive experience, extraordinary service and high quality standards. The German PV sector exported about 65% of output in 2013. At the end of 2013, the industry had about 60,000 full-time employees in about 5,000 companies, of which 2000 were manufacturers of cells, panels and other photovoltaic components with demanding quality standards.

German companies are world leaders in the development and research of new photovoltaic technologies. At the same time, German research institutes are introducing internationally-accepted quality standards. Solar panel factories throughout the world use equipment and machines designed and manufactured by German companies. The industry offers advanced solutions in systematic integration of photovoltaics in power grids for the most diverse energy sources.

Main German photovoltaic energy companies

The table below shows the leading companies operating in the German photovoltaic energy industry.

TABLE 27. Main German photovoltaic energy companies (Part 1.)

COMPANY NAME	ACTIVITY	PLACE (GERMANY)	WORKFORCE /DATA
Avancis GmbH	Production of solar modules with CIS / CIGS photovoltaic technology (with an ultra-thin layer just 2 microns thick)	Torgau	500 employees 120 MW /year Produces more than 800,000 modules of solar thin sheet cells (CIS) per year
Deutsche Energieversorgung GmbH	Design and implementation of photovoltaic systems, installation, maintenance and operation of energy plants	Leipzig	35 employees €12m turnover
FENECON GmbH & Co. KG	Manufacture of energy storage systems, working in close partnership with the BYD technology group	Deggendorf	30 employees
IBC SOLAR AG	Promotion of photovoltaic projects	Bad Staffelstein	400 employees €600m turnover More than 2.2 GW and 150,000 photovoltaic installations worldwide
KOSTAL Solar Electric GmbH	Manufacture of components, installation, storage technology and photovoltaic inverters	Breisgau	15,083 employees worldwide. Total installations 30,179 Output from its modules: 640,17 GWh

Source: Own elaboration.

TABLE 28. Main German photovoltaic energy companies (Part 2.)

COMPANY NAME	ACTIVITY	PLACE (GERMANY)	WORKFORCE /DATA
Renusol GmbH	Produces and markets assembly systems for photovoltaic panels	Köln	90 employees More than 2.4 million photovoltaic modules installed in Europe
Ritter Energie- und Umwelttechnik GmbH & Co KG	Develops, produces and distributes photovoltaic and ecological energy systems	Dettenhausen	1,600 employees $150m turnover
SMA Solar Technology AG	Manufacturer of inverters for photovoltaic energy	Niestetal	6,500 employees €1.7 bn turnover Inverters for diverse range of installations: from 6 kW to 40 MW
Solarnova Deutschland GmbH	Manufacturer of solar panels	Wedel	35 employees

Source: Own elaboration.

TABLE 29. Main German photovoltaic energy companies (Part 3.)

SOLARWATT AG	Manufacture, marketing, distribution and sale of solar panels and all kinds of components for alternative energies, as well installation, maintenance and reparation	Dresden	500 employees €350m turnover 300 MW/year production capacity
SolarWorld AG	Manufacture and marketing of photovoltaic products, integration of the different components of the solar value chain, from raw material (polysilicon) to production module and from marketing solar panels to promotion and key construction in solar energy systems.	Bonn	3200 employees €700m turnover

Note 1: BYD is a high technology Chinese company specialising in automobile and renewable energy. In 2015 it had 187,000 employees, an annual turnover of about 9.2 billion dollars. It is a leader in the market of lithium-ion batteries with a capacity of 10 GWh, creator of the world largest energy storage plant.

Note 2: SMA Solar Technology AG is the world's largest manufacturer of inverters for solar energy. In 2010 and 2011 it was awarded the *Energy Efficiency Award* by the German Energy Agency for its carbon neutral production.

Source: Own elaboration.

Note that unlike the wind industry, in the photovoltaic sector, German companies are not among the world leaders. The world's ten largest manufacturers of photovoltaic modules in 2014 (in descending order of market share) were: Trina Solar (China), Yingli Green (China), Canadian Solar (Canada), Hanwha SolarOne- Q-Cells (South Korea), Jinko Solar (China), JA Solar (China), Sharp (Japan), ReneSolar (China), First Solar (USA) and Kyocera (Japan) (Tsanova, 2015).

As can be seen, China tops the ranking of industry leaders. Indeed, as we shall see below, the entry of Chinese companies into the sector has had a tremendous impact on German industry. The low prices offered by Chinese firms have been gaining them market share at the expense of German firms. Many German companies have been bought out or taken over by Asian companies and others have gone bankrupt. One of the main companies in the country's photovoltaic industry, Q-Cells, was purchased in 2012 by South Korean firm Hanwha after being declared insolvent. Other examples include REC Wafer (bankrupt), SOLON AG (purchased by Microsol from India) and Soltecture Solartechnik GmbH, previously Sulfurcell Solartechnik GmbH (bankrupt).

10.3. Biomass and biogas

In the area of energy production from solid biomass, wood is the most commonly used raw material in Germany.

More than half of the energy generated from wood is obtained using domestic boilers. Forty percent of this is in the form of firewood and the rest as sawdust, waste and shavings, although the use of wood pellets has risen significantly. In order to meet *Energiewende* targets, in which biomass plays also an important role, the German government has been subsiding the purchase of biomass boilers.

Value chain

The value chain for biomass[154] can be described as follows: a) transformation and production of the raw material for conversion into energy; b) production of energy; c) manufacture of steam boilers; d) manufacture of auxiliary devices for boilers; e) manufacture of steam turbines and fixed, variable and adjustable electric condensers; f) wholesale distribution and marketing; g) fitters and companies promoting installation for third partners. These come in many different sizes and characteristics; h) importers of other types of product.

According to DENA (2015), thanks to continued development, German technology harnessing solid biomass for energy purposes is characterized by a high level of reliability and by offering optimum solutions for customers' needs. As a result, German companies have highly efficient technologies and are world leaders in all forms of power. Modern heaters are supplied for heating individual rooms or for producing hot water, small combustion installations for supplying heat to single family homes or buildings, and biomass boilers that provide an efficient heat supply to multiple consumers and industrial processes. Modern fireplaces by German manufacturers are notable for their efficient low-carbon technology.

The strengths of German suppliers of small combustion boilers include sophisticated technologies for user-friendly control and regulation, such as interconnection with smart phones, and development of convenient automatic supply systems. This achieves relatively high performance, while considerably reducing emissions.

Biomass-fired CHP (combined heat and power) facilities, developed in Germany, stand at the vanguard of global technology. German providers offer state-of-the-art installations in a power range from 10 kW, with international experience, as they have about 500 installations operating worldwide.

In recent years, German companies have contributed to readying wood gasification technology[155] for commercialization. The German biogas industry is a pioneer in the generation and recovery of this fuel. Germany is simultaneously the market and

[154] (Gorozarri Jiménez, 2012)
[155] Wood gas synthesis into second generation biofuel is being tested at an experimental plant in Karlsruhe (Germany).

technology leader, and has acquired important expertise, mostly in the field of gasification from organic waste and renewable resources. German companies are even leading the way in the growing biogas supply market, and have positioned themselves at the different stages in the biomethane production chain with effective technologies (DENA, 2015).

German companies in the biogas industry cover the entire value chain, from design and financing to operation and maintenance of biogas plants, as well as supply of biogas to the natural gas network. They also have extensive experience in biology oriented towards the process and the corresponding laboratory services. Advanced biological products are also available in the field of cogeneration plants, in installations with fuel and storage tanks, as well as in biogas analysis technology.

In 2013, German companies exported about 45% of output, and more than half of all energy produced from biogas in Europe is of German origin. At the end of 2012, this figure was 12 Mtoe.

At the end of 2013, about 7,700 biogas plants were operating in Germany with a total installed capacity of approximately 3.5 GW. These plants produced about 24,000 GWh of power and supplied approximately 6.8 million households. In May 2011, the German gas distribution network was supplied by 151 biomethane plants (DENA, 2015).

Main German biomass companies

The table below shows the main German biomass companies, with the same structure as previous sections in this chapter.

TABLE 30. Main German biomass companies (Part 1.)

COMPANY NAME	ACTIVITY	PLACE (GERMANY)	WORKFORCE /DATA
AgriKomp	Biogas plants Supplier of comprehensive solutions	Merkendorf	More than 400 employees €50m turnover More than 600 plants in Europe between 30 kW and 2 MW
AVANCTECH	Supplier for biogas plants Wholesalers in the field of photovoltaic energy, wind energy, bioenergy and electric transport	Barssel	50 employees
HPC BIOSYSTEMS GmbH & Co. KG	Field of renewable raw materials – farming, commerce and recycling. Bio-refineries	Berlin	
HR Energiemanagement (Germanpowergenerators)	Advice, planning of development, production and sale of cogeneration plants of biomass, systems for energy management	Bünde	10 employees $10m

Source: Own elaboration

TABLE 31. Main German biomass companies (Part 2.)

IE-S GmbH Integrated Energy Systems	It focuses on the re-utilization of waste flows, which can be transformed into renewable energy (natural gas or biomass)	Leipzig	104,944 employees €71.02 bn turnover Biomass gasification plant of 2.5 MW
PlanET Biogastechnik GmbH	Construction and service of biogas plants	Vreden	More than 250 employees €100m sales Installed 141,145 kW (75 kW plants) with 360 biogas plants worldwide

Source: Own elaboration

10.4. Some considerations on the impact of the *Energiewende*

We have analysed and listed the main German companies[156] operating in in each of the former sub-industries for the main renewable energies. As we can see, there are many local companies which, *a priori* are benefitting from the *Energiewende*, thus achieving one of the secondary objectives of the programme, to benefit the local economy.

However, it is also important to note that it is impossible to cover the entire German renewable market or consider the whole country only with German companies, although to judge from the tables quoted, it might be assumed that these companies would be responsible for most of the country's energy transition, increasing their turnover to support the increase in consumption of renewables required.[157] Other powerful multinationals in the industry will also benefit, such as the Danish Vestas in wind energy, or the American First Solar in photovoltaic energy, both of which have a large market share in Germany in these industries.

The real economic benefit of Germany's energy transition will therefore not only be for German companies, favouring the local economy as initially intended.[158] Nonetheless, as previously discussed, exports from the wind and solar industries make up a large share of the country's total exports.

[156] For more information on companies in the renewable energy industry, see Appendix 13.6, which shows that, as well as the large manufacturers with renewable technology, current synergies mean that there are also many other smaller firms involved in value chains in a number of technologies.
[157] As indicated, estimates are for an increase in the share of renewables of 38% by 2020, 50% by 2030, 67% by 2040 and 80% by 2050, and in final energy consumption by 18% by 2020, 30% by 2030 and 60% by 2050.
[158] (Morris & Pehnt, 2012)

V. REFLECTIONS AND FINAL CONSIDERATIONS

11. THREE PRELIMINARY CONSIDERATIONS AND SEVEN TOPICS

Given the complexity of the issue dealt with in this study and the extent of the topics addressed in it, the following is meant more as a reflection and some final considerations than a summary or a set of systematic conclusions on the various topics discussed.

The German energy transition has many different aspects. Here we deal with the perspectives of policy, regulation, energy structure and power generation, development of the proposed objectives, costs, investments and competitiveness and industry. These are the seven topics basically analysed in this study, which will be discussed, in the form of reflections, below.

11.1. Three preliminary considerations

In this section, we will identify various ideas as a personal summary and result of the study conducted.

Firstly, although it is evident that the *Energiewende* is the result of policy, regulation, economy and history, there is a fundamental contradiction between its goals and its tools.

The main objective appears to be to reduce greenhouse gas emissions and for this purpose the tools available are those offered by energy efficiency and low-carbon energies (renewables and nuclear). However, what might be considered tools are actually seen as objectives, and some technologies with limited or zero carbon emissions are not taken into account, because they are not politically acceptable, namely nuclear energy.

The second is the difference between the periods "required" for the different targets and the differential effort required depending on the type of target. Thus, the targets are generally set for 2050, a horizon that seems reasonable for the ambitions of the goals pursued. Nonetheless, other targets have much shorter periods (such as the accelerated nuclear closure programme approved in 2010).

Our third consideration relates to the total costs of developing renewables, nuclear closure and dismantling and investment in new coal plants. These all require large-scale funding and the costs and benefits are not normally grouped together. This is made more complicated by the differences between the types of costs, benefits and their economic valuations, and between the periods in which each of them are generated and achieved.

These costs are clearly damaging to industrial competitiveness, as a consequence of the need to increase the sale price of electricity to enable the companies to afford such an outlay. In this framework, the large power-consuming companies, for the moment, enjoy exemptions on the renewables payment, although this means that a large part of German industry, consisting of small and medium enterprises, is bearing a major burden, together with domestic consumers. At the same time, this kind of consumption increases the number of consumers at risk of energy poverty.

11.2. Seven topics

Policy

The *Energiewende* is a very ambitious programme. On the one hand, it needs to undertake a great diversity of changes related to energy while on the other, it needs time to accomplish the transformations pursued.

Although the *Energiewende* and a number of its key issues have recently been in the news, the real origins of the programme can be traced back to the seventies. Its development cannot be understood without reference to the Greens' electoral gains, achieving its first entry into a German government in 1985, in Hessen, and subsequently (in 1998 and 2002) joining in coalition governments.

This forms part of a political culture of coalition governments between Christian Democrats and Liberals, Socialists and Greens or Christian Democrats and Socialists. As a result, given the variety of issues addressed by the *Energiewende*, Germany's energy policy is an issue which, from the perspective of the state, has had a major impact on society in general, sparking strong divergences of opinion among German citizens.

In addition to the objectives of combatting climate change, driven by the development of renewable energy and greater energy efficiency, there is also the question of opposition to nuclear power, which probably reached a turning point following the Chernobyl accident and whose cost has not been highlighted in all its importance and severity. The nuclear issue has been the subject of long debate, with opposing opinions, actions and decisions over the last few decades. In 1974, for example, nuclear energy was supported as a reaction to the oil crisis. In 1986 it was decided to abandon nuclear within ten years, and there were two new plans, one in 2001 and other in 2011.

The objectives or "ambitions" involve not only transforming the energy and power mix. Another aim is to increase the weight of citizens and local communities, by giving them increasing decision-making capacity. In this context, distributed generation might be said to have become an "emblem" that seeks to showcase a certain way of life.

The *Energiewende* involves an energy transition that goes beyond simple targets on renewable energy penetration or the fight against climate change. It is a combined work (*Gemeinschaftwerke*) that requires the participation of a large number of social and economic agents.

Germany's geographical position in the centre of Europe, with a major land area in the European framework, sea access and ten borders with other countries, and its powerful infrastructure of oil and gas pipelines, refineries and power transmission, gives the country a privileged place, since it has interconnections and infrastructure for importing and exporting energy. All of these factors underline the strategic relevance of energy integration with neighbouring markets.

Despite the political changes, particularly with regard to nuclear energy, there appears to be social and ecological consensus on the need for energy transition, and to make any increase in power prices more affordable for the consumers by raising income levels, since industrial consumers are less affected thanks to the exemptions they enjoy.

However, the growing number of households in risk of energy poverty could in the future represent a limitation, or at least, an obstacle to the *Energiewende*; this could also be the case if the exemptions to feed-in tariffs are not maintained in energy-intensive industry and the industrial network of SMEs that are not eligible for exemptions and are supporting high energy prices.

Regulation

The political objectives have been translated into numerous and ever more ambitious instruments of legislation. The origins for this initiative go back to 1985, when it was possible to gain support from the federated states for the issue of renewable energy; this has been extended to include energy efficiency (in final use, industry and building), transport, and in financing programmes, incentives and subsidies.

At the same time, it is important to note the subsequent amendments to the regulations, in order to adapt it progressively to new objectives and take into account the results (with their successes and failures) of successive plans and regulations.

Energy mix

Gradual changes are taking place in the energy mix. Germany's energy situation shows the vast weight of oil in the country's energy mix (although it accounts for a smaller share than in Spain), and the continued importance of coal and gas, with fossil fuels making up 80% of primary energy.

It should be borne in mind that progress towards reduced dependency on oil is a complex task, given the current state of technology, incentives and effectiveness. The importance of coal must be seen in terms of its tradition and the fact that at present Germany is benefiting from a domestic resource, lignite, which allows the technology of the advanced plants to be combined with competitiveness.

Gas is a mainly imported resource, and there is an ambivalent attitude towards its use for power generation, despite the existence of an infrastructure for direct supply from Russia.

Power generation structure. Power mix

As mentioned, there have been successive changes since 1986 in the way the role of nuclear energy in the power mix has been viewed. Political and economic attitudes have varied and some commitments have not been respected. Finally the country has opted for accelerated dismantling, with important repercussions in terms of costs and a strong impact on traditional energy companies.

For its part, one can see a renaissance in coal and coal-related technologies, particularly in the case of lignite. Power production and historical analysis show that, despite a reduction in hard coal, the same is not true of lignite, which continues to play an important role in Germany's energy structure, albeit the share is falling, a role it will continue to hold in coming years despite discussions and political action to progressively reduce its use.

In wind energy, there has been a switch from investing in onshore power, which offers "near-competitive" prices, to offshore, which is more expensive and requires the development of an important transmission infrastructure.

In any case, progress has been made towards the deployment of renewable technologies and distributed generation, with major consequences for the strategy and balance sheets of power companies, together with nuclear dismantling.

Although this study does not analyse electricity markets (a relevant issue and the subject of future reform), we do need to consider Germany's role in the Central European context. As discussed with regard to the political field, the energy transition involves a need for greater regional cooperation, and interconnections will be an element of the infrastructure which, together with energy interchanges will gain greater importance. Debate is also required on the capacity mechanisms to support the development of renewables and for the security of supply.

Development of the objectives

One of the most explicit targets –and one on which most has been written– is the penetration of renewables in the power mix, an area in which success is more evident. Nevertheless, the percentages achieved to date are lower than in Spain, (which already had major levels of hydro power generation), 42.8% in Spain as compared to 26.2% in Germany in 2014.

Although there has been a significant reduction in CO_2 emissions, Germany is not on track to meet its targets for 2020. Emission reductions in absolute terms must be seen in the context of a country like Germany with a high volume of emissions, which is an economic, industrial and energy power in the centre of Europe.

In any case, there appears to be progress toward greater energy efficiency, which will lead to a reduction or stabilisation of energy needs.

Nevertheless, difficulties are being encountered in achieving the plans on penetration of renewables in final energy and changes in transport and building efficiency.

Investments, costs and competitiveness

Of all the implications and difficulties of the *Energiewende*, perhaps the most important is related to the economy, as major investments for the development of renewables have an impact on the final consumer and the competitiveness of the industry, due to an increase in final prices. Furthermore, this process also involves expenditure on investments in power transport and distribution, nuclear closure and dismantling, and the development of new coal plants with high specific costs.

However, once again, Germany's importance in Europe means that exemptions for energy-intensive industry find a place in the EU context and directly facilitate industrial competitiveness.

Another difficulty –and it is not a minor one– is the increase in total cost resulting from new developments in renewables, for example new offshore wind, and the need for a transmission infrastructure from northern coastal areas to the south (including not only expansion of the transmission grid, but also investment in the medium-voltage and distribution grids). Moreover, development of these transmission infrastructures will meet with a certain degree of social opposition.

Although for the moment, there is political consensus in support of a continuous increase in electricity prices for domestic consumers, there are two consequences. On the one hand, there seems to be a clear weakening in social support and, on the other, an increasing proportion of the population is now slipping below the energy poverty line. However, it should be noted that the *Energiewende*-introduced surcharge for supporting renewables has barely increased in the last two years and neither has the price of electricity, while at the same time there has been a fall in the price of wholesale electricity, which now stands at very low levels.

Industry

Germany has had a very strong industrial policy and its industrial base in the coal and steel sectors has evolved toward establishing policies that are consistent with new energy sectors (first nuclear and more recently renewable) and after that to find ways of making them more transversal, though nonetheless active and integrating.

Renewable-energy-related industry has seen undisputed successes in wind energy, with companies such as Enercon, Siemens, Nordex and Senvion not only achieving a major market share in Germany (nearly 70%) but also on the global market, where some of them now have a share of between 8% and 10%.

In the development of biomass and biogas, Germany is creating a powerful base of capital goods and engineering; albeit the type of market and volume means that the quantities involved are not as great as in the case of wind energy.

In the field of photovoltaics, a number of issues need to be clarified, and the performance of the sector can be defined as ambivalent. Whilst China and Japan lead the global market in photovoltaic modules (Chinese competition has seriously harmed German industry), when it comes to manufacturing and marketing of photovoltaic products and integration of diverse components in the value chain, there are numerous companies in Germany catering for the domestic market that have exporting capacity.

In the industrial context the relationship between industrial policy and export of renewable energy technologies is important. This is the case of the IRENA (International Renewable Energy Agency), which was promoted by the United Nations, although particularly by the EU and Germany. Germany managed to have the agency's technological centre, which handles important funds for renewable energies in developing countries, located in Bonn.

All of these points provide some idea of the importance Germany gives to its industry and the prospects of exporting its technology and expertise.

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13. APPENDIXES

13.1. APPENDIX 1: Abbreviations and acronyms

ACEEE	American Council for an Energy-Efficient Economy
bcm	Billion cubic metres
BDEW	German Association of Energy and Water Industries (*Der Bundesverband der Energie und Wasserwirtschaft e. V.*)
BEE	German Renewable Energy Federation (*Bundesverband Erneuerbare Energie e.V.*)
BMBF	Federal Ministry for Education and Research (*Bundesministeriums für Bildung und Forschung)*
BMEL	Federal Ministry of Food and Agriculture (*Bundesministerium für Ernährung und Landwirtschaft*)
BMUB	Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (*Bundesministreium für Umwelt, Naturschutz, Bau und Reaktorsicherheit*).
BMVBS	Federal Ministry for Transport, Building and Urban Development (*Bundesministerium für Verkehr, Bau und Stadtentwicklung*)
BMWi	Federal Ministry of Economic Affairs and Energy (*Bundesministerium für Wirtschaft und Energie*)
bn	Billion 10^9 (1,000,000,000)
BNetzA	German Federal Agency for the Power Grid (*Bundesnetzagentur*)
BSW	German Solar Association (*Bundesverband Solarwirtzchaft*)
BWE	German Wind Energy Association (*Bundesverband WindEnergie*)
BWR	Boiling water reactor
CCS	Carbon Capture and Storage
CCTS	Clean Coal Technologies
CDU	Christian Democratic Union
c	eurocent
CHP	Combined heat and power
CO_2	Carbon Dioxide
CO_2 eq.	Carbon Dioxide equivalent
COP21	Twenty-First Conference of the Parties

CPV	Concentrator Photovoltaics
CSU	Christian Social Union
DENA	German Energy Agency (*Deutsche Energie-Agentur GmbH*)
EC	European Commission
EEG	Renewable Energy Sources Act (*Erneuerbare-Energien-Gesetz*)
EER	Energy Efficiency Rating
EI	Energy intensity
EnEV	Energy Conservation Ordinance (*Energieeinsparverordnung*)
EP	European Parliament
EPS	Emission Performance Standards
ErP	Energy-related Products (Germany)
ETS	European Trade System
EU	European Union
EUA	ETS allowance unit (measured in euro per tonne of CO_2)
FDP	Free Democratic Party
FiT	*Feed-in Tariffs*
FTA	Free trade agreement
FV	Photovoltaics
GDR	German Democratic Republic
GHG	Greenhouse gases
GIZ	German International Cooperation Agency (*Deutsche Gesellschaft für Internationale Zusammenarbeit*)
GVA	Gross value added
GW	Gigawatt
GWh	Gigawatt-hour
ICSID	International Centre for Settlement of Investment Disputes
IEA	International Energy Agency
IITC	IRENA Innovation and Technology Centre
ILSR	Institute for Local Self-Reliance
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency

kb/d	Thousand barrels of oil per day
kW	Kilowatt
kWh	Kilowatt-hour
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
m	Million
MgC	Marginal Cost
Mt	Million tonnes
Mtoe	Million tonnes of oil equivalent
MW	Megawatt
MWh	Megawatt-hour
NABEG	Grid Expansion Acceleration Act (*Netzausbaubeschleunigungsgesetz*)
NAPE	National Action Plan on Energy Efficiency
NCRE	Non-Conventional Renewable Energy
OECD	Organisation for Economic Co-operation and Development
OJ	Official Journal of The European Union
OPEC	Organization of Petroleum Exporting Countries
OPV	Organic Photovoltaic
PJ	Petajoule
ppm	Parts per million
PPP	Purchasing power parity
PURPA	Public Utility Regulatory Policies Act (USA)
PV	Photovoltaic
PWR	Pressurized water reactor
RE	Renewable energy
ROI	Return on Investment
RRM	Renewable raw materials
SED	Socialist Unity Party
SMEs	Small and medium-sized enterprises
SPD	Social Democratic Party

StrEG	Electric Act for feed-in tariffs (*Stromeinspeisungsgesetz*)
t	tonne
TAZ	*Die Tageszeiturg* (German newspaper)
TFEU	Treaty on the Functioning of the European Union
toe	Tonnes of oil equivalent
TSO	Transmission System Operator
TWh	Terawatt-hours
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
USD	United States dollar
Wp	Watt-peak
WWF	World Wildlife Fund

13.2. APPENDIX 2: Basic information on Germany

It is difficult to overestimate the importance of the German economy in Europe. It has the highest GDP (Gross Domestic Product) in the European Union (EU) and the fourth highest in the world.

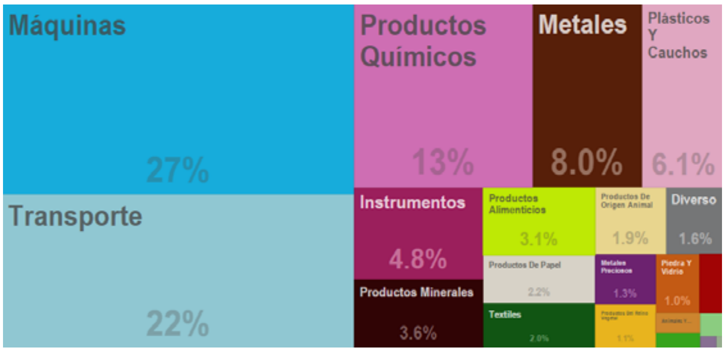
TABLE 32. Basic information on Germany (2014)

DATUM	GERMANY
Capital	Berlin
Flag	
Coat of Arms	
Government model	Parliamentary Federal Republic
Membership of international organizations	EU, UN, NATO, CBSS, OSCE, OECD, G8 and COE
Leaders	President: Joachim Gauck Federal Chancellor: Angela Merkel Vice-Chancellor: Sigmar Gabriel
Legislative institutions	Bundesrat Bundestag
Land area	357,168 square kilometres
Location	Northern Europe  Borders: Denmark (North) Netherlands, Belgium, Luxemburg and France (West) Switzerland and Austria (South) and Czech Republic and Poland (East)
Population (density)	79,800,000 inhabitants (223 inhab/ km^2)
HDI	0.911
Official language	German
Currency	Euro (€)
GDP	€2,915,650 million
Sectorial GDP	Agriculture: 0.9% Industry: 27.1% Services: 67.5 %
GDP per capita	€35,400
Inflation (CPI)	0.3 %
Central bank	Deutsche Bundesbank
Exports	€1,134 billion
Imports	€916.5 billion
Coverage rate (Exports/Imports)	123.7%
Trade balance	€217.5 billion

Source: Own elaboration

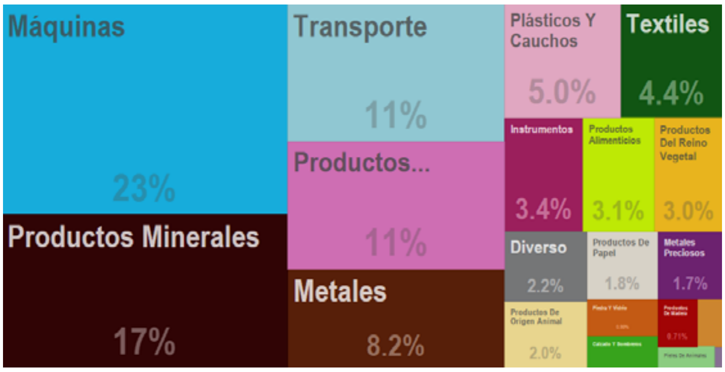
The manufacturing industry is an important part of the German economy, accounting for 30.5% of its GDP, a high figure when compared to other large economies. The German industrial sector focuses mainly on exports, which represented 7.7% of global exports in 2013, making the country the world's third-largest exporter. Internationally, German industry is known for production of automobiles, machines and chemical products, as well as electrical engineering. Many of the basic products used in the production cycles of these industries, such as aluminium, steel and glass, are produced in Germany, which boosts the entire German economy (Rutten, 2014).

FIGURE 23. German exports by type in 2013 (%)



Source: (Observatory of Economic Complexity, 2013)

FIGURE 24. German exports by type in 2013 (%)



Source: (Observatory of Economic Complexity, 2013)

FIGURE 25. Location of German states (*Länder*) and neighbouring countries

Source: (Dengler et al., 2012).

13.3. APPENDIX 3: The Greens

The following paragraphs provide more information on the German Green Party (Die Grünen), its policies, its electoral results, representation in the federated states and the main points of its most recent programme.

Policy

Driven by its thinking on ecologic policy, the Greens' ideology is also related to left-wing liberalism, pacifism and the fostering of a mixed and sustainable environmentally-friendly economy. The Greens also attracted a dissident sector of the Free Democrat Party (FDP), which was related to the civil rights movement and radical feminism. Their main political stance on a range of issues is discussed below.[159]

In energy and environmental policy, a basic tenet of the Greens' policy is sustainable development. This includes respect for the environment, the protection of natural resources and the promotion of renewable energies. As well as their environmental policy, since 2007 the Greens have also defended a climate policy that includes issues of socioeconomic and security policy. Hans-Josef Fell, who has been a member of the Greens since 1992 and a spokesman of the Alliance '90/The Greens in the *Bundestag,* has been one of the main promoters of the party's energy and environmental policy.

Sustainable development is also the main platform of the Greens' socioeconomic policy (related to the above issues). The aim is to meet current needs without harming the interests of future generations. One section of the party also defends the idea of an "unconditional basic income" in order to widen the existing social security system.

In the area of social policy, the Greens firmly defend individual and collective freedom and civil rights. Examples of this policy include integration of immigrants in a "multicultural society", recognition of same-sex marriage and gender equality. The Greens have a strict policy on quotas to ensure a gender balance in all their guilds; for this reason, they have two presidents (in 2015 Simone Peter and Cem Ozdemir).

As regards their stance on Europe, the Greens support both the deepening and extension of the European Union (EU). Among other issues, this includes support for Turkey's membership bid and for the Lisbon Treaty.

In educational matters, the Greens support the principle of comprehensive schools, in order to end the current education system in Germany with its segregation of pupils at different school levels. On university policy, the Greens reject university fees (banned in Germany until 2005), although in Hamburg, where they form part

[159] (Decker & Neu, 1980)(Bündnis 90 / Die Grünen, 2015)(Probst, 2007)(Gómez, 2011) (DW, 2011) (Nordsieck, 2013)

of the regional government, they have accepted a model in which students pay fees retrospectively if they find well-paid employment after completing their studies.

Electoral results

TABLE 33. Federal elections

ELECTORAL YEAR	NO. OF VOTES FOR THE GREENS	% OF VOTES	SEATS/TOTAL	VARIATION
1980	569,589	1.5	0 / 497	
1983	2,167,431	5.6	27 / 498	▲ 27
1987	3,126,256	8.3	42 / 497	▲ 15
1990	2,347,407	5.0	8 / 662	
German Unification	Results for Alliance'90/The Greens (East) and The Greens (West)			
1994	3,424,315	7.3	49 / 672	▲ 41
1998	3,301,624	6.7	47 / 669	▼ 2
2002	4,108,314	8.6	55 / 603	▲ 8
2005	3,838,326	8.1	51 / 614	▼ 4
2009	4,641,197	10.7	68 / 622	▲ 17
2013	3,690,314	8.4	63 / 630	▼ 5

Source: Own elaboration

TABLE 34. ELECTIONS TO THE EP

ELECTORAL YEAR	NO. OF VOTES FOR THE GREENS	% OF VOTES	SEATS/TOTAL	VARIATION
1979	893,683	3.2	0 / 81	
1984	2,025,972	8.2	7 / 81	▲ 7
1989	2,382,102	8.4	8 / 81	▲ 1
1994	3,563,268	10.1	12 / 99	▲ 4
1999	1,741,494	6.4	7 / 99	▼ 5
2004	3,078,276	11.9	13 / 99	▲ 6
2009	3,193,821	12.1	14 / 99	▲ 1
2014	3,138,201	10.7	11 / 96	▼ 3

Source: Own elaboration

Presence in federated states

The Greens govern with the SPD in Baden-Wurttemberg, and with the Social Democrats in Lower Saxony, Bremen, Hamburg, North Rhine-Westphalia, Rhineland-Palatinate and Schleswig-Holstein. In Thuringia, they govern in coalition with the SPD and *Die Linke* (The Left). In Hesse, they are partners of the CDU. They are in opposition in Bavaria, Berlin Brandenburg, Mecklenburg-Western Pomerania, Saxony, Saxony-Anhalt and Sarre.

FIGURE 26. Green representation in regional parliaments (2015)

Source: (Statistische Ämter des Bundes und der Länder, 2015)

Recent programme

These are the main points in the Greens' programme[160] for the 2013 elections, which sought to represent "all those who want to live in a modern, fair and sustainable society". In a brief and direct pamphlet-summary, the Greens asked voters: "What about you?". If they obtained enough votes, they promised to govern in coalition with the SPD. Here we describe their nine government projects: a) in energy, pursuit of a clean, secure and affordable "citizen-owned" supply, to be 100% met with renewable energy; b) minimum general wage of at least €8.50 per hour; c) more public kindergartens, instead of the current system of economic assistance for parents; d) abolition of the existing healthcare system, which they consider to be "class-based" and introduction of a universal healthcare system; e) control of financial markets and restrictions on bank indebtedness; f) adaptation of agriculture "to the needs of animals and the environment"; g) introduction of new quality-of-life wellbeing indicators, "because economic growth is not the only measure of what is important in life"; h) control of weapons exports; and e) "firm" fight against the extreme right.

[160] (DW, 2011) (Nordsieck, 2013) (Bündnis 90 / Die Grünen, 2015)

13.4. APPENDIX 4: Legal development of the *Energiewende*

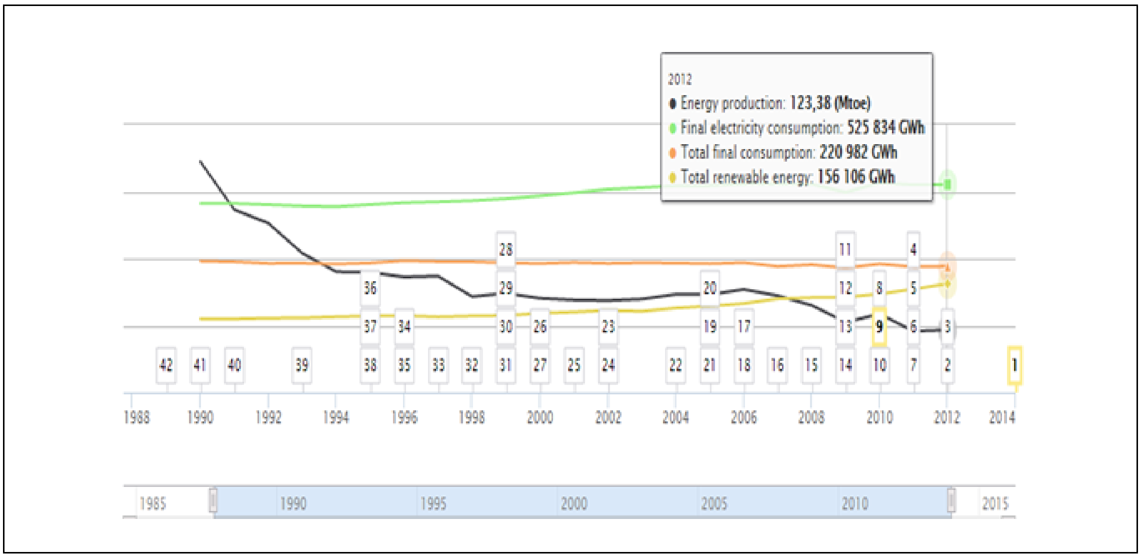
The table below gives a timeline of the main energy legislation enacted by the German government.

TABLE 35. German energy laws of the last 30 years

No. (Graph)	YEAR	NORMATIVE
1	2014	Amendment to the Renewable Energy Sources Act (EEG)
2	2012	Agreements on cogeneration with industry
3	2012	Amendment to the Renewable Energy Sources Act (EEG)
4	2011	Financing by the KfW bank for first offshore wind farm
5	2011	Monitoring process of "The Energy of the Future"
6	2011	Law on environment and climate and renewable energies and programme for progressive closure of nuclear plants (*Atomausstieg*)
7	2011	Sixth programme for research on energy
8	2010	National Action Plan on Energy
9	2010	Energy Concept Plan
10	2010	Law on biofuel share
11	2009	Amendment to the Renewable Energy Sources Act (EEG)
12	2009	Financing by the KfW bank for the renewable energy programme and the programme of energy efficiency and rehabilitation (*Energieeffizient Sanieren*)
13	2009	Renewable Energy Sources Act (EEG) for heat generation
14	2009	National Plan for Development of Electric Transport
15	2008	Raft of laws on climate change and the energy programme
16	2007	Programme for climate change and energy
17	2006	Klimazwei research programme
18	2006	Foundation of the solar energy development centre
19	2005	Energy Industry Act (*Energiewirtschaftsgesetz* or EnWG)
20	2005	Financing by the KfW for the solar energy production programme
21	2005	Fifth energy research programme
22	2004	Amendment to the Renewable Energy Sources Act (EEG) and the *Solarthermie* 2000Plus programme
23	2002	Law on Combined Heat and Power
24	2002	Modification of tariffs for installation of EEG renewables
25	2001	Investment in the "Future" programme
26	2000	Extra law for heating and electricity
27	2000	Renewable Energy Sources Act (EEG)
28	1999	Preferential loans programme offered by the reconstruction loans corporation (KfW bank)
29	1999	Reform of the Eco-Tax
30	1999	Programme for market incentives
31	1999	"100,000 Solar Roofs" programme
32	1998	Group on energy efficiency of the Baltic Sea
33	1997	Federal construction codes for production of renewable energy
34	1996	Fourth energy research programme
35	1996	"Green Energy" programme
36	1995	"100 million" programme
37	1995	Ecological Subsidy
38	1995	Ordinance on list of tariffs for architects and engineers
39	1993	Total cost rates
40	1991	Law on Electricity Uptake to the Grid (StrEG) or *Stromeinspeisungsgesetz*
41	1990	Programme for the environment and energy saving
42	1989	"250 MW of Wind Energy" programme
43	1985	Support to federated states for renewable energies

Source: Own elaboration from (IEA, 2015)

GRAPH 58. Timeline of German energy laws

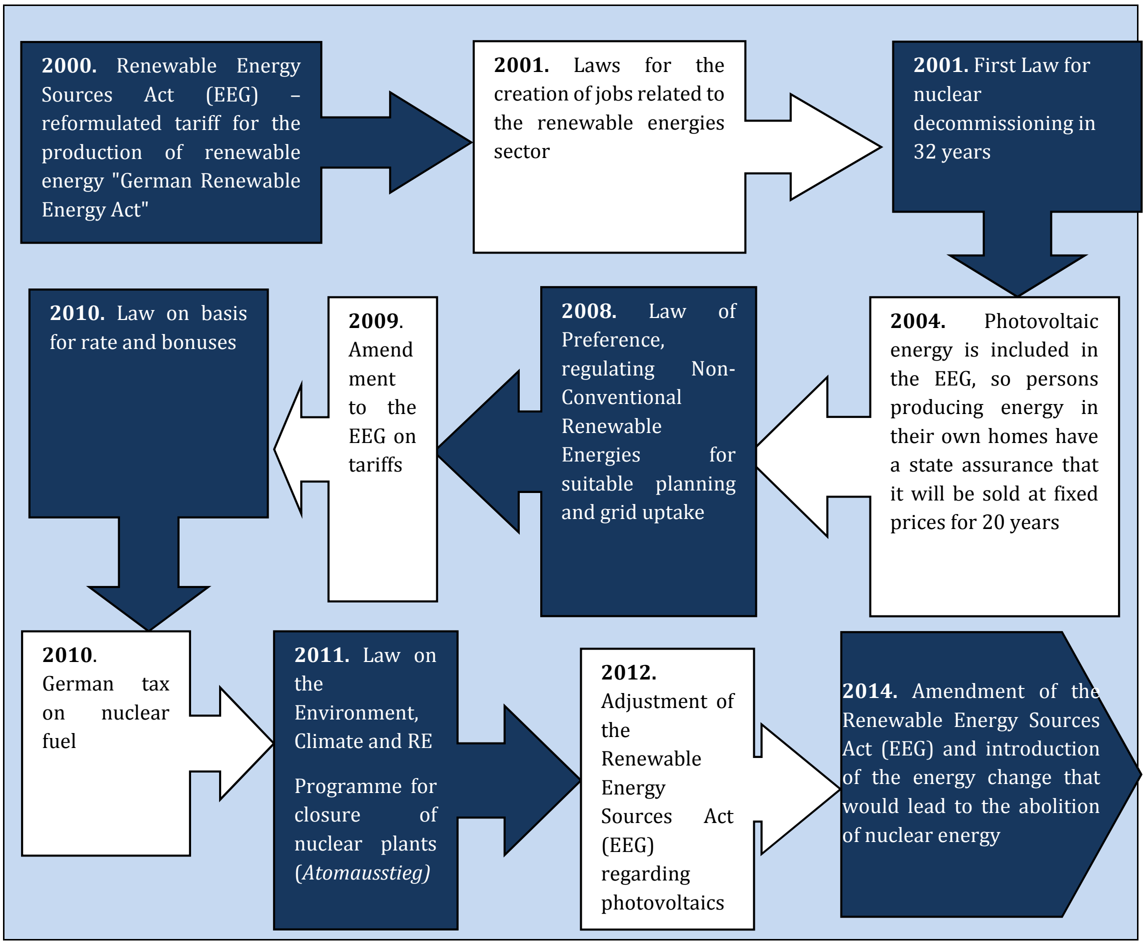


Source: (IEA, 2015)

As the graph above shows, some periods saw more intense legislative activity, particularly the years from 2009 to 2013, when more laws were promulgated.

The figure below summarises the main legislation on renewable energy.

IGURE 27. Timeline of main RE legislation in Germany



Source: Own elaboration

The table below summarises the progress of the legal framework of the *Energiewende* and the various landmarks reached.

TABLE 36. Relevant facts related to the *Energiewende*

YEAR	RELEVANT FACTS
1974	Federal Environmental Agency founded.
1977	As a result of the oil crisis, "thermal insulation" and "heating operation" ordinances are passed, governing maximum energy demand for buildings and efficiency requirements for heating systems.
1978	Blauer Engel (Blue Angel) label created in Germany certifying an absence of environmentally harmful products. The label was created by a coalition ranging from environmentalists to labour unions and church groups (14 years before the Energy Star label was created in the US by the US Environmental Protection Agency).
1980	Publication of a study entitled *Energiewende* showing that it is possible to maintain economic growth even if less energy is consumed.
1983	For the first time in history, the Green Party enters the German Parliament and gives voice to environmental concerns.
1985	*Länder* support for renewable energy.

1986	Nuclear accident at Chernobyl (Ukraine, former USSR). Five weeks later, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety is created.
1987	- German Chancellor Helmut Kohl (PDC) speaks of the "threat of serious climate change due to the greenhouse effect" in the German Parliament. -The Fraunhofer Institute builds Rappenecker Cottage, the first off-grid solar-powered mountain facility for hikers in Europe.
1989	The "250 MW Wind Energy" programme is introduced.
1990	- German Parliament (Bundestag) approves the first NCRE (non-conventional renewable energy) Development Act. -Environment and Energy Saving programme.
1991	-Adoption of the law on supply during the coalition government of Chancellor Helmut Kohl, the Conservative Party and the Libertarian Party PDC FDP. This law (known as the *Stromeinspeisungsgesetz* or StrEG) establishes feed-in tariffs (FiTs) and stipulates that green energy should take priority over conventional energy. -The "*Schönauer Stromrebellen*" (Power Rebellion of Schönau, a small town in the Black Forest) is a grassroots movement for buying from and recovering the local network.
1992	The Fraunhofer Institute for Solar Energy Systems builds an off-grid solar-powered house in Freiburg. The aim is to show that an average household can meet all its home energy needs using renewable energy.
1993	- Total cost rates.
1995	- "100 million." programme -Ecological Subsidy. -Ordinance on fee schedule for architects and engineers.
1996	-KfW, a publicly owned development bank, launches its Carbon Reduction Programme to support retrofitting of existing housing, particularly in the former German Democratic Republic. -Private Energy research programme. - "Green Energy" programme.
1997	-The Schönau Energy Rebels gain control of their local network and start to promote renewable energy. -Federal building codes for renewable energy production.
1998	-"Liberalisation" of the German energy market. Henceforth, power generating companies and network operators have to be legally separate entities and thus new energy suppliers may start operating selling only green electricity. Despite liberalization, no body is created in the country for another seven years. - Baltic energy efficiency group.
1999	-The "100,000 Solar Roofs" programme starts the solar market in Germany. It also launches the Market Incentive Programme, a scheme with a multimillion-dollar fund to financially support renewable heating systems. -Germany applies an "eco-tax" which annually increases the price per litre of petrol and kWh of electricity generated from fossil fuels. This results in increased car sales, more fuel efficiency and a reduction in overall consumption. -Programme of preferential loans offered by the reconstruction loan corporation (KfW). -Programme of market incentives.
2000	-The coalition government of Social Democrats and Greens, led by Chancellor Schroeder, launches the Renewable Energy Act (EEG) which replaces the Supply Act and specifies that the fees paid will be linked to the cost of the investment and not the retail price.

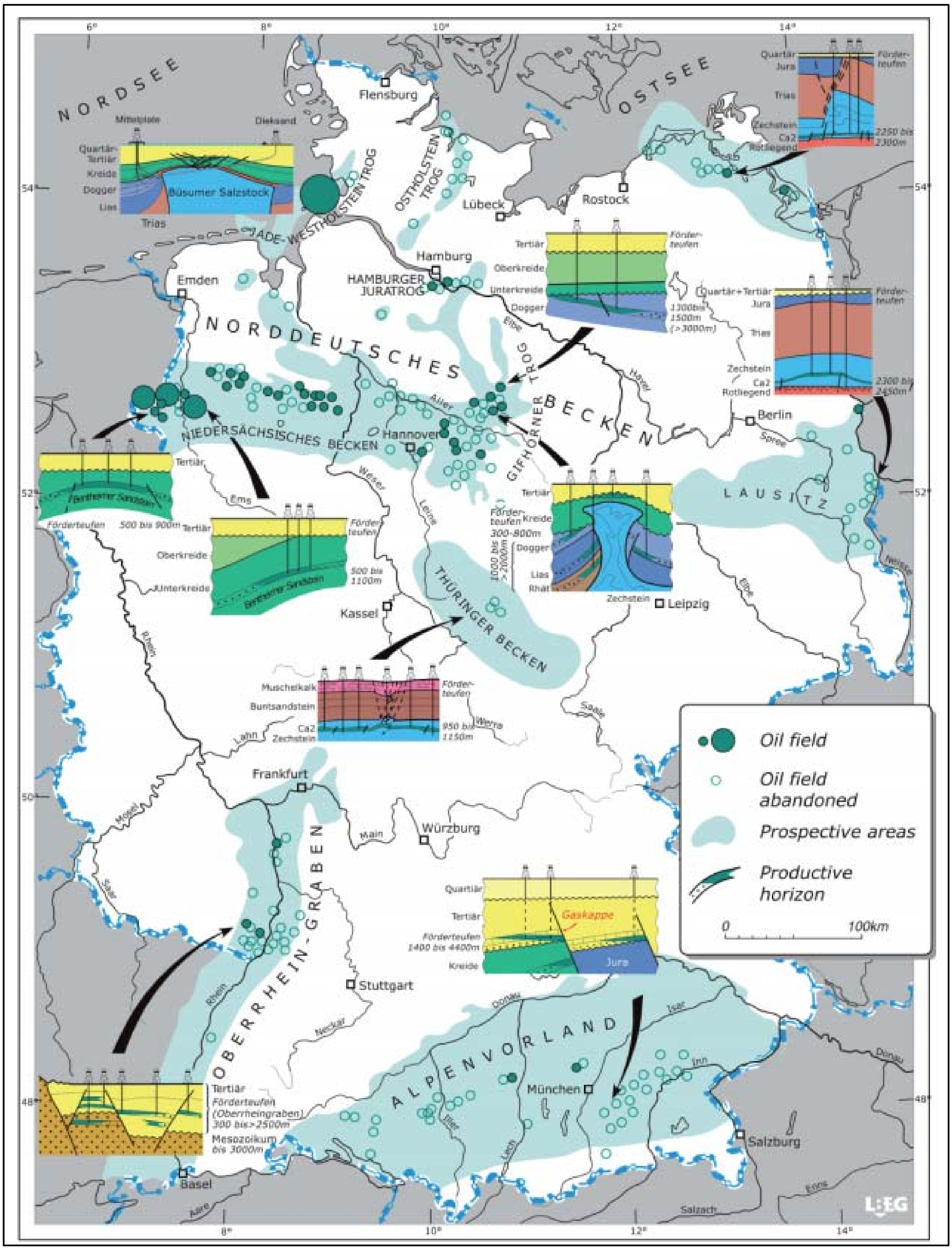
	- Chancellor Schroeder's coalition government reaches an agreement with the owners of German nuclear power plants to gradually decommission them by 2022. - Extra Law for heating and electricity.
2001	-The Court of Justice of the European Union confirms that feed-in tariffs do not constitute state aid and are therefore legal. -Investment in the "Future" programme.
2002	- *Energieeffizienz* initiative set up, focusing on promoting end use efficiency in private homes and businesses. This initiative is followed by the Energy - Conservation Ordinance, *Energieeinsparverordnung* (EnEV). Thermal energy cogeneration law passed, with two subsequent amendments. This is the most important instrument supporting the production of thermal energy. -Change in tariffs for installation of renewable EEG.
2004	-Unrestricted acceptance of photovoltaics in the EEG. - Solarthermie 2000 plus programme.
2005	-The German Network Agency, which previously oversaw postal and telecommunications services, begins monitoring the power grid and gas market, partly for settlement of disputes over fees related to the renewable energy network. -The European Union launches its emissions trading system. -Germany launches the ecological directive which regulates the efficiency of energy-consuming products (except buildings and cars). - Energy Industry Act (*Energiewirtschaftsgesetz* or EnWG). - KfW financing bank's program for solar energy production. -Fifth energy research program.
2006	- *Kimazwei* research programme (Research for Climate Protection and Reduction of Climate Impact). -Foundation of solar energy development centre.
2007	New goals, policies and support schemes for efficiency and renewable energy are set out in the Integrated Energy and Climate programme.
2008	Raft of legislation on climate change and the energy program.
2009	-First amendment to the EEG without input from Social Democrats or Greens. The new law focuses increasingly on what Chancellor Merkel's coalition government understand as "MBI". -Law on renewable energy for heating passed. This is the first law to explicitly address renewable heating and requires builders to use renewable heating systems. -Adoption of Eco-design of the Law on Energy-Using Products (ErP) incorporating the European eco-design directive in German law, renamed as the 2005 Ecological Directive. Implementation of the National Electric Transport Development Plan. - KfW financing program for renewable energy and energy efficiency and rehabilitation (*Energieeffizient Sanieren*).
2010	- Chancellor Merkel's coalition government decides to extend the working life of the 17 remaining nuclear plants by 8 and 14 years. -The biomass sustainability ordinance addresses the issue of sustainability of biomass production. -Creation of the Special Fund for Energy and Climate, the first German efficiency fund, which is financed through carbon emission certificates. Funding is halved as a result of the low price of the certificates. - National Energy Action Plan. -Energy Concept.

	-Biofuel quota law.
2011	-The accident at the Fukushima nuclear plant causes Chancellor Angela Merkel to reconsider her position on nuclear energy and approve the gradual closure of nuclear power plants (*Atomausstieg* program) at a faster rate even than that envisaged in Chancellor Schroeder's program. Forty percent of generation capacity from nuclear power plants is switched off in one week and closure of the final plant is scheduled for 2022. -The German parliament approves a law to accelerate expansion of the network. The law aims not only to expand the network but also to update and optimize existing networks. - KfW financing for first offshore wind farm. -Network Expansion Act *Netzausbaubeschleunigungsgesetz* (NAGEB). - "Energy of the Future" monitoring process. -Law on the environment and climate and renewable energy. -Sixth energy research program.
2012	-Adjustment to the Renewable Energy Act (EEG) on photovoltaic solar energy. In May, Germany sets a new world record for solar power generation, 50% of demand. -In November, German energy exports reach their highest ever level. -Cogeneration agreements with industry.
2013	-In January, the rate for renewable energy increases to 5.3 cents per kWh. - German energy exports increase by about 50%.
2014	-The rate for renewable energy increases to 6.3 cents per kWh. -Amendment of the Renewable Energy Act (EEG) including network expansion considerations, market efficiency and capacity and reserves. - National Energy Efficiency Plan (NAPE).

Source: Own elaboration from (Morris & Pehnt, 2012)

13.5. APPENDIX 5: Plans and figures on energy structure in Germany

FIGURE 28. Oil prospecting and production areas



Fuente: (BGR, 2009)

TABLE 37. List of refineries

REFINERY	LOCATION	OWNERSHIP
Bayernoil Raffineriegesellschaft mbH	Neustadt	Varo Energy Refining GmbH (45%) Ruhr Oel GmbH (25%) Eni Deutschland Gmbh (20%) BP Europa SE (10%)
BP Lingen	Lingen	BP Europa SE (100%)
Buna SOW Leuna Olefinverbund GmbHl	Böhlen	DOW Chemical (100%)
Gunvor Raffinerie Ingolstadt GmbH	Kösching	Gunvor Group Ltd (100%)
H & R Chemisch-Pharmazeutische Spezialitäten GmbH	Salzbergen	H & R WASAG AG (100%)
H & R Oelwerke Schindler	Hamburg	H & R WASAG AG (100%)
Holborn Europa Raffinerie GmbH	Hamburg	Holborn Investment Company Ltd. (100%)
MiRO Mineraloelraffinerie Oberrhein GmbH & Co. KG	Karlsruhe	Shell Deutschland Oil GmbH (32,25%) Esso Deutschland GmbH (25%) Ruhr Oel GmbH (24%) Phillips 66 Continental Holding GmbH (18,75%)
Mitteldeutsches Bitumenwerk GmbH	Webau	Mitteldeutsches Bitumenwerk GmbH (100%)
Nynas GmbH & Co KG	Hamburg	Nynas AB (100%)
OMV Deutschland GmbH	Burghausen	OMV, Wien (100%)
PCK Raffinerie GmbH Schwedt	Schwedt	Shell Deutschland Oil GmbH (37,50%) Ruhr Oel GmbH (37,50%) AET Raffineriebeteiligungsges. mbH (25%)
Raffinerie Heide GmbH	Heide/Holstein	Klesch & Company Ltd. (100%)
Rheinland Raffinerie Werk Godorf	Köln	Shell Deutschland Oil GmbH (100%)
Rheinland Raffinerie Werk Wesseling	Wesseling	Shell Deutschland Oil GmbH (100%)
Ruhr Oel GmbH	Gelsenkirchen	BP Europa SE (50%) Rosneft Holdings Limited S.A. (50%)

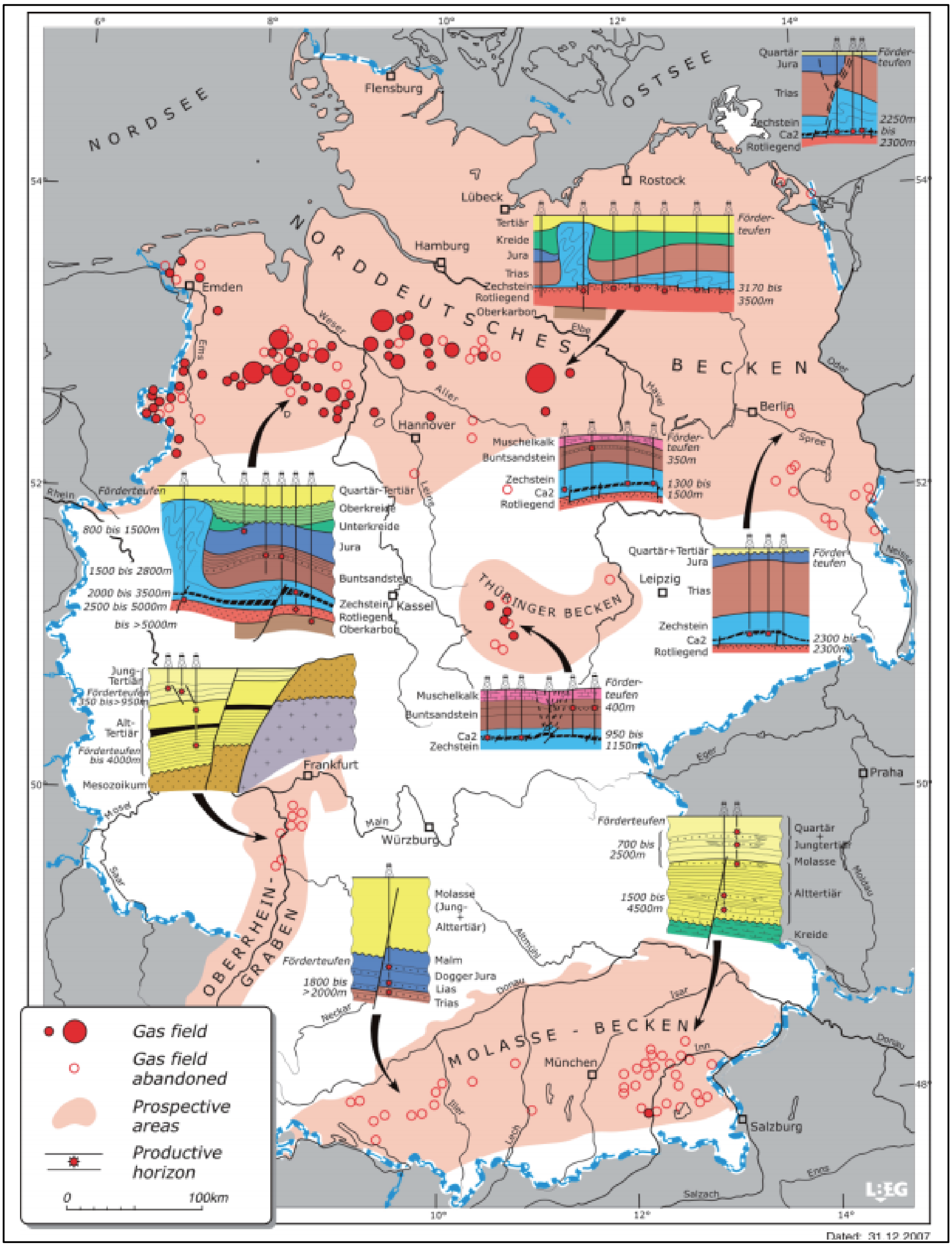
Source: Own elaboration from (Association of German Petroleum Industry, 2014)

TABLE 38. List of main oil pipelines

NAME	SECTION	LENGTH (Km)	ANNUAL CAPACITY (Mt)
MERO (Mitteleuropäische Rohölleitung AG)	Vohburg	343	10
MVL (Mineralölverbundleitung GmbH)	Adamowo-Schwedt	707	20
	Schwedt-Spergau	338	13.5
	Rostock-Schwedt	201	6,8
NDO (Norddeutsche Oelleitungsges. m.b.H.)	Wilhelmshaven-Hamburg	144	8
NWO (Nord-West-Oelleitung GmbH)	Wilhelmshaven-Wesseling	391	16.3
RMR (Rhein-Main-Rohrleitungstransportgesellschaft mbH)	Rotterdam-Ludwigshafen	525	12.5
RRP (N.V. Rotterdam-Rijn, Pijpleiding Maatchappij)	Rotterdam-Wesseling	323	36
SPSE (Südeuropäische Ölleitung, Lavera-Fos-Karlsruhe)	Lavera-Karlsruhe	770	35
TAL (Deutsche Transalpine Oelleitung GmbH)	Triest-Ingolstadt	759	37 currently (54 at final stage)
	Ingolstadt-Karlsruhe	272	14 currently (21 at final stage)

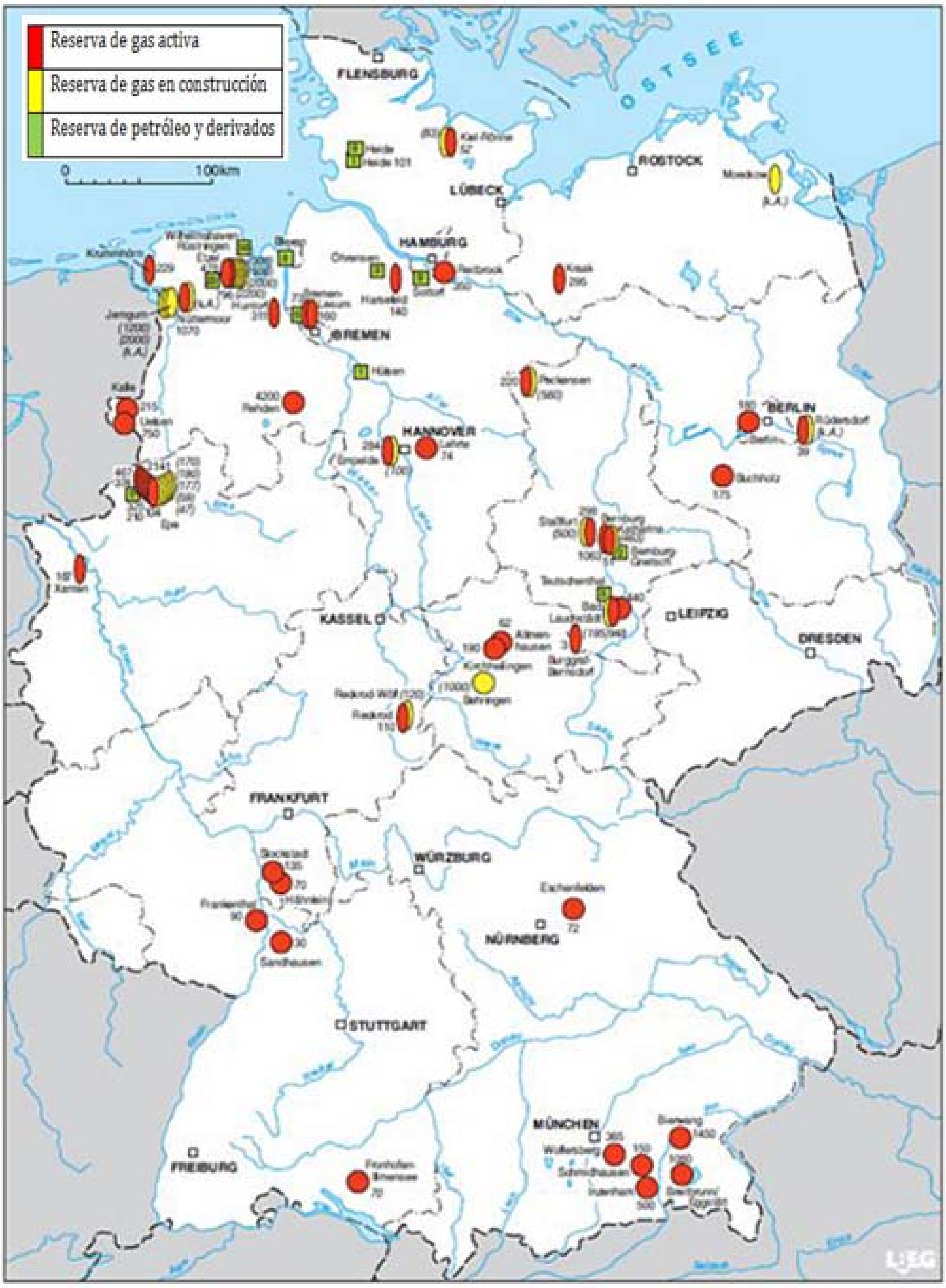
Source: Own elaboration from (Association of German Petroleum Industry, 2014)

FIGURE 29. Prospecting areas and gas fields



Source: (BGR, 2009).

FIGURE 30. Subterranean installations for storage of natural gas, crude oil, oil products and liquefied petroleum gas

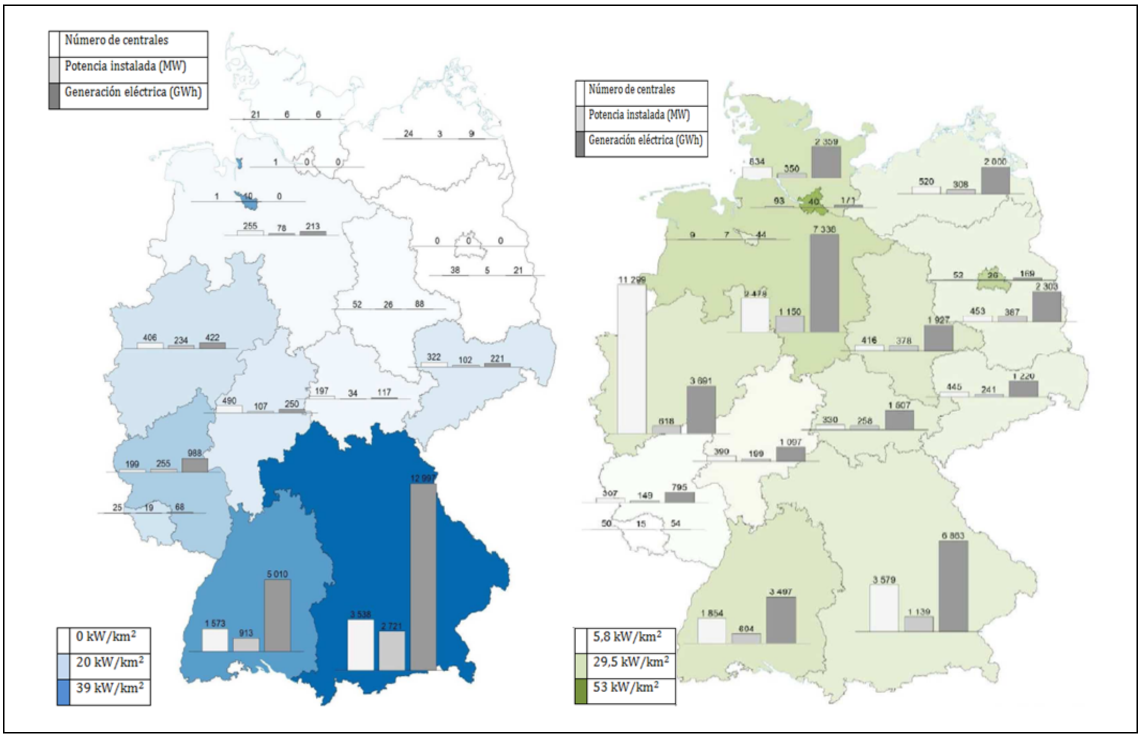


Source: (BMWi, 2015d)

Regional renewable energy generation

The maps below show renewable generation (hydroelectric or biomass) figures for each *Länder* or region.

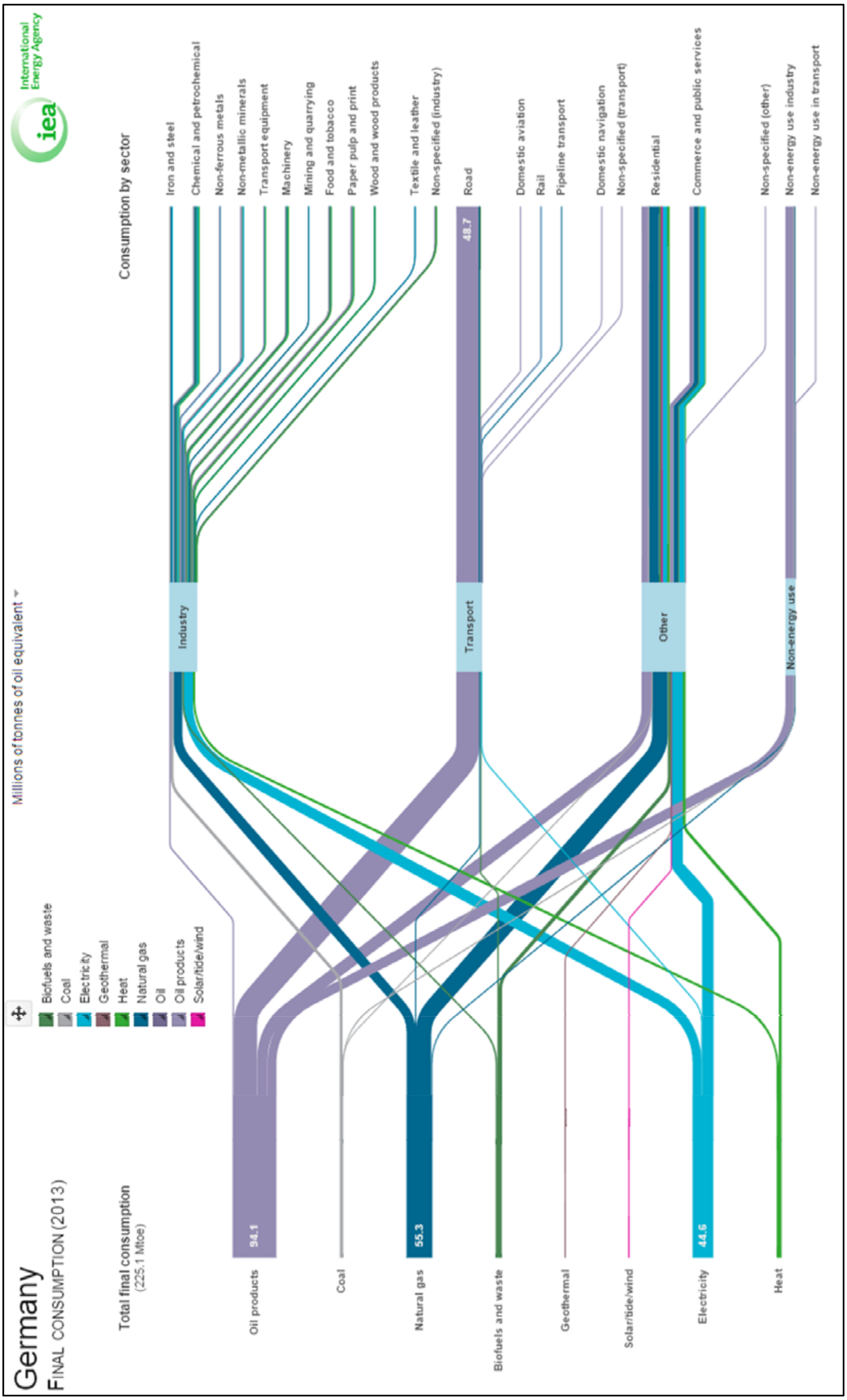
FIGURE 31. Regional hydroelectric and biomass generation



Source: Own elaboration from (Dombrowski, 2014)

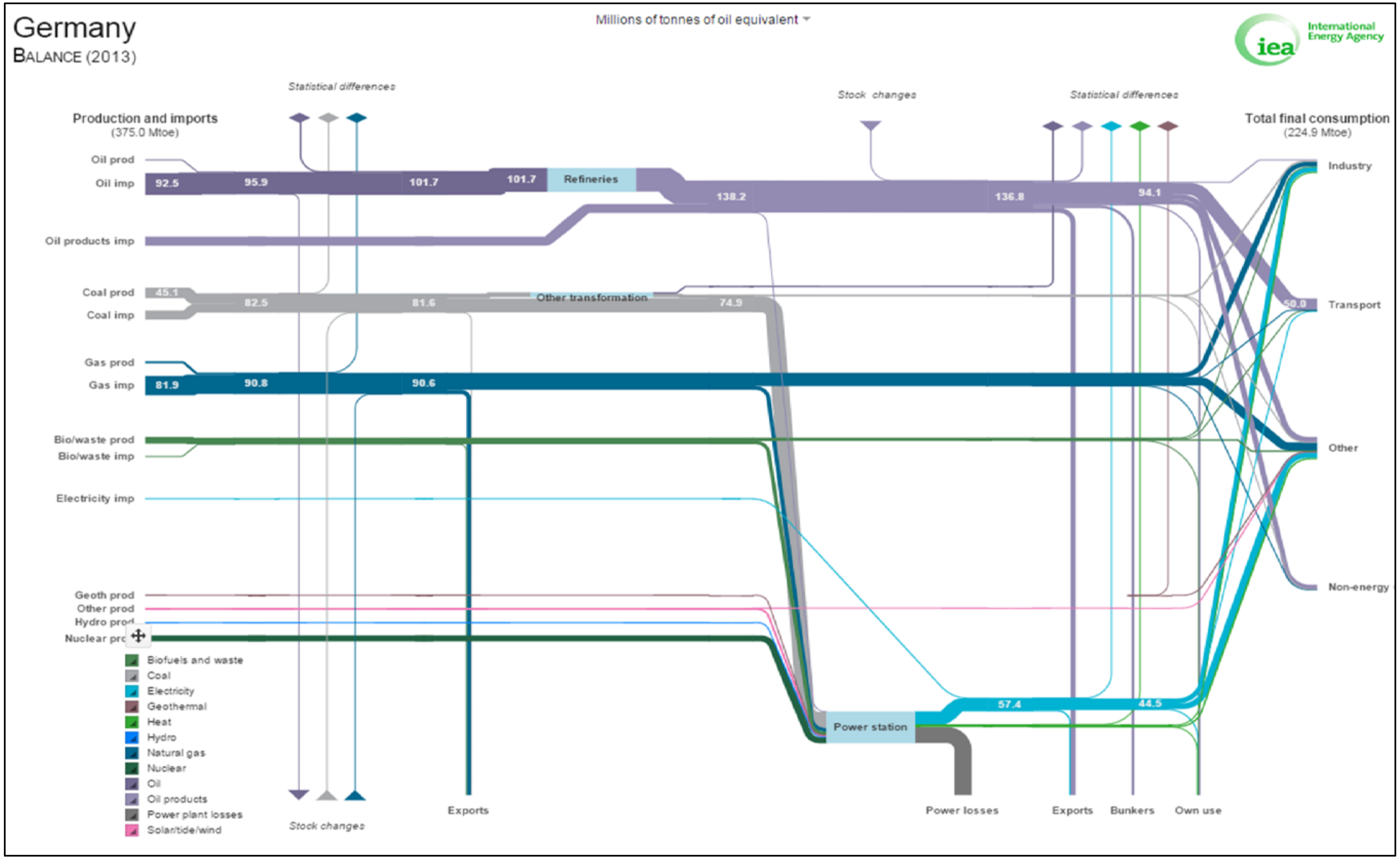
Sankey diagrams

GRAPH 59. Sankey diagram of German energy consumption in 2013



Source: (IEA, 2013)

GRAPH 60. Sankey diagram of German energy balance



Source: (IEA, 2013)

13.6. APPENDIX 6: German companies in the renewable energies sector

The table below lists German companies operating in the renewable energies sector in Germany.

TABLE 39. German companies in the renewable energies sector

COMPANY	TECHNOLOGIES	ACTIVITY	BASED IN
7C Solarparken AG	Photovoltaics	Manufacturer and supplier	Hamburg
abakus solar AG	Photovoltaics	Supplier of integral solutions	Gelsenkirchen
abc GmbH advanced biomass concepts	Biomass	Supplier of integral solutions and planner	Bremen
ABO Wind GmbH & Co.KG	Wind	Manufacturer	Wiesbaden
actensys GmbH	Photovoltaics	Manufacturer	Ellzee
AD AGRO systems GmbH & Co. KG	Biomass, Biogas	Manufacturer	Vechta-Calveslage
Agenpa GmbH	Photovoltaics, Biogas, Biomass	Supplier of integral solutions, planner and others	Berlin
AgriKomp GmbH	Biogas	Supplier of integral solutions	Merkendorf
AkoTec Produktionsgesellschaft GmbH	Thermal solar, Biomass	Supplier of integral solutions, planner and others	Angermünde
Aleo Solar AG	Photovoltaics	Manufacturer	Prenzlau
AlfaSolar Vertriebsgesellschaft GmbH	Photovoltaics	Manufacturer	Hannover
ALGATEC Solarwerke Brandenburg GmbH	Photovoltaics	Manufacturer and supplier	Röderland
Alpha New Technology Services GmbH	Wind, Hydroelectric, Photovoltaics, Biogas	Supplier and others	Berlin
Ammonit Measurement GmbH	Wind, Photovoltaics, Thermal solar	Manufacturer and distributor	Berlin
Andritz Hydro GmbH	Hydroelectric	Supplier of integral solutions	Ravensburg
ANTARIS SOLAR GmbH & Co.KG	Photovoltaics	Manufacturer, distributor and supplier	Waldaschaff

●: Wind
●: Hydroelectric
●: Geothermal
●: Photovoltaics
●: Thermal solar
●: Thermosolar
●: Biogas
●: Biomass
●: Storage and power grids
●: Other energy sectors

COMPANY	TECHNOLOGIES	ACTIVITY	BASED IN
ANTEC Solar GmbH	Photovoltaics	Manufacturer and supplier	Arnstadt
A.P. Bioenergietechnik GmbH	Biomass	Manufacturer	Hirschau
Arinna Energy GmbH	Photovoltaics	Manufacturer and supplier	Berlin
AS Solar GmbH - Fachgroßhandel für Solartechnik	Photovoltaics	Manufacturer and supplier	Hannover
asola Technologies GmbH	Photovoltaics	Manufacturer and supplier	Erfurt
Availon GmbH	Wind	Manufacturer and supplier	Rheine
Avancis GmbH	Photovoltaics	Manufacturer	Torgau
Avantis Energy Group GmbH	Wind	Manufacturer and supplier	Hamburg
AVANCTECH - Renewable Energy Systems	Wind, Hydroelectric, Photovoltaics, Biogas	Manufacturer, distributor and supplier	Barßel
Awite Bioenergie GmbH	Biogas	Supplier	Langenbach
AZUR SPACE Solar Power GmbH	Photovoltaics	Manufacturer	Heilbronn
Baju energy GmbH	Wind	Manufacturer, distributor and supplier	Eberswalde
BARD Holding GmbH	Wind	Manufacturer	Emden
BayWa r.e. renewable energy GmbH	Wind, Geothermal, Photovoltaics, Biogas	Supplier of integral solutions and distributor	Munich
BBB Umwelttechnik GmbH	Wind	Consultant, evaluator and planner	Gelsenkirchen
Bekar Europe GmbH	Wind, Photovoltaics	Manufacturer and distributor	Hamburg
BELECTRIC Solarkraftwerke GmbH	Photovoltaics	Manufacturer, distributor and supplier	Kolitzheim
BerlinWind GmbH	Wind	Manufacturer	Berlin
BIOFerm GmbH	Biomass, Biogas	Manufacturer	Schwandorf
Bionardo Repower GmbH	Biomass, Biogas	Supplier of integral solutions and manufacturer	Munich
Bosch Solar Energy Services	Photovoltaics	Supplier of integral solutions	Arnstadt
C&D Ölservice GmbH	Wind	Manufacturer, distributor and supplier	Oldenswort
Carbotech GmbH	Biogas	Manufacturer	Essen
cebeEnergy GmbH	Wind, Hydroelectric, Photovoltaics, Biogas	Manufacturer, projects developer and planner	Rehlingen-Siersburg
Centrosolar Group AG	Photovoltaics	Manufacturer	Munich

- : Wind
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- : Thermosolar
- : Biogas
- : Biomass
- : Storage and power grids
- : Other energy sectors

COMPANY	TECHNOLOGIES	ACTIVITY	BASED IN
CEPP Capital AG	Wind, Hydroelectric, Photovoltaics, Biogas	Supplier of integral solutions	Berlin
CEPP Invest GmbH	Wind, Hydroelectric, Photovoltaics, Biogas	R & D	Berlin
CIS Solartechnik GmbH & Co. KG	Photovoltaics	Manufacturer and supplier	Bremen
Concentrix Solar GmbH	Photovoltaics	Manufacturer	Freiburg
Conergy AG	Photovoltaics	Supplier of integral solutions	Hamburg
Conti Solar GmbH	Photovoltaics	Manufacturer	Weingarten
Corporate Energies GmbH & Co.KG	Wind, Hydroelectric, Photovoltaics, Biogas	Supplier of integral solutions and distributor	Berlin
cp.max Rotortechnik GmbH & Co. KG	Wind	Supplier of integral solutions	Dresden
CTS Tandem Solar GmbH	Photovoltaics	Manufacturer	Chemnitz
CUBE Engineering GmbH	Wind	Consultant, projects developer and planner	Kassel
DCH Solar GmbH	Photovoltaics	Manufacturer	Siegen
Deutsche Energieversorgung GmbH	Photovoltaics, Storage and power grids, Other energy sectors	Manufacturer and supplier	Leipzig
Deutsche Windtechnik AG	Wind	Manufacturer and supplier of integral solutions	Bremen
DeWind Europe GmbH	Wind	Manufacturer	Hamburg
D.I.E. Erneuerbare Energien	Wind	Supplier of integral solutions, planner and projects developer	Oppenheim
Dirk Hansen Elektro-und Windtechnik GmbH	Wind	Supplier of integral solutions	Husum
DIVE Turbinen GmbH & Co.KG	Hydroelectric	Manufacturer and supplier	Amorbach
e:craft systems GmbH	Photovoltaics	Supplier of integral solutions and planner	Nöbdenitz OT Lohma
Ecofin Concept GmbH	Wind, Photovoltaics	Manufacturer and supplier	Hückelhoven
Ecostream International B.V.	Photovoltaics	Manufacturer	Köln
EEG Service & Technik GmbH	Wind	Supplier of integral solutions	Melle
EG-Solar e.V.	Photovoltaics, Thermal solar	Manufacturer	Altötting
elgris UG	Other energy sectors	Supplier of integral solutions	Aachen
Enercon	Wind	Manufacturer	Aurich
ENERLOG GmbH	Biomass, Other energy sectors	Manufacturer and supplier of integral solutions	Wolfen
Energiebau Solarstromsysteme GmbH	Photovoltaics, Thermal solar, Other energy sectors	Manufacturer and supplier of integral solutions	Köln

- : Wind
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- : Thermosolar
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- : Biomass
- : Storage and power grids
- : Other energy sectors

COMPANY	TECHNOLOGIES	ACTIVITY	BASED IN
Energiequelle GmbH	●●●	Manufacturer and supplier of integral solutions	Bremen
Energy Competence Centre GmbH	●●●●	Supplier of integral solutions, planner and projects developer	Berlin
ENERTRAG Service GmbH	●	Supplier of integral solutions and planner	Dauerthal
eno Energy GmbH& Co. Silmersdorf KG	●	Manufacturer	Ostseebad Rerik
EnviTec Biogas AG	●	Supplier of integral solutions	Saerbeck
EuroSkyPark GmbH	●●	Supplier and others	Saarbrücken
EWS GmbH & Co. KG	●●	Manufacturer, distributor and provider	Handewitt
ExTox Gasmess-Systeme GmbH	●	Others	Unna
F&S solar concept GmbH	●	Manufacturer and supplier	Euskirchen
FARMATIC Anlagenbau GmbH	●	Supplier	Nortorf
FENECON GmbH & Co. KG	●●●	Manufacturer and supplier	Deggendorf
Fichtner GmbH & Co. KG	●●●●●●●●	Supplier of integral solutions and projects developer	Stuttgart
FR-Frankensolar GmbH	●	Manufacturer and supplier	Nürnberg
FRANK GmbH	●	Manufacturer and distributor	Mörfelden-Walldorf
Fraunhofe-Institut for Solar (ISE) and Wind (IWES) Energy Systems	●●●●●	R & D	Freiburg
FWT energy GmbH & Co. KG	●	Supplier of integral solutions and planner	Weigandshain
Gehrlicher Solar AG	●	Manufacturer and supplier	Dornach
GEO-NET Umweltconsulting GmbH	●	Consultant	Hannover
GFC AntriebsSysteme	●	Manufacturer	Coswig
GICON-Grossman Ingenieur Consult GmbH	●●	Supplier of integral solutions	Dresden
GM Wassertechnik	●	Manufacturer and supplier	Bad Abbach
Grammer Solar GmbH	●	Supplier	Amberg

●: Wind
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●: Storage and power grids
●: Other energy sectors

COMPANY	TECHNOLOGIES	ACTIVITY	BASED IN
Green Energy World GmbH	Wind, Hydroelectric, Photovoltaics, Biogas	Supplier of integral solutions, project developer and others	Berlin
GUGLER GmbH - Hydropower Technology	Hydroelectric	Manufacturer	Passau
Halio Wind Systems GmbH & Co. KG	Wind	Supplier	Haiger
Hautec GmbH	Thermal solar, Thermosolar, Other energy sectors	Manufacturer and supplier	Bedburg-Hau
Havelland-Solar Projekt GmbH & Co. KG	Photovoltaics	Manufacturer	Nauen
Heckert Solar GmbH	Photovoltaics	Manufacturer and supplier	Chemnitz
Heinz-Dieter Jäkel REEGAS GmbH	Biomass	Manufacturer and supplier	Berlin
Heliatek GmbH	Photovoltaics	Supplier	Dresden
HelioSolar GmbH	Photovoltaics	Supplier	Umkirch
Heos Energy GmbH	Wind, Photovoltaics, Thermal solar	Manufacturer	Chemnitz
HPC BIOSYSTEMS GmbH & Co. KG a. A.	Biomass, Biogas	Manufacturer and supplier	Berlin
HR-Energiemanagement GmbH Holzvergaserwerkstatt	Biomass	Manufacturer, distributor and supplier	Bünde
IBC SOLAR AG	Photovoltaics, Storage and power grids	Distributor, project developer and planner	Bad Staffelstein
IE-S GmbH Integrated Energy Systems	Biomass, Biogas	Supplier of integral solutions and planner	Leipzig
IMO Anlagenbau GmbH	Wind	Manufacturer	Merseburg
Industrial Solar GmbH	Photovoltaics	Manufacturer and supplier of integral solutions	Freiburg
Ingfeld GmbH	Photovoltaics, Storage and power grids, Other energy sectors	Supplier of integral solutions and planner	Berlin
INTEC Engineering GmbH	Thermal solar, Biomass	Manufacturer, distributor and supplier	Bruchsal
Intersolar Europe 2015	Photovoltaics, Thermal solar	Others	Pforzheim

: Wind
: Hydroelectric
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: Thermal solar
: Thermosolar
: Biogas
: Biomass
: Storage and power grids
: Other energy sectors

COMPANY	TECHNOLOGIES	ACTIVITY	BASED IN
INTRA photovoltaics	Photovoltaics	Manufacturer, distributor and supplier	Bochum
Juwi AG	Wind, Photovoltaics	Manufacturer	Wörrstadt
K&S Solarsysteme GmbH	Photovoltaics	Manufacturer	Weikersheim
KACO new energy GmbH	Photovoltaics	Manufacturer, distributor and supplier	Neckarsulm
KBB Kollektorbau	Thermal solar	Manufacturer	Berlin
Kenersys GmbH	Wind	Manufacturer, distributor and supplier	Münster
KGW Schweriner Maschinen- und Anlagenbau	Wind	Manufacturer	Schwerin
KIKA Sun Solution GmbH	Wind, Photovoltaics, Thermal solar, Other energy sectors	Manufacturer, distributor and supplier	Munich
KOSTAL Solar Electric GmbH	Photovoltaics	Manufacturer	Breisgau
Krannich Solar GmbH & Co. KG	Photovoltaics	Manufacturer, distributor and supplier	Weil der Stadt
Lahmeyer International GmbH	Wind, Hydroelectric, Geothermal, Photovoltaics, Thermal solar, Thermosolar, Biogas, Biomass, Storage and power grids	Supplier of integral solutions, planner and project developer	Bad Vilbel
Lambion Energy Solutions GmbH	Biomass	Manufacturer, project developer and planner	Bad Arolsen
LTB Hochsauerland GmbH	Wind	Supplier of integral solutions	Lichtenau
LTi REEnergy GmbH	Photovoltaics	Manufacturer and supplier	Unna
M+W Zander FE GmbH	Photovoltaics	Manufacturer	Stuttgart
MANAGESS Energy GmbH	Wind, Photovoltaics, Other energy sectors	Supplier of integral solutions, planner and project developer	Erfurt
Mare Solar Marc Reiß Solartechnik	Wind, Photovoltaics	Supplier and distributor	Berlin
Masdar PV GmbH	Photovoltaics	Manufacturer	Ichtershausen
MHH Solartechnik GmbH	Photovoltaics	Manufacturer and supplier	Tübingen
MMM-Windtechnik GmbH	Wind	Supplier of integral solutions	Crimmitschau
Mola Solaire Produktions GmbH	Photovoltaics	Manufacturer and supplier	Hamburg
MSS Mola Solar Systems Ltd. & Co. KG	Wind, Hydroelectric, Photovoltaics, Thermal solar	Distributor	Duisburg
Natcon7 GmbH	Photovoltaics	Manufacturer	Hamburg
Nolting Holzfeuerungstechnik GmbH	Biomass	Manufacturer and project developer	Detmold
Nordex SE	Wind	Manufacturer	Hamburg
N.T.E.S. GmbH WINDKRAFTSERVICE	Wind	Manufacturer and supplier of integral solutions	Bremervörde

Key (coloured dots):

- : Wind
- : Hydroelectric
- : Geothermal
- : Photovoltaics
- : Thermal solar
- : Thermosolar
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- : Biomass
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COMPANY	TECHNOLOGIES	ACTIVITY	BASED IN
OBAG BioEnergy Anlagenbau GmbH	Biomass, Biogas	Manufacturer and supplier	Bautzen
OneShore Energy GmbH	Photovoltaics, Other energy sectors	Manufacturer	Berlin
Ossberger GmbH + Co	Hydroelectric	Manufacturer and project developer	Weiβenburg
Parker Hannifin Manufacturing Germany GmbH & Co. KG Hiross Zander Division	Biogas	Manufacturer	Essen
PerfectEnergy GmbH	Photovoltaics	Manufacturer	Bad Honnef
Phaesun GmbH	Photovoltaics, Thermal solar, Other energy sectors	Distributor, planner and project developer	Memmingen
Phoenix Solar AG	Photovoltaics	Manufacturer and supplier of integral solutions	Sulzemoos
Phocos AG	Photovoltaics, Thermal solar, Other energy sectors	Manufacturer	Ulm
PlanET Biogastechnik GmbH	Biomass, Biogas	Supplier of integral solutions, manufacturer and planner	Vreden
Planungsbüro SolarForm	Hydroelectric, Photovoltaics, Thermal solar	Planner	Hannover
PNE Wind AG	Wind	Manufacturer	Cuxhaven
PowerWind GmbH	Wind	Manufacturer and supplier of integral solutions	Hamburg
Protarget AG	Thermal solar	Manufacturer and supplier	Köln
PSE Engineering GmbH	Biogas	Manufacturer	Hannover
psm GmbH & Co. KG	Wind, Photovoltaics	Supplier of integral solutions	Erkelenz
PV-Projects Agency – Project for Sustainable Development – Global Marketing of PV	Photovoltaics, Thermal solar, Other energy sectors	Supplier of integral solutions and project developer	Berlin
PVflex Solar GmbH Hersteller von Solarzellen und Solarmodulen	Photovoltaics	Manufacturer and supplier	Fürstenwalde
REFU Elektronik GmbH | REFU Energy	Storage and power grids, Other energy sectors	Supplier of integral solutions	Pfullingen
Renergiepartner Group	Wind, Geothermal, Biogas, Storage and power grids	Operator, projects developer and others	Berlin

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COMPANY	TECHNOLOGIES	ACTIVITY	BASED IN
Renertec GmbH	Wind, Hydroelectric	Manufacturer and supplier of integral solutions	Brachttal
Renewables Academy AG (RENAC)	Wind, Photovoltaics, Thermal solar, Thermosolar, Biogas, Other energy sectors	Training centre, consultancy and others	Berlin
Renusol GmbH	Photovoltaics	Manufacturer	Köln
Ritter Energie- und Umwelttechnik GmbH & Co. KG	Photovoltaics	Manufacturer and distributor	Dettenhausen
RoSch Industrieservice GmbH	Wind	Consultant	Lingen
Roto Sunroof Verwaltung GmbH	Photovoltaics	Manufacturer and distributor	Bad Mergentheim
Rotor Control GmbH	Wind	Supplier and consultant	Struckum
RUF Maschinenbau GmbH & Co. KG	Biomass	Manufacturer and distributor	Zaisertshofen
RuSiTec GmbH	Biogas	Manufacturer and distributor	Bremerhaven
S-power Entwicklungs & Vertriebs GmbH	Thermal solar	Manufacturer	Meppen
Schlaich bergermann und partner, sbp sonne GmbH	Thermal solar, Thermosolar	R & D and consultant	Stuttgart
Schmack Biogas GmbH	Biogas	Supplier of integral solutions	Schwandorf
Schmid Silicon Technology GmbH	Photovoltaics	Manufacturer and supplier	Freudenstadt
SCHNELL Motoren AG	Biogas	Manufacturer and distributor	Amtzell
SCHOTT Solar AG	Photovoltaics	Manufacturer and supplier	Mainz
Schütz GmbH & Co. KGaA	Wind	Manufacturer and supplier of integral solutions	Selters
Seilpartner Windkraft	Wind	Supplier of integral solutions	Berlin
SEN Solare Energiesysteme Nord Vertriebsgesellschaft mbH	Photovoltaics	Manufacturer and supplier	Grasberg
Senvion SE	Wind	Manufacturer	Hamburg
Service4Wind GmbH & Co. KG	Wind	Supplier, consultant, evaluator and planner	Osnabrück

: Wind
: Hydroelectric
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: Thermosolar
: Biogas
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: Other energy sectors

COMPANY	TECHNOLOGIES	ACTIVITY	BASED IN
SES 21 AG	● (Photovoltaics)	Manufacturer	Polling
SHW Storage & Handling Solutions	● (Biomass)	Supplier, consultant, evaluator and planner	Hüttlingen
Siemens AG	● ● ● ● (Wind, Hydroelectric, Photovoltaics, Thermal solar)	Supplier of integral solutions, manufacturer, R & D and supplier	Berlin, Munich and Erlangen
sinoPARTNER Technologie AG	● (Photovoltaics)	Manufacturer	Bretten
skytron energy GmbH	● (Photovoltaics)	Manufacturer, distributor and supplier	Berlin
SMA Solar Technology AG	● (Photovoltaics)	Manufacturer	Niestetal
Smart Energysystems International AG	● ● ● ● (Wind, Hydroelectric, Photovoltaics, Thermal solar)	Supplier of integral solutions	Karlsruhe
Solar-Fabrik AG	● (Photovoltaics)	Manufacturer	Freiburg
SOLARC Innovative SolarprodukteGmbH	● (Photovoltaics)	Manufacturer, distributor and developer	Berlin
Solarion AG	● (Photovoltaics)	Manufacturer and supplier	Zwenkau and Dresden
Solarnova Deutschland GmbH	● (Photovoltaics)	Manufacturer	Wedel
Solarschmiede GmbH	● (Photovoltaics)	Manufacturer and supplier	Munich
SolarSpring GmbH	● (Photovoltaics)	Manufacturer and supplier	Freiburg
SolarTec International AG	● (Photovoltaics)	Manufacturer	Aschheim
SOLARWATT AG	● (Photovoltaics)	Manufacturer	Dresden
SolarWorld AG	● (Photovoltaics)	Manufacturer	Bonn
Solarzentrum Allgäu e.K GmbH & Co. KG	● (Photovoltaics)	Supplier	Biessenhofen
Solea Capital GmbH	● (Photovoltaics)	Manufacturer and supplier	Unterhaching
Solemio GmbH	● (Photovoltaics)	Manufacturer and supplier	Vogtsburg
SOLEOS Solar GmbH	● (Photovoltaics)	Manufacturer	Bornheim

● : Wind
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COMPANY	TECHNOLOGIES	ACTIVITY	BASED IN
Solland Solar Cells GmbH	Photovoltaics	Manufacturer	Aachen
SOLVIS GmbH & Co. KG	Photovoltaics, Thermal solar	Manufacturer and supplier	Braunschweig
SoMa Solar Holding GmbH	Photovoltaics	Manufacturer and supplier	Ellzee
Sonnenbatterie GmbH	Photovoltaics, Storage and power grids	Manufacturer	Wildpoldsried
Speedwind GmbH	Wind	Supplier and consultant	Helmstedt
Steca Elektronik GmbH	Photovoltaics, Thermal solar	Manufacturer and supplier	Memmingen
STELA Laxhuber GmbH	Biogas, Biomass, Other energy sectors	Manufacturer	Massing
STI Solar-Technologie-International GmbH	Photovoltaics	Manufacturer and supplier	Meerane
STIEBEL ELTRON GmbH & Co. KG	Wind, Hydroelectric, Photovoltaics, Thermal solar, Thermosolar, Biogas, Biomass	Manufacturer	Holzminden
SunEnergy Europe GmbH	Photovoltaics, Storage and power grids, Other energy sectors	Consultant, evaluator and planner	Hamburg
Sunovation GmbH	Photovoltaics	Manufacturer and supplier	Elsenfeld
Sunset Energietechnik GmbH	Photovoltaics	Manufacturer	Adelsdorf
SunWare Solartechnik Produktions GmbH & Co. KG	Photovoltaics	Manufacturer and supplier	Duisburg
Systaic AG	Photovoltaics	Manufacturer and supplier	Düsseldorf
Tembra GmbH – Wind Turbine Development	Wind	Manufacturer	Berlin
Torres & Cie. Consulting International	Wind, Hydroelectric, Geothermal, Photovoltaics, Thermal solar, Thermosolar, Biogas, Biomass, Storage and power grids, Other energy sectors	Supplier of integral solutions and project developer	Münster
UTW Dienstleistungs GmbH	Wind	Supplier and planner	Hamm
Valentin Software GmbH	Geothermal, Photovoltaics, Thermal solar	Manufacturer	Berlin
Vensys Energy AG	Wind	Manufacturer and supplier	Neunkirchen

- ● : Wind
- ● : Hydroelectric
- ● : Geothermal
- ● : Photovoltaics
- ● : Thermal solar
- ● : Thermosolar
- ● : Biogas
- ● : Biomass
- ● : Storage and power grids
- ● : Other energy sectors

COMPANY	TECHNOLOGIES	ACTIVITY	BASED IN
Vertrieb von innovativen Energiesparsystemen	Biogas, Other energy sectors	Distributor	Kesselsdorf
Viessmann	Geothermal, Photovoltaics, Thermal solar, Biogas, Biomass, Storage and power grids, Other energy sectors	Supplier of integral solutions	Allendorf (Eder)
Voith Hydro Holding GmbH & Co.KU	Hydroelectric	Supplier of integral solutions	Heidenheim
Wagner & Co Solartechnik GmbH	Photovoltaics	Manufacturer and supplier	Cölbe
Webasto Solar GmbH	Photovoltaics	Manufacturer and supplier	Stockdorf
WELTEC BIOPOWER	Biogas	Supplier of integral solutions	Vechta
Windigo GmbH	Wind	Manufacturer and supplier	Berlin
Windwärts Energie GmbH	Wind, Photovoltaics, Biogas, Other energy sectors	Consultant, evaluator and planner	Hannover
Wolf GmbH	Thermal solar	Manufacturer	Mainburg
WSB Neue Energien Holding GmbH	Wind	Supplier of integral solutions	Dresden
Wulfmeier Solar GmbH	Photovoltaics	Manufacturer and supplier	Bielefeld
Würth Solar GmbH & Co. KG	Photovoltaics	Supplier	Schwäbisch Hall
Yandalux GmbH	Photovoltaics	Manufacturer and supplier	Hamburg
ZOPF Energieanlagen GmbH	Wind	Manufacturer and supplier	Leipzig

: Wind
: Hydroelectric
: Geothermal
: Photovoltaics
: Thermal solar
: Thermosolar
: Biogas
: Biomass
: Storage and power grids
: Other energy sectors

Source: Own elaboration based on (BSW & Solarpraxis AG, 2010)(BWE, 2015)(DENA, 2013),(DENA, 2014),(ENF Solar, 2015),(Gorozarri Jiménez, 2012) and (Posharp, 2015)

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