IASS STUDY
Institute for Advanced Sustainability Studies (IASS)
Potsdam, March 2016

The German Energy Transition in International Perspective

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Acknowledgements

The authors would like to thank Sebastian Helgenberger, Christian Hey and Andreas Kraemer for their valuable suggestions and comments. Thanks are also due to Peter Rigney for the translation and to Jan Peuckert and Sara Lingstaedt for their work in creating the diagrams and illustrations in the text.

Germany is an important pioneer for the worldwide deployment of renewables. It is the country with the worldwide highest solar PV capacity and its ranks third with regard to wind energy and biopower.

1. Introduction

The German energy transition (in German: *Energiewende*) has an international signaling effect. There is enormous worldwide interest in the transformation of the German electricity sector. With its domestic support scheme for renewable energy sources, Germany has made a substantial contribution to the global technological development of wind power, photovoltaics and to the associated cost degression. Furthermore, the Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz – EEG) serves as a model for other countries around the world. By now more than 70 countries are using feed-in tariffs to promote the successful operation and production of electricity from renewable energy sources (REN21 2015). In addition, the German government has a proven track record of supporting the global expansion of renewable energy. With its initiative to establish an International Renewable Energy Agency (IRENA), it succeeded in giving the topic greater weight on the international political stage.

The global energy transition, however, has more than one pioneer. The impression sometimes arises, both from the discussion in Germany as well as in international reporting, that Germany has deviated from international energy policy trends through its *Energiewende* and the associated ambitious expansion targets for renewable energy. However, developments in recent years, both in Europe and around the world, paint a different picture. Germany is not going it alone with its energy transition. Renewable energy sources are on the rise around the world, and the expansion of renewables is not only making progress in industrialized countries, but also in many developing and emerging economies.

This study examines the German *Energiewende* within the context of the global expansion of renewable energy. It underlines the global significance of the German *Energiewende*, while also making clear that it has been a dynamic interplay of *various* pioneering countries that has led to the global rise of renewables. The focus here is on the electricity sector, since this is largely where the expansion of renewable energy is taking place, not only in Germany but also around the world. As the study shows, the multiple benefits presented by renewable energy sources constitute the decisive drivers of a global energy transition. However, given the sharp increase in global energy demand and the negative environmental impacts of the existing energy system, the pace of renewables expansion is not yet sufficient. Important opportunities for social and economic development associated with an increased deployment of renewable energy remain untapped. With its international energy transition policy, Germany is well positioned to make a key contribution to building a sustainable global energy supply system. The study concludes with recommendations on how to continue to strengthen the international energy transition policy.

In regions with particularly high solar irradiation levels such as in the Atacama Desert in Chile, solar energy is now competitive even without long-term purchase guarantees.

2. Renewable energy – a trend not only in Germany, but around the world

Germany's ambitious expansion of renewable energy is in line with international trends. In many European countries, renewables are increasingly replacing conventional energy sources. and the use of renewable energy is on the rise globally. This chapter gives a short overview of the German *Energiewende* and the related expansion of renewable energy sources in Germany. The developments are then placed in the context of corresponding changes taking place on the international stage, both in Europe and beyond.

2.1. The expansion of renewable energy in Germany

The origins of the *Energiewende*, Germany's energy transition, date back to the 1980s. Krause et al (1980) developed the conceptual principles of an energy transition. Two Bundestag enquete commissions – "Future Nuclear Energy Policy" (1979/80) and "Preventive Measures to Protect the Earth's Atmosphere" (1987) – strengthened the existing knowledge base and established the topic within Germany's political institutions. Since the early nineties, renewable energy sources have been promoted by way of a feed-in tariff. But it was not until the year 2000 – following a change of government to a coalition of the SPD (Social Democratic Party) and Buendnis 90/Die Gruenen (Alliance '90/The Greens) – that renewables received more substantial support, e.g. through significantly more attractive feed-in tariffs within the framework of the Renewable Energy Sources Act (EEG). In addition to the introduction of the EEG, the decision to phase out nuclear energy played a decisive role. This decision was passed in the year 2000 by the SPD/Green government coalition and was reaffirmed with the broad support of the German Bundestag following the reactor catastrophe in Fukushima in 2011 (see also Kraemer 2011, 2012). The last nuclear power plant in Germany is to be taken off the grid in the year 2022. At the same time, an ambitious expansion path for renewables has been laid out: Their share of the electricity production is to reach 40–45 percent by the year 2025, 55-60 percent 10 years later, while by the year 2050 it is to reach at least 80 percent (Energy Concept of the German Federal Government, 28 Oct. 2010).

As Figure 1 illustrates, the share of renewable energy sources in the gross electricity consumption since the introduction of the EEG has increased from 6.2 percent to 27.4 percent in the year 2014. This corresponds to a more than fourfold increase (from 36,036 to 161,379 TWh), primarily driven by a rapid expansion of wind power, bioenergy and photovoltaics (PV). Electricity production from wind power increased sixfold during this period, from 9,513 TWh to 57,357 TWh. Among renewable energy sources, wind power today makes up the largest share of gross electricity consumption, at 9.7 percent. Bioenergy at 8.3 percent takes second place.[1] Its share in gross electricity consumption increased more than tenfold during the same time period.[2] PV shows an even more rapid expansion path: 60 TWh in the year 2000 compared to 35,115 TWh in the year 2014. As a result, PV now accounts for 6 percent of gross electricity consumption. The share of hydropower fell slightly from 3.7 percent to 3.3 percent, which corresponds to a slight decrease from 21,732 to 19,590 TWh (BMWi 2015a).

[1] Bioenergy for electricity consumption entails both biomass supplied by agriculture and forestry as well as residual and' waste products from biogenic sources. The largest share of bioenergy is made up of biogas and biomethane, which together account for a share of 4.9 percent of gross electricity consumption (29,140 TWh). Biogenic solid fuels and sewage sludge make up 11,800 TWh, which corresponds to a share of 2 percent, while the biogenic share of the waste is 1 percent (6,130 TWh). In addition, sewage treatment plant gas (1,409 TWh, 0.2%), landfill gas (420 TWh, 0.1%) and biogenic liquid fuels (320 TWh, 0.1%) are also used.

[2] In the year 2000, the share of bioenergy in the gross electricity consumption was 0.8 percent.

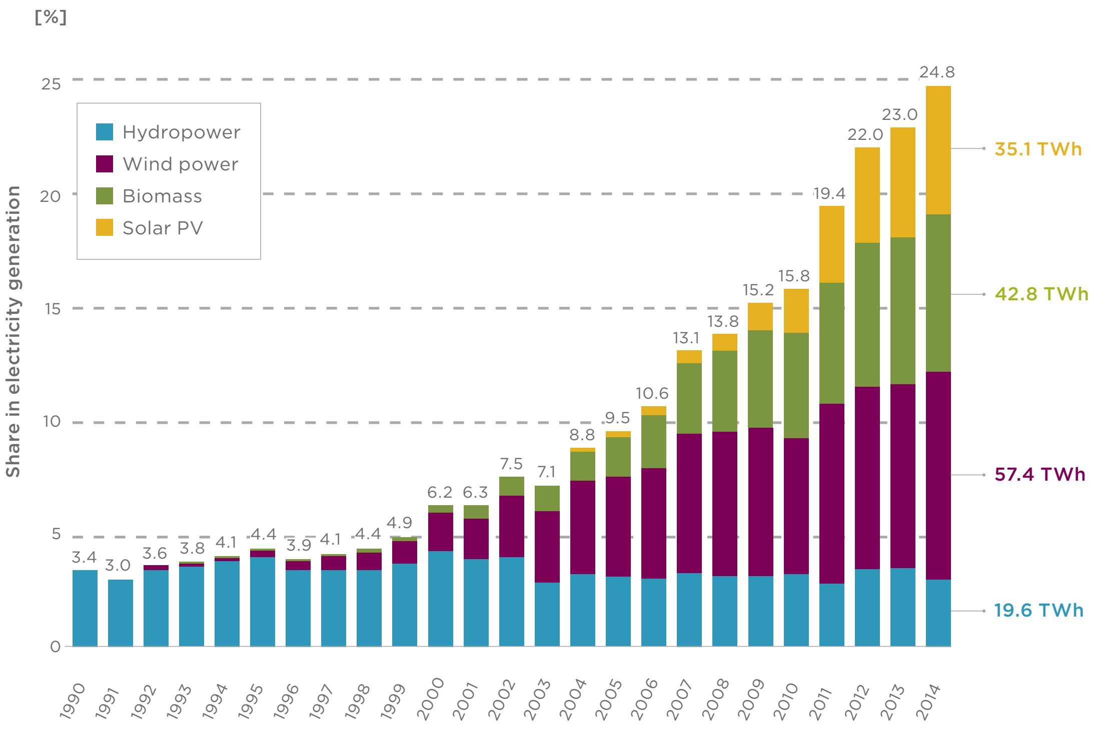


Figure 1
Contribution of renewable energy sources to electricity generation in Germany (1990 – 2014)

Source: IASS based on BMWi (2015a)

2.2 Renewable energy sources in Europe

Although Germany is an important pioneer in the expansion of renewable energy, it is not alone in its efforts. In other European Union countries, renewable energy sources are also increasingly replacing conventional electricity generation. The share of renewable energy sources in Europe's electricity generation was at 25.4 percent in 2013 (Eurostat[3]), which is approximately the same level as in Germany (BMWi 2015b). With 45 percent, hydropower made up the largest share of electricity generated from renewable energy sources in the EU. In Germany, wind power constituted the majority of production, representing one third of the total amount, while hydropower accounted for only 15 percent. Between 2011 and 2013, renewable energy installations already made up some 70 percent of newly installed capacity in the EU. By 2014, this number had already increased to 78 percent. In Germany, renewable energy accounted for 84 percent of newly installed capacity in the year 2015 (own calculations based on Fraunhofer ISE Energy Charts[4]). As Figure 2 shows, the structural development of electricity generation in the EU does not differ fundamentally from that in Germany. While Germany does exhibit a significantly higher increase in the share of renewable energy, the decline of electricity generation from coal was not as significant as that at European level.

[3] See Eurostat data at http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=tsdcc330&plugin=1

[4] See Fraunhofer Energy Charts at https://www.energy-charts.de/power_inst_de.htm

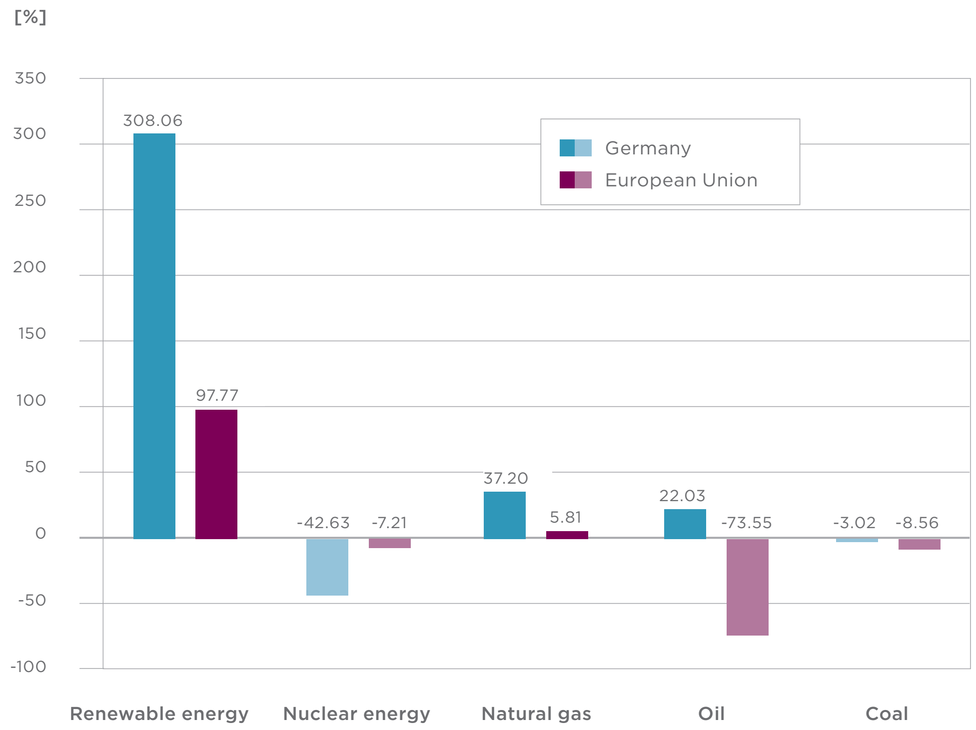


Figure 2
Change in electricity generation in Germany and the EU (2000–2013)

Source: IASS based on BMWi (2015a)/EU-ROSTAT Electricity and Heat Statistics as of May 2015

A less favorable picture – both for the EU and for Germany – emerges with regard to the renewable energy shares in total final energy. According to Eurostat, the share of renewables in the total energy consumption in Germany in 2013 was, at 12.4 percent, significantly below the share of renewables in the electricity sector. This put Germany below the EU average of 15 percent (Eurostat[5]) in that year. The reason for this is the low share of renewable energy in the heat and transport sectors. In the year 2014, renewable energy sources in Germany made up 12.2 percent of final energy consumption in the heating sector and 5.6 percent of final energy consumption in the transport sector (BMWi 2015a). In the future, however, the share of renewable energy in Germany's total final energy consumption is also expected to rise significantly, to 30 percent by 2030 and 60 percent by 2050 (German Federal Government Energy Concept, 28 Oct. 2010). EU-wide targets call for the share of renewables in the total final energy consumption to reach at least 27 percent by the year 2030 (European Council Conclusions, 24 Oct. 2014).

2.3 Global trends

The estimated global share of renewable energy in the overall power supply amounted to 22 percent in 2013, which is below the European average. The electricity sector is where the use of renewable energy sources has so far been most prevalent. This is true not only in Germany and the EU, but also around the world. Renewables only reached a share of 10 percent in the heating sector in the year 2013, which is less than the share in Germany, as Figure 3 shows. With regard to transport fuels, the global share of renewable energy sources only amounted to three percent (IEA 2015a: 348).

[5] See Eurostat data at http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=t2020_31&plugin=1

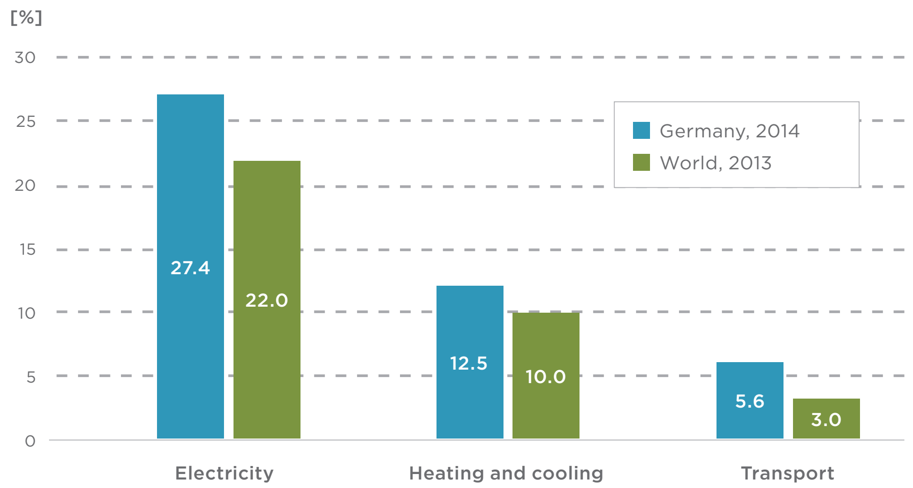


Figure 3
Share of renewables in the different energy sectors in Germany and around the world (2013/2014)

Source: IASS based on BMWi (2015a) (Germany)/IEA (2015a) (world)

Within renewable electricity production, hydropower makes up the greatest global share (74 percent), followed by wind power and bioenergy, with shares of 12.4 and 9 percent respectively. Photovoltaics and geothermal energy so far make up only very small shares of 2.7 and 1.4 percent respectively (own calculations based on IEA 2015a: 348). Due to the large share of hydropower, the global renewable energy mix differs significantly from that in Germany. Hydropower makes up only 12.1 percent of Germany's electricity production from renewables. At nearly 22 percent, the share of PV in Germany, on the other hand, is significantly higher than at the global level (own calculations based on BMWi 2015a).[6]

China now leads the world in terms of investment in renewable energy, accounting for approximately 30 percent of worldwide investments in 2014 (see Figure 4). After a peak of 11 percent in 2010, Germany's share dropped to less than 7 percent (own calculation based on BMU 2011; BMWi 2015a; Frankfurt School-UNEP Centre/BNEF 2015).

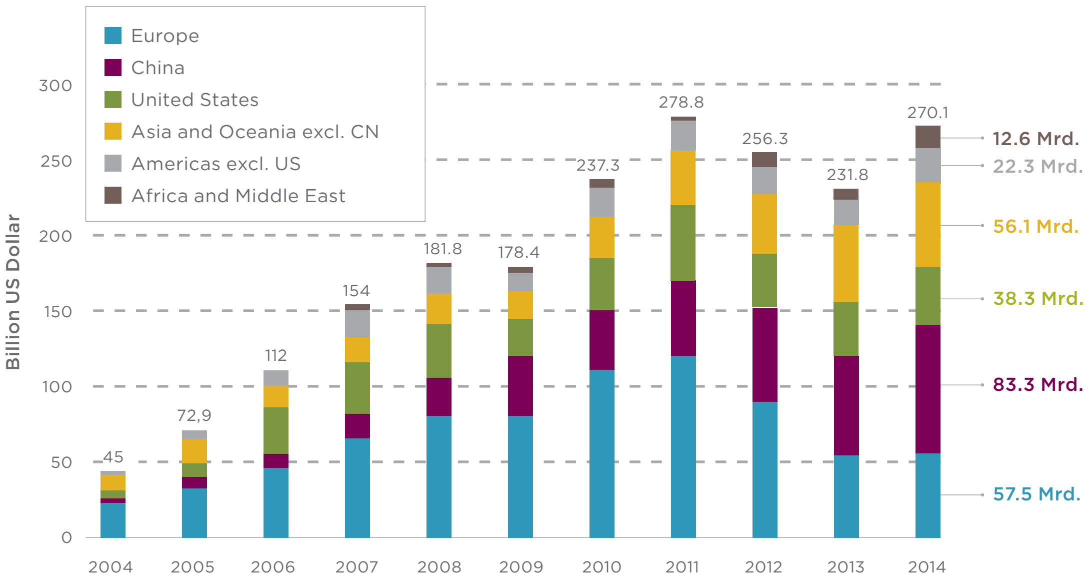


Figure 4
Global investments in renewable energy sources (2004–2014)

Source: IASS based on Frankfurt School-UNEP Centre/BNEF (2015)

[6] The shares of wind power and bioenergy in Germany are also higher than the global average. In Germany, wind power makes up 35.5 percent of renewable electricity generation, followed by bioenergy with a share of just above 30 percent.

In other developing and emerging economies, investments in renewables have recently also seen a sharp increase. In 2014 they increased by 40 percent to USD8bn (not including China), which corresponded to around 18 percent of total investments in the energy sectors of these countries (Frankfurt School-UNEP Centre, 2015). It is also notable that renewables now clearly dominate new investments in electricity production. According to the International Energy Agency (IEA), that share was at USD 250bn in 2013, which corresponds to over 60 percent of total global investments in new electricity production capacity (IEA 2014a). The year 2013 also marked a turning point in global capacity additions: In 2014, the share of renewable energy investment was at 59 percent, which is significantly higher than the capacity additions from fossil fuel and nuclear capacities (REN21 2015a; IRENA 2014: 25). In IEA member states, renewables already made up over 80 percent of total capacitiy additions in 2012 (IEA 2014d: II.5).

The dynamic expansion of renewable energy sources in the past years has been accompanied by a corresponding diffusion of renewable energy targets and the associated support mechanisms, in particular in the electricity sector. As Figure 5 shows, since the introduction of the EEG in the year 2000, the feed-in tariff has become an increasingly common instrument for promoting the market entry of renewable energy sources in countries around the globe.

Cumulative number of countries, states and provinces enacting feed-in policies

"Cumulative" refers to number of jurisdictions that had enacted feed-in policies as of the given year.

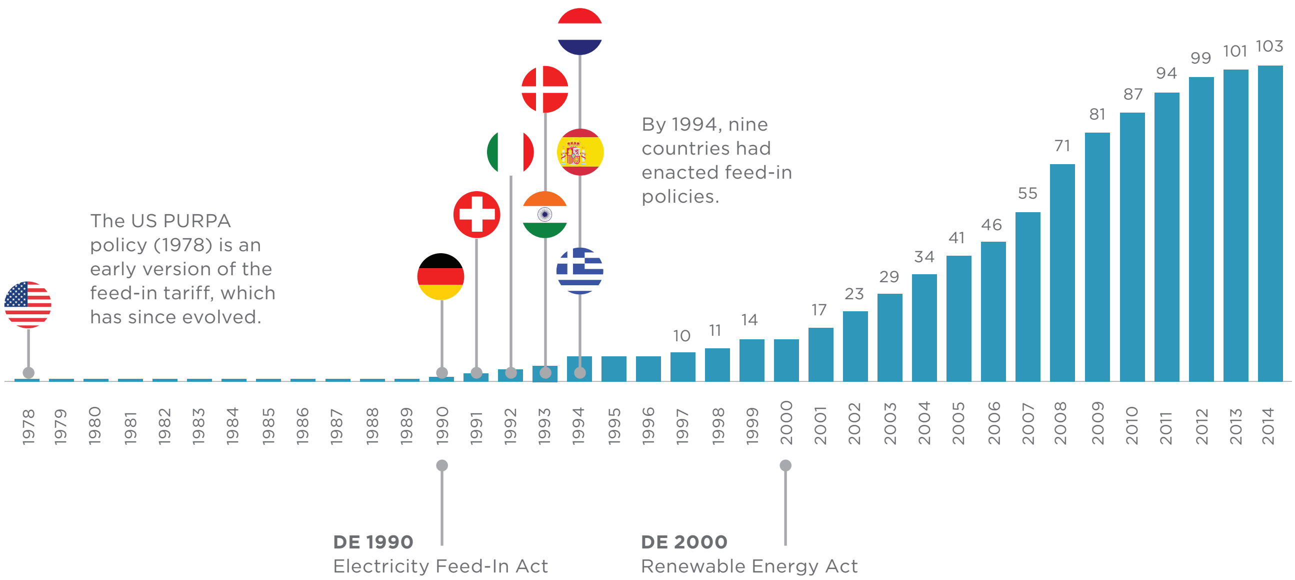
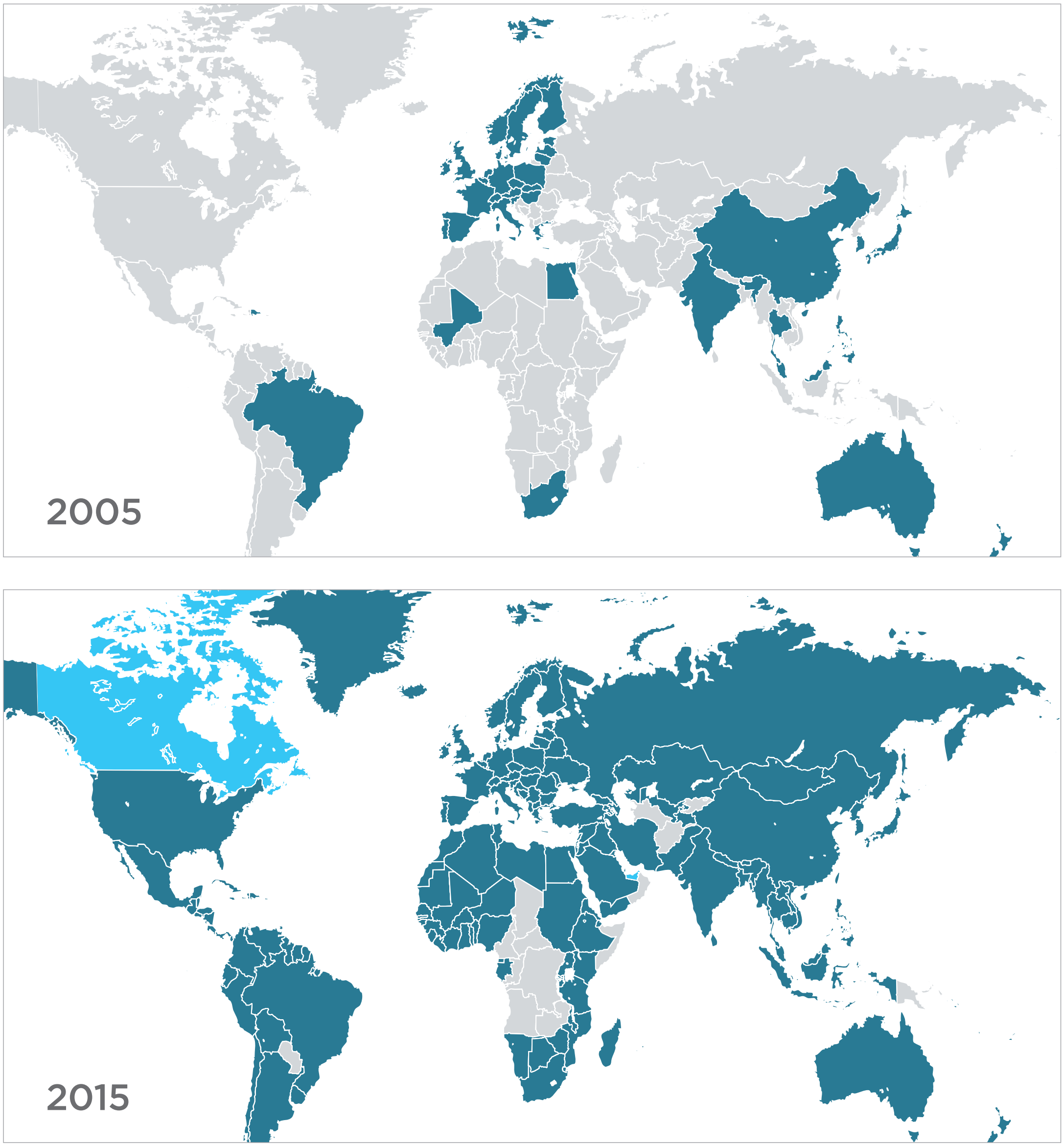


Figure 5
Global diffusion of the feed-in tariff (1978 – 2014)

Source: IASS based on REN21 (2015)

Whereas renewable energy sources have long been promoted in high-income countries, in the past ten years more and more emerging and developing economies have been introducing policies promoting the expansion of renewables. According to the International Renewable Energy Agency IRENA, by now 164 countries, or 85 percent of United Nations member states, have introduced national renewable energy targets (see Figure 6). In the year 2005, this was true for only 43 countries. In other words, within 10 years the number of countries with renewable energy targets has nearly quadrupled (IRENA 2015a; IPCC 2014).



Countries with at least one type of national renewable energy target

Countries with targets at the sub-national level only

Countries without targets

Figure 6
Countries with renewable energy targets (2005 and 2015)
Source: IRENA (2015a)

The expansion dynamic is partly due to the fact that in many regions of the world, production costs for electricity from renewable energy sources can by now (or will soon be able to) compete with the costs of conventional energy sources, even without taking externalized costs into account (see Figure 7). While hydropower, geothermal power and bioenergy have for years been competitive in many parts of the world, today even the costs of wind power and solar energy are, depending on factors such as resource availability and financing costs, well below the costs associated with new coal and gas fired power plants. In regions with particularly high solar irradiation levels such as in northern Chile, solar energy is now competitive even without long-term purchase guarantees (IRENA 2014).

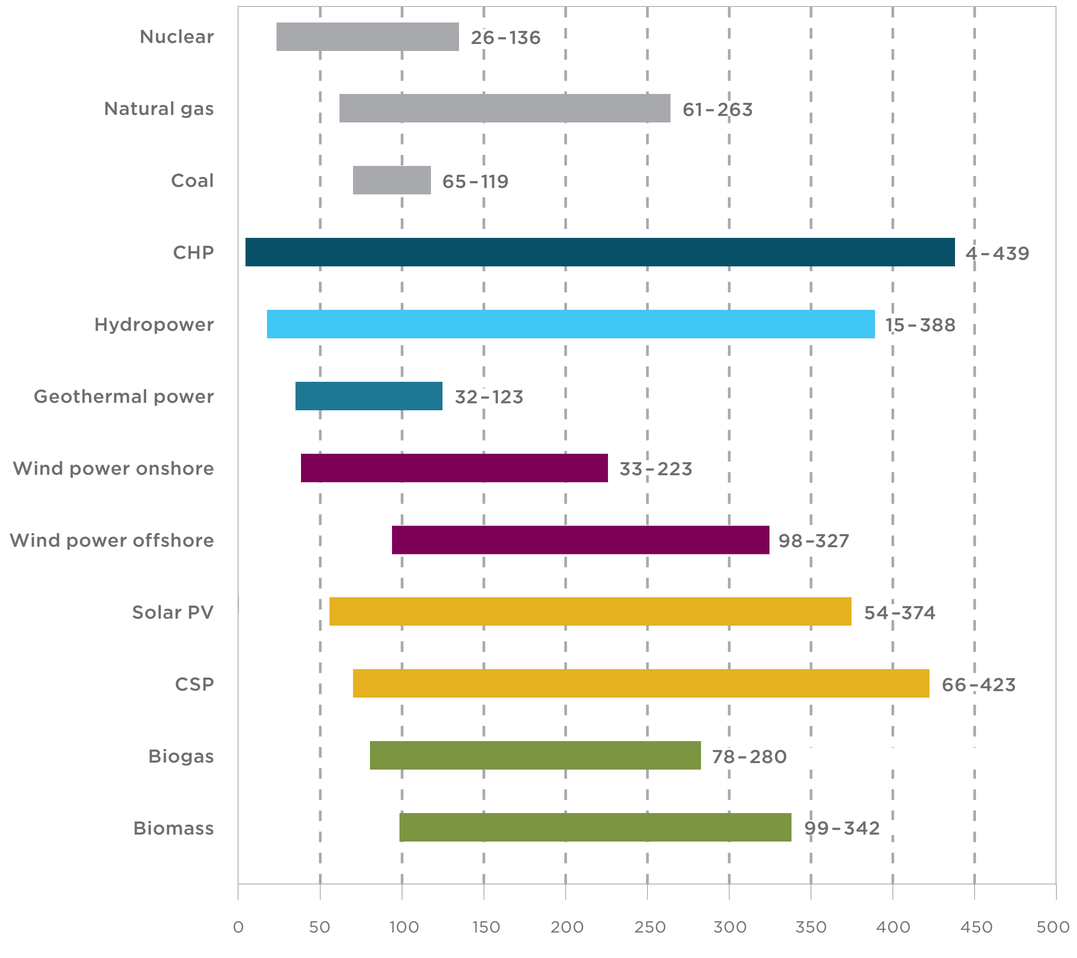


Figure 7
Electricity production costs by comparison

Source: IASS based on IEA/NEA (2015)

*combined power to heat

The figure shows the range of LCOE costs based on data from selected OECD and non-OECD countries. The maximum and minimum values are calculated on the basis of an assumed weighted average cost of capital of 3% and 10%, respectively.

Germany does not only expand the domestic deployment of renewables, but also engages in the worldwide promotion of renewables. With the Initiative Sustainable Energy For All (SE4All), the United Nations now also actively promotes renewable energy.

3. The global significance of the German *Energiewende*

The global significance of the German *Energiewende* is based on two key components: First, the German *Energiewende* generates demonstration and lead market effects. It shows other countries the fundamental feasibility of an energy transition and provides an example of the economic advantages that come with embarking on a sustainable energy path. Additionally, German market support for wind and solar power have contributed significantly to price reductions and efficiency improvements. Taken together, these effects have helped bring about a rapid acceleration of the global expansion of renewable energy technologies. Secondly, the domestic energy transition is also reflected in Germany's international engagement. The German federal government is firmly committed to promoting the expansion of renewable energy sources, not only within its own borders, but also in the context of its international cooperation.

3.1 Demonstration and lead market effects

In the area of sustainability and climate policies, globalization processes often follow the pattern of "lesson drawing" (Rogers 1993; Kern 2000; Tews et al. 2003; Busch/Joergens 2012). This means that the innovative solutions of pioneering countries act as a pattern for other countries to emulate, often in order to avoid their own "trial and error" processes (Jaenicke 2015). Based on Germany's economic strength as a highly industrialized country, the energy transition in Germany has a particularly strong signaling effect for other countries (see also Westphal 2012; Messner/Morgan 2013). Political measures and the technical-economic implementation of the energy transition in Germany thus attract a high level of international interest.With the introduction of feed-in tariffs for electricity from renewable energy sources, Germany has shaped the choice of policy instruments for the promotion of renewables. The Renewable Energy Sources Act (EEG), adopted in the year 2000, has been emulated by many countries around the world. At the same time, the stability of market support measures in Germany has contributed significantly to development of renewable energy technologies on their way toward reaching global competitiveness. The fixed feed-in tariff created a secure business model and the necessary framework conditions for significant investments in renewable energy systems when prices were still high relative to conventional energy sources. Together with the long-term goals set out for the expansion of renewable energy sources, this also became the basis for investments in the industrial manufacturing of technologies for electricity production from wind and solar power. Through the cost allocation of the feed-in tariff onto German final consumers, German electricity market customers financed an important part of the development costs (Matschoss/Toepfer 2015). The simultaneous R&D support measures further strengthened technology development through targeted investment. Both of these factors helped facilitate a global market penetration for wind and solar power by lowering manufacturing costs and improving efficiency levels. The particularly stable framework conditions in Germany constituted another reason why project costs, in particular in the PV sector, are significantly lower than in comparable markets (IRENA 2012). This illustrates the economic value of a stable, long-term support policy. Such state-induced market processes in environmental and climate policy have taken on a significant role and now have an exemplary function that also extends beyond the energy sector (Ernst & Young 2006; OECD 2011).

With the increasing shares of renewable energy sources in the German electricity mix, the interest of international observers is now focusing on the restructuring of an electricity supply system previously based on nuclear power and fossil fuels to one based on renewables. It should be emphasized that Germany must make this transition without significant hydropower resources. Instead, it must rely primarily on the fluctuating energy sources of wind and solar power. Furthermore, Germany, in contrast to many other countries, does not enjoy particularly favorable conditions in terms of solar and wind resources.As a result, the German *Energiewende* represents a particular challenge. This is also why Germany must rely on the cooperation of its neighbors. An increasing regional integration of the electricity markets offers important flexibility options, which are of great significance for the integration of fluctuating electricity production from wind and solar power. In this context, Germany's central position in a European electricity market constitutes a potential advantage. If successful, the further integration with the surrounding electricity markets will offer important lessons for other countries.

Finally, the German *Energiewende* is characterized by broad citizen participation and a very high level of support from the domestic population (see also Hirsch 2015; KAS 2013; KAS 2014). Not only is there widespread public support for the nuclear phase-out, the grassroots character of the expansion of renewable energy to date also promotes the support for projects at the community level. In the past, the high share of private owners and cooperative projects has meant that project development has often been initiated and financed by citizens themselves. In the year 2013, 47 percent of installed capacity was owned by citizens (Trend:research/Leuphana University Lueneburg 2013). Here too, we have recently begun to see similar trends in several other countries, particularly in Japan, the United States and China (UNEP/Bloomberg 2015).

3.2 International cooperation for the expansion of renewable energy sources

Over the past two decades, Germany has established itself as the driving force in international cooperation for a global expansion of renewable energy. Figure 8 shows key milestones of international cooperation on renewables since the year 2000.

One major success story was the foundation of the International Renewable Energy Agency (IRENA) in the year 2009, which by now has over 140 member states. IRENA promotes the global expansion of renewables by providing data and statistics on renewable energy sources and offering policy advice on funding mechanisms, technologies and policy developments. The German government took the initiative to found IRENA, mobilized support and organized the process of establishing the organization. To this day,

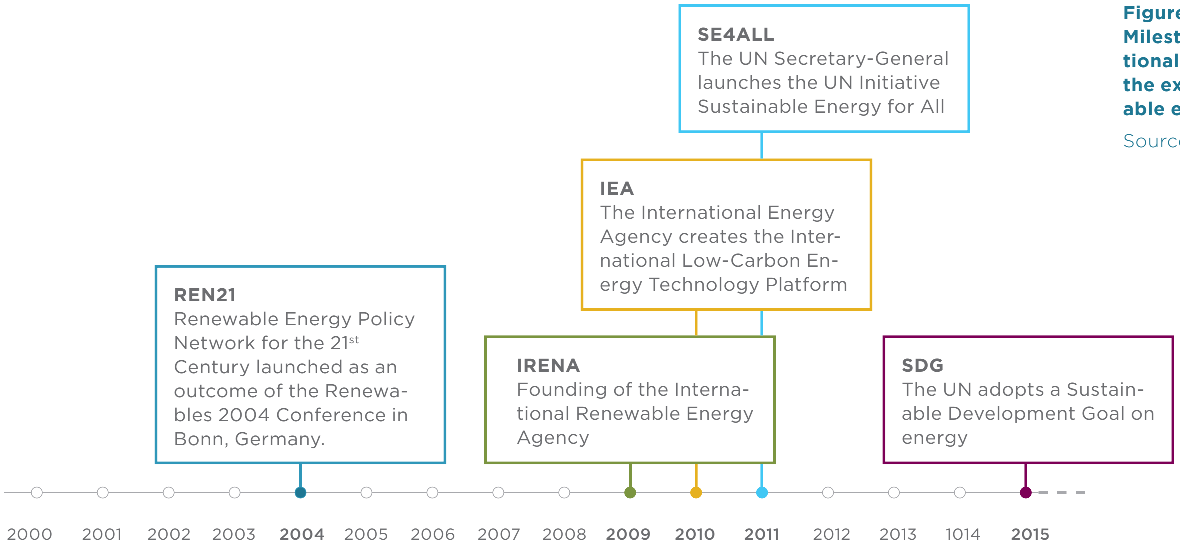


Figure 8
Milestones of international cooperation for the expansion of renewable energy sources
Source: IASS

Germany has played a key role in financing and organizing IRENA (Roehrkasten 2015a; Roehrkasten/Westphal 2013). Germany was also a co-founder of the multi-stakeholder network Renewable Energy Policy Network for the 21st Century (REN21). One of its central products is the Renewables Global Status Report, which is published annually and documents the promotion and use of renewable energy sources around the world. REN21 also organizes international conferences on renewable energy, which take place every two to three years in alternating countries.

Since the founding of REN21 and IRENA, there have been significant advances in international cooperation on renewable energy. The IEA has strengthened its institutional capacities in this area (Van de Graaf 2012). Even the United Nations, which had previously largely neglected renewable energy, are now becoming active. In fall of 2011, the UN Secretary-General launched the initiative Sustainable Energy for All (SE4All), which calls for a doubling of the share of renewables in a global energy mix by the year 2030. Within the same time period, the initiative aims to ensure universal access to modern energy services and double the improvement rate for energy efficiency. In September 2015, the United Nations also adopted sustainable development goals (SDGs) that forsee a significant global expansion of renewable energy.

In addition to these multilateral approaches, Germany is working through bilateral cooperation to promote the expansion of renewable energy (see BMZ 2014). For over 10 years now, renewable energy has been a focus of German development cooperation efforts. The energy sector is the largest funding area of German development cooperation, and Germany is the world's largest bilateral donor in the energy sector.[7] Germany's energy-related development cooperation entails the three areas of access to energy, renewable energy and energy efficiency. Between 2004 and 2011, Germany committed funds amounting to around 6 billion euros – 1.86 billion euros in the year 2011 alone. As a contribution to the UN initiative SE4ALL, the German federal government plans to significantly expand this funding. By the year 2030, funds are to be doubled to a total of 3.6 billion euros per year (BMZ 2014: 11). Beyond its development cooperation, the German government maintains bilateral energy partnerships with 11 countries (Algeria, Brazil, China, India, Morocco, Nigeria, Norway, Russia, South Africa, Tunisia and Turkey). According to official sources, these partnerships with key countries in the areas of energy production, transit or consumption aim primarily at the expansion of renewable energy and the improvement of energy efficiency.[8]

Finally, Germany has in recent years also been active on the European stage in promoting an ambitious energy and climate policy. An important achievement was the introduction of the binding target of a 20 percent renewables share in the EU's electricity mix by 2020, and the setting of corresponding national targets. In negotiating the targets for the year 2030, however, Germany showed less of a commitment (Ancygier/Szulecki 2013). The elimination of binding national targets for the expansion of renewable energy sources in the EU 2030 climate and energy framework must be seen as a setback for Germany's energy transition policy. Within the context of its European policy, Germany also failed to actively pursue a greater harmonization of European funding policy on the basis of the successful German model. Instead, German policymakers have chosen to rely on the exemplary effect of Germany's energy transition policy (Geden/Fischer 2014; Solorio, Oeller and Joergens 2014). More recently, efforts to enable a more active coordination and integration with Germany's electricity neighbors have increased. In June 2015, for example, the federal government and the governments of 12 important neighboring countries signed a political declaration to strengthen cooperation with regard to security of supply (BMWi 2015c).

[7] According to OECD.Stat (2016) data Germany has been the biggest bilateral donor in the energy sector, followed by Japan. Between 2010 and 2014, 18 percent of German official development aid has been channeled to the energy sector.

[8] BMWi, energy partnerships, http://www.bmwi.de/DE/Themen/Energie/Europaische-und-internationale-Energiepolitik/internationale-energiepolitik,did=551754.html

China leads the world in terms of installed windpower capacities.

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4. The global expansion of renewable energy – a dynamic interplay of pioneer countries

Despite the key role it plays, Germany is not the only pioneer of the global expansion of renewable energy. Already in its early phase, the global expansion of renewables was driven by a number of pioneering countries and their support mechanisms and strategies. The dynamic acceleration of the expansion of renewable energy was enabled not by one single country or event, but by the interplay of the strategies of various countries. In addition to Germany, other countries such as Japan, the United States, Denmark and, more recently, China, made key contributions to the global development in this sector and thus also to the expansion of renewable energy in Germany.

4.1 International pioneers of wind and solar power development

In the area of wind and solar power, developments in Germany played a key role for an *acceleration* of the expansion dynamic. After the U.S. and Denmark put great effort into expanding wind power in the 1970s and 1980s, the German support policy in the 1990s then became the main driver for an exponential increase of the global wind power capacity. The installed capacity in Germany increased a hundredfold, from 62 MW (1990) to over 6 GW (2000), and accounted for more than one third of global capacity additions during that time period.[9] The German market played a similarly pivotal role in the global breakthrough of solar energy during the subsequent decade. In the year 2000, the German government introduced the world's first support scheme without volume restrictions. An increase of the support rates in the year 2004 was then the trigger for Germany's dynamic market growth. In the subsequent years, the stable market conditions that were instituted here created the foundation for substantial investments in module production and thus for far-reaching cost reductions in the course of the decade (see Figure 9). In addition, the close cooperation between module manufacturers, research institutions and the engineering industry enabled a steady improvement of the means of production (Bruns et al. 2009; Quitzow 2014).

[9] Own calculations based on data from Earth Policy Institute Data Center (http://www.earth-policy.org/?/data_center/C23/).

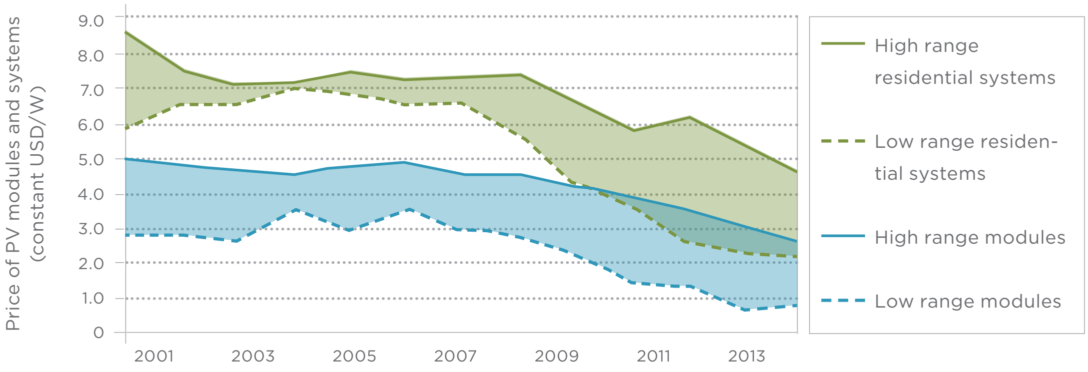

Figure 9
Cost reductions for photovoltaic modules and systems (2001–2013)
Source: IEA-PVPS (2014)

In both sectors, however, developments in Germany must be seen as dependent on the strategies of other countries, which prepared or amplified market expansion in Germany.In Europe, besides Germany, markets in Italy and Spain were for years the key drivers of global demand. China has also made a significant contribution to the development of solar and wind power. In the solar sector, as of 2005 investments by Chinese firms played a central role in developing mass production of photovoltaic cells and modules, thus overcoming the scarcity on the global market that existed at the time. From 2004 to the end of 2008, this scarcity had brought about an increase in module prices (Quitzow 2014). Following the expansion of Chinese production capacities, the country established itself as a central engine for increasing global demand. Since 2013, China has led global expansion with over 10 GW per year (REN21 2015, 2014). And for nearly 10 years now, China has played a similar role in the global expansion of wind power, accounting for the highest amount of new wind capacity since 2009 (Fraunhofer IWES 2014, 2015).[10]

The United States has also played an important role in both sectors at various stages of development. At the end of the 1970s, a series of measures at state and federal level triggered a veritable wind power boom in California. In the 1980s, the American market accounted for over 75 percent of global demand. Due to the lack of domestic production in the U.S., it was mainly companies from Denmark, the pioneering country for technology development in the wind sector, which profited from these market developments (Ohlhorst 2008). The interaction of these two countries during this period enabled important technological advancements as well as significant cost reductions. Denmark is still the country with the highest market penetration, while the U.S., following a phase of very slow growth, has over the past 10 years led the expansion of wind power together with China (Fraunhofer-IWES 2015).

In the solar power sector, the United States was long the pioneer in terms of technological development. Particularly impressive was the “Flat-Plate Solar Array Project,” which between 1975 and 1985 was funded with a budget of USD 1.5bn and contributed significantly to reductions in cost (Callaghan/McDonald 1986). Early market and industrial developments were driven by Japan. Since the 1970s, market developments there were dominated by applications in household appliances, energy supply of telecommunication masts and other *off-grid* applications. In the 1990s, Japan introduced the first large-scale program for rooftop PV systems. Japan’s stable funding policy during this period led to important investments in the industrial production of photovoltaic modules by manufacturers such as Sharp, Sanyo and Kyocera. A steady reduction of subsidies resulted in module prices falling by half between 1994 and 2000 (Kimura/Suzuki 2006). Box 1 provides a detailed account of the historical development of the photovoltaic sector.

[10] The U.S. only managed to achieve a slightly higher level of new capacity in the year 2012.

HISTORICAL DEVELOPMENT OF THE PHOTOVOLTAIC SECTOR

Box 1

The history of the modern photovoltaic industry begins in the United States with the discovery of crystalline photovoltaic technology by Bell Labs in 1954. The technology was subsequently developed further in the U.S., primarily for aerospace applications such as power supply for satellites. By contrast, Japan began in the 1960s to pursue the use of solar technology in household appliances such as in calculators (Kimura/Suzuki 2006; Willeke/Raeuber 2012).

As a result of the oil crisis, photovoltaics were for the first time discussed as a serious alternative to conventional energy supply. In addition to Japan and the United States, Germany also invested in the development of photovoltaic technology during this period. However, the most ambitious level of activity was in the United States. In 1975, the "Flat-Plate Solar Array Project" was launched, which was funded with a budget of USD 1.5bn over a period of 10 years. A central project goal was the reduction of manufacturing costs to USD 0.50 per Wp. Although that target was not attained, manufacturing costs were still greatly reduced – by USD 75 to under USD 10 and to an estimated USD 1.50 for industrial manufacturing (Callaghan/ McDonald 1986).

In the 1980s, the United States and Japan continued to be the world's largest manufacturers and users of photovoltaic products. In Japan, the energy supply of telecommunication masts and other off-grid applications played a particularly significant role. In the early 1990s, Germany launched an important initiative with its 1000-roof program, which was the first large-scale program for grid-connected photovoltaic systems. After this program was phased out in the year 1994, funding for new photovoltaic installations by the German federal government came to a standstil, so that for the following five years the market was primarily kept alive by local citizens and municipal initiatives (Willeke/Raeuber 2012).

In Japan, by contrast, the government continued its ambitious policies of previous decades and in 1993 launched a 70,000-roof program. For the next 10 years, Japan remained the world's largest market for photovoltaic products. Japan's stable funding policy during this period led to important investments in the industrial production of photovoltaic modules by manufacturers such as Sharp, Sanyo and Kyocera. During this period, the continuous reduction of subsidies also led to steady decreases in module prices from around USD 6 to USD 3 per Wp. This was both due to a reduction of production costs as well as the willingness of these companies to sell modules at a loss in order to secure their leading position in this newly developing market (Kimura/Suzuki 2006; Mints 2012).

In the year 2004, Germany began its rise to become the largest market for photovoltaic systems. That year, the feed-in tariff for photovoltaic electricity, introduced in the year 2000, was increased to a maximum of EUR 0.574 per kWh, which made the installation of rooftop solar systems profitable even without additional funding measures. As the first funding policy without volume restrictions, this triggered a rapid rise in demand. However, bottlenecks in the silicon production initially impeded the necessary expansion of module manufacturing. In the year 2008, a short-term boom in the Spanish market brought about an additional rise in demand, so that international module prices for that year even increased to USD 4 per Wp (Quitzow 2014; Willeke/ Raeuber 2012).

For a time, this imbalance of supply and demand triggered a global investment boom. Chinese companies in particular took advantage of the favorable market environment to increase their sales in Europe and attract new investors. Between 2005 and 2008, 10 Chinese solar power companies went public on the New York and London exchange. These IPOs achieved around 50 percent of the global revenue from the sale of shares during this period. The associated increase in supply then led, in the year 2009, to the expected drop in module prices to around USD 2 per Wp (Quitzow 2014). This in turn led to an acceleration of new photovoltaic deployment, in particular in Europe, but also in Japan and the United States. In addition to Germany, Italy also instituted particularly favorable support conditions, so that between the years 2009 and 2012, nearly half of new global deployment took place in those two countries.[11]

In both countries, the feed-in tariff is allocated onto the electricity price and paid for a period of 20 years. As a result, during this boom phase, the annual amount of surcharges increased to nearly EUR 20bn in Germany and over EUR 8bn in Italy (Antonelli/Desideri 2014; Matschoss/Toepfer 2015). In both cases, the increasing cost of support was the reason for introducing mechanisms to restrict further expansion. Since 2013, however, the slow-down of expansion in Europe was more than made up for by the deployment of new capacity in other regions of the world. Due to the large production capacity in China, the Chinese government in 2009 set out ambitious expansion targets. These have been raised on numerous occasions since then, and by now are at 100 GW. Since 2013, China has led the global expansion of photovoltaics with over 10 GW, followed by Japan and the United States. European markets, by contrast, now account for less than 20 percent of annual new deployment (REN21 2013a, 2014, 2015).

[11] Own calculations based on data from Earth Policy Institute Data Center (http://www.earth-policy.org/?/data_center/C23/).

4.2 Pioneers of electricity production from renewable energy sources

With regard to the cumulative capacity of the renewable energy supply, China and the United States play an important role in other areas of renewable energy technology as well (see Figure 10). In addition to wind power and PV, China also leads in the area of hydropower. The only fields in which China does not play a leading role are geothermal and concentrated solar power (CSP, also known as solar thermal power). The United States leads the areas of bioenergy and geothermal, while it ranks second in wind power and concentrated solar power. In hydropower and PV, the U.S. is among the top five. Brazil, India, Italy, Japan and Spain also figure among the leading countries in multiple technology fields. In addition to wind power and PV, Germany also plays a leading role in the area of bioenergy.

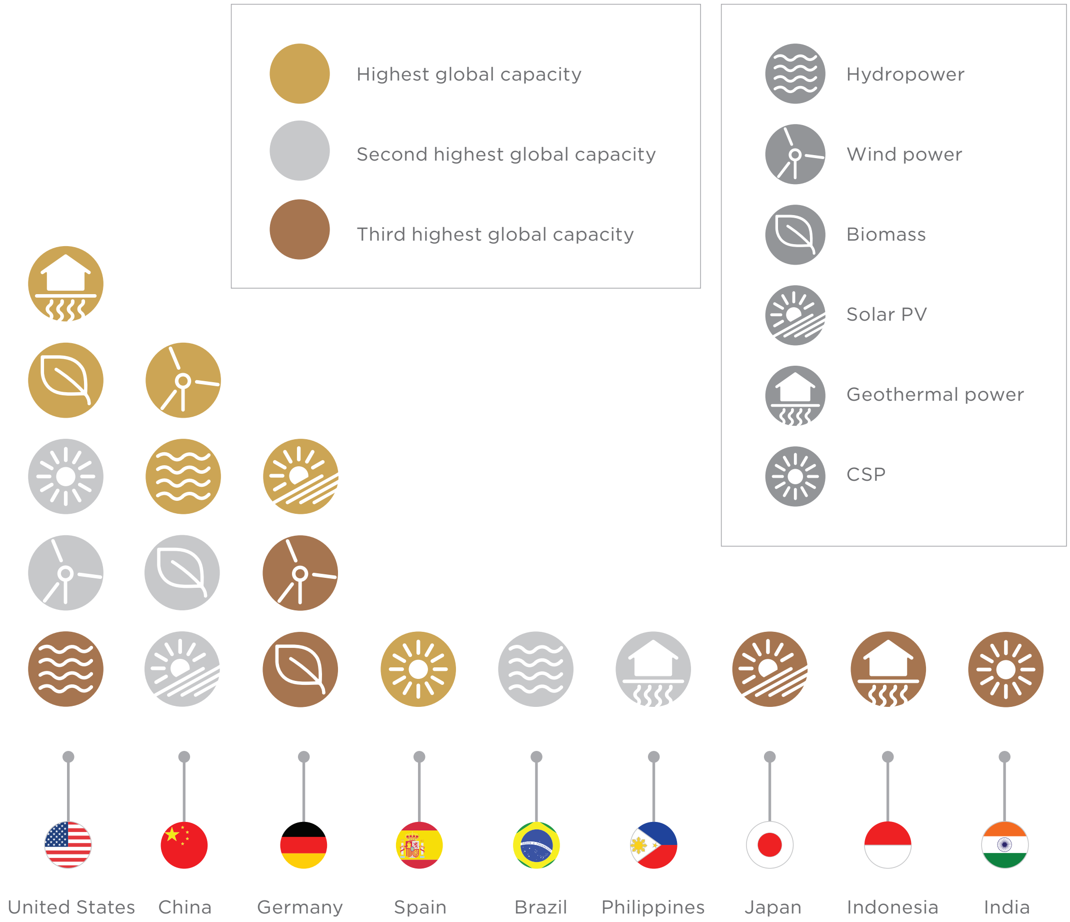

Figure 10
International leaders in the expansion of renewable energy sources (2014)
Source: IASS based on REN21 (2015)

Today, according to the U.S. Energy Information Administration (EIA)[12], in more than 50 countries in the world, over 50 percent of electricity production already comes from renewable energy sources (EIA International Energy Statistics 2012) (see Figure 11). This applies in particular to countries with significant hydropower capacities. In these countries, hydropower was able to prevail early on against other energy sources. In 12 countries, including Ethiopia, Costa Rica, Iceland, Nepal, Norway and Zambia, as much as 98 to 100 percent of the electricity supply is covered by renewable energy sources. Within the EU, Austria (78 percent), Latvia (68 percent), Sweden (60 percent), Denmark (51 percent), Croatia (50 percent), Portugal (44 percent) and Finland (42 percent) have particularly high shares of renewables in their electricity mix. In some cases, countries reach high shares of renewable energy even without hydropower. Denmark presents the most remarkable case. It has reached a share of nearly 50 percent of its electricity production with renewables, not including hydropower. Similarly, Portugal, Nicaragua, El Salvador and Iceland all reach renewables shares of around 30 percent without hydropower. According to statistics by the U.S. Energy Information Administration for the year 2012, Germany ranked 10th, with just over 20 percent of its electricity production from renewables not including hydropower (EIA International Energy Statistics 2012).

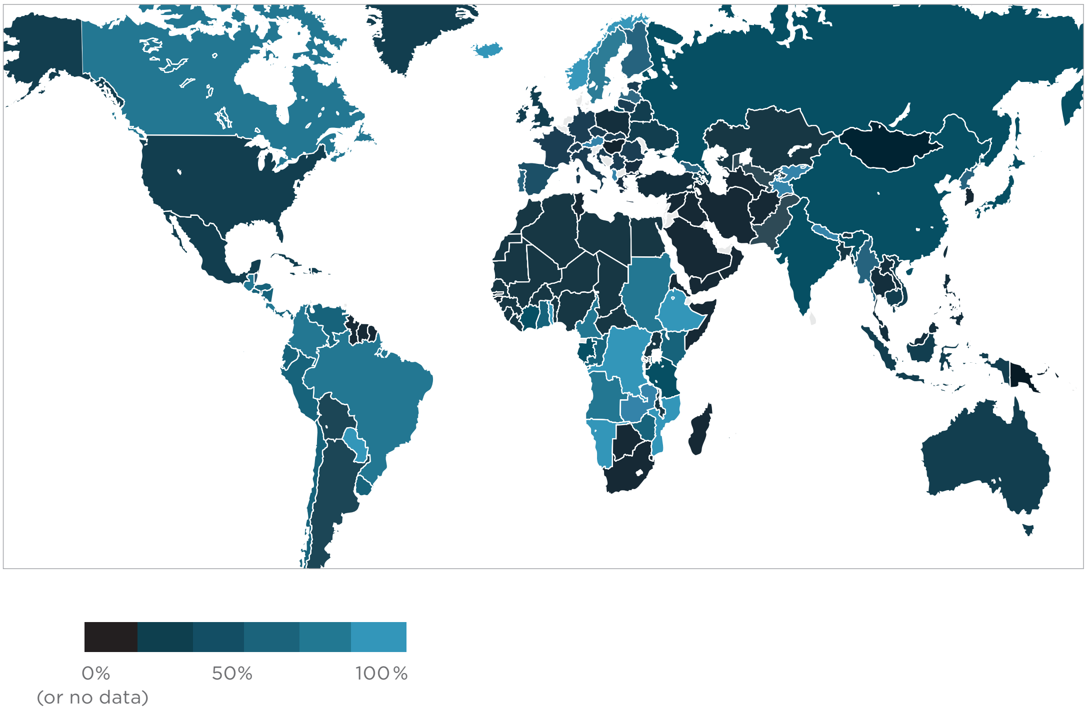

Figure 11
Renewables-share in electricity generation in global comparison (2013)

Source: IASS based on data of the World Bank and the IEA World Energy Balances 2013

[12] The figures in this section have been calculated using data from the U.S. Energy Information Administration for the year 2012 (http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=2&pid=2&aid=12).

In terms of its deployment so far, but also its ambitious expansion targets for renewables, Germany does not stand alone. While Germany aims to provide for an 80 percent share of renewables in the electricity sector and a 60 percent share of total final energy consumption in 2050, some countries have set out a goal of covering 100 percent of their electricity or energy supply with renewable energy sources. On the one hand this includes countries in which hydropower plays an important role, such as Costa Rica, Scotland and the Republic of Fiji. But also Denmark and Tuvalu intend to rely completely on renewable energy sources, even though they do not have significant hydropower capacities at their disposal. While Denmark relies primarily on wind power and bioenergy to do so, Tuvalu's main energy source is solar power (REN 2015: 140f., 151; IRENA RESource).[13]

4.3 Beyond the transition in the electricity sector

Finally, there are other pioneering countries that are advancing the expansion of renewable energy in areas beyond the electricity sector. Particularly noteworthy are the measures to promote an energy transition in the transport sector in countries like Brazil, the U.S., Sweden and Norway (see Box 2). The transport sector, after all, poses a particular challenge for a global energy transition, as no other sector is still so dependent on fossil fuels (IEA 2015a: 348).

Pioneering countries can also be identified in the area of heating and cooling with renewable energy sources. Renewables account for a share of 10 percent of energy supply in this area (IEA 2015a: 348). In an international comparison, very high shares of renewables in heating and cooling can be found in northern European countries. Sweden leads the world in this area with 67.2 percent, followed by Finland and Latvia, each with approximately 50 percent. Denmark, Estonia, Lithuania, Austria, Portugal and Slovenia also achieve a renewables share of over 30 percent. In Germany, by comparison, the share of renewables in heating and cooling is only 12.2 percent, which is slightly above the world average (REN21 2015: 142). In the area of renewable heat, energy from biomass and biogas has played the greatest role so far. It is used primarily in Europe, Asia and North Africa. In northern Europe, it is used mainly used to power district heating systems. Among European countries, Sweden, Finland, Germany, France and Italy play a leading role. Solar and geothermal heating also contribute to the energy supply for renewable heating. For the generation of cooling, there has so far only been minimal use of renewable energy sources. Within the past few years, however, the global market for solar cooling technologies has grown significantly, with annual growth rates of over 40 percent. Solar cooling is used mainly in Asia, Europe, the Middle East and North America (REN21 2015: 33f, 42.).

A final area that is of great significance for the global energy transition is energy efficiency. Between 2006 and 2011, the number of countries with national energy efficiency targets has doubled (ADEME/World Energy Council 2013). The EU has set out the indicative target of attaining energy savings of at least 27 percent by 2030, relative to the business as usual scenario (European Council Conclusions, 24 Oct. 2014). Furthermore, energy efficiency targets have been adopted by countries such as China, India, South Africa, Thailand, the U.S., as well as the ECOWAS countries (REN21 2015: 119f.). In a study published by the American Council for an Energy-Efficient Economy, the performance of the 16 largest economies was compared in the area of energy efficiency, based on 31 indicators.[14] In the overall assessment as well as in the industrial sector, Germany ranks first, followed by Italy, the EU and China (in the overall assessment). In the transport sector, Italy leads the field, followed by India, Japan and Great Britain. Here, Germany ranks only 13th. In the building sector, China is ranked first, followed by Germany, the EU, and France (Young et al. 2014).

[13] In Denmark the 100-percent target applies to the energy supply system as a whole, while in the other countries it applies only to the electricity sector.

[14] The indicators represent both policy measures as well as quantitative data on the performance and improvement rate in both the economy as a whole as well as in the building, industry and transport sectors. Individual indicators are weighted differently according to a point system.

Box 2

PIONEERS OF AN ENERGY TRANSITION IN THE TRANSPORT SECTOR

The worldwide pioneer of an energy transition in the transport sector is Brazil. It began in the 1970s with the transformation of the transport sector to renewable energy sources. As a reaction to the oil crisis, Brazil launched an ambitious program to substitute oil with ethanol produced from sugar cane. This period was also when the country's ethanol infrastructure was created, which now allows Brazilian motorists to fill up with ethanol at any of the country's filling stations. A key milestone was reached with the development of flex-fuel vehicles, which had their market rollout in the year 2003. These vehicles can be operated with any blend of gasoline and ethanol. They now they make up 95 percent of new cars sold in Brazil. Brazilian drivers can thus decide flexibly between gasoline, which in Brazil contains a mandatory blend of 18 to 25 percent ethanol, and pure ethanol. During the period from 2008 to 2014, the Brazilian market reached ethanol blend rates of between 47 and 90 percent. This makes Brazil the country with the world's highest fuel blend levels. Brazil is the second highest biofuel producer in the world, behind the United States. In the year 2014, the country reached a rate of 23.4 percent, which is a much smaller percentage than that reached in the U.S., where 47 percent of the world's biofuel is produced. However, that is still significantly higher than the world's third largest producer Germany, which only has a 3.4 percent share of the world market. The environmental impact of the Brazilian ethanol production is disputed, however. While critics mainly point out the negative effects of the spread of monocultural agriculture, supporters emphasize the positive CO_2 balance as a result of using ethanol from sugar cane (IEA 2014b: 254; Roehrkasten 2015b; USDA Foreign Agricultural Service 2014; REN21 2015: 129).

In the United States, the introduction of the Renewable Fuel Standard in 2005 was the decisive driver for the use of biofuels (IEA 2014b: 252), which set the target to replace 7.5 billion gallons of gasoline with renewable fuels by the year 2012. In an expansion of the Renewable Fuel Standard in 2007, the U.S. government raised this target to 36 billion gallons by the year 2022. At filling stations in the U.S., gasoline with an ethanol fuel blend of 10 percent (E10) is available. Flex-fuel vehicles are also becoming more important in the U.S. market. By now they account for five percent of light utility vehicles in the United States and can be operated with an ethanol fuel blend of up to 85 percent (E85). However, only two percent of filling stations in the United States offer E85. These are located primarily in the Midwest, for example in Minnesota, Illinois, Iowa and Wisconsin, where ethanol production has traditionally been strongest. In the year 2013, ethanol replaced around 10 percent of gasoline demand in the U.S. (REN21 2014: 34).

Sweden has established very ambitious targets for the energy transition in the transport sector: Sweden aims for a completely fossil fuel-free vehicle fleet by the year 2030, relying fully on biofuels and electromobility (REN21 2014: 29), and aims for an energy supply system with zero net greenhouse gas emissions by 2050. This requires major efforts, in particular in the transport sector, which at 45.3 percent accounts for the largest share of energy-related CO_2 emissions in Sweden (IEA 2013: 11). Already today, the share of biofuel in Sweden is, at 11 percent, the highest in the EU (EurObservEr 2014: 8).[15] In addition to an Increased use of bioenergy (ethanol, biodiesel, hydrogenated vegetable oils (HVO) and biogas), Sweden is particularly interested in improving energy efficiency in the transport sector. Furthermore, Sweden aims to reduce the demand for (fossil) energy sources and promote electromobility by bringing about changes in societal behavior in the transport sector. Tax incentives promote energy efficiency and the use of renewable energy sources in passenger cars. In terms of vehicle technology, Sweden is focusing on flex-fuel vehicles, electric and hybrid vehicles. In its country study on Sweden in the year 2013, however, the IEA points out that more ambitious measures are necessary in order to actually achieve the goal of a fossil fuel-free vehicle fleet by 2030 (IEA 2013). In Sweden and Norway, biofuels are already being used in commercial aviation. Norway is also investing heavily in electromobility. In 2014, Norway had the world's highest share of electric vehicles relative to total new vehicle sales. While this share was still at 12 percent in 2014, already during the first quarter of 2015 more than one third of newly registered vehicles in Norway were powered by electricity (REN21 2015; Forbes 23 July 2015).

[15] http://www.eurobserv-er.org/pdf/eurobserver-biofuels-barometer-2014-en/

In Delhi and many other cities of the world, inhabitants suffer from air pollution. Renewables can significantly improve air quality.

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5. The multiple benefits of renewable energies – drivers of a global energy transition

The worldwide expansion of renewable energy is linked to a wide range of benefits that can be achieved with renewables. The first benefit to be stressed is the close correlation between the energy transition and climate protection. That said, a central difference between international climate policy and the global expansion of renewable energy should be highlighted: While international climate policy still emphasizes the need for *burden sharing* as a way of distributing the costs of an ambitious climate policy, in the expansion of renewable energy a greater priority is attached to *opportunity sharing*. It is these opportunities which have enabled the global expansion of renewable energy sources. The following section outlines the most important benefits of renewable energy and discusses their role as drivers of renewables deployment around the world.

5.1 The energy transition: indispensable for climate protection

The increased expansion of renewables within the context of a global energy transition is indispensable for the reduction of greenhouse gas emissions and for the attainment of international climate protection targets. Global energy supply is, after all, responsible for two thirds of global greenhouse gas emissions (IEA 2015b). According to IEA estimates (2012: 3), by 2050 only two thirds of the world's proven reserves of fossil fuels may be extracted if global warming is to be limited to an increase of two degrees and CCS (carbon capture and storage) technologies have not become widespread. To achieve effective climate protection, a curtailment of the global use of coal and oil is paramount (IEA 2014b: 87f.). Important partial successes have already been achieved. Recent figures from the IEA show that global emissions of carbon dioxide from the energy sector stalled in 2014, marking the first time in 40 years that this did not occur as a result of an economic downturn. This is the first indication of a decoupling of energy-related carbon emissions from economic growth. The IEA attributes this development in particular to the increased expansion of renewable energy sources (hydropower, solar and wind) as well as to a reduced coal consumption in China, as well as greater efforts in energy efficiency and in the promotion of renewable energy in OECD economies (IEA 2015b: 11).[16] The global consumption of coal declined slightly in 2014 and to an even greater extent in 2015 (BloombergBusiness, 9 Nov. 2015).

The expansion of renewable energy with a concurrent increase in energy efficiency also brings with it important potentials that extend beyond climate protection, both with regard to economic and social development as well as to a greater degree of environmental sustainability for the energy system. Ultimately, the broad range of so-called *co-benefits* created by an environmentally-friendly development path means that climate protection can be combined with a new model of prosperity. The IPCC identified 18 *co-benefits* of the expansion of renewable energy sources (IPCC 2014; Jaenicke, Schreurs and Toepfer

[16] See also IEA, "Global energy-related emissions of carbon dioxide stalled in 2014," http://www.iea.org/newsroomandevents/news/2015/march/global-energy-related-emissions-of-carbon-dioxide-stalled-in-2014.html

2015). The IEA has also developed a *multiple benefits* approach with regard to energy efficiency (IEA 2014c). The expansion dynamic outlined above could not be explained without these benefits, in particular the economic ones.

5.2 Renewable energy as an economic development opportunity

IRENA estimates that in 2015 approximately 7.7 million jobs are directly and indirectly dependent upon the renewable energy sector (IRENA 2015b). In Germany, gross employment in this sector is estimated at approximately 400,000 (O'Sullivan et al. 2014). This amounts to around half the number of jobs in the domestic automobile industry, Germany's most important industrial sector. Even after job losses have been taken into account, for example from job cuts in the coal-based energy supply sector, a positive balance is still expected (Lutz et al. 2014). For many countries, these economic potentials constitute a central driver for the domestic expansion of renewable energy. An increasing number of countries are striving to take the lead in the industrial manufacturing of technologies for renewables-based electricity generation. Already in 2010, China developed a strategy to promote seven so-called *emerging industries*, including the renewable energy industry (State Council of the PRC 2010). But also countries such as Korea or the United States have formulated corresponding policy goals (Presidential Commission on Green Growth 2009; The White House 2011). A number of emerging and developing economies are focusing efforts on maximizing domestic shares of value creation and employment effects (Jacob et al. 2014). In many cases, there is a higher degree of labor intensity associated with renewable energy as compared to conventional power plants, which given similar production costs has positive effects on employment.

5.3 Potentials of a decentralized energy supply for poverty reduction and innovation

Decentralized energy supply using renewable energy sources also creates an important opportunity for expanding access to energy at the base of the income pyramid. Here, the challenges are still considerable: 1.2 billion people around the world have no access to electricity. This corresponds to 17 percent of the world's population – or the entire population of the OECD world (IEA 2015a: 101). Sub-Saharan Africa is particularly affected, where two thirds of the population still have to get by without electricity (IEA 2014b: 28f., 73f.). By avoiding the high costs of network expansion, the use of renewable energy technologies can lower the barrier for electrification. Synergies with other innovative business models and technologies also create important new development paths. The combination with the microfinance and mobile telephone sectors as well as the digital communications infrastructure offers great potential for developing new products and business models that can make a significant contribution to improving living conditions in poor communities. New energy services are both the result and an important pillar of these emerging development paths.

5.4 Energy security and price stability

Renewable energy and energy efficiency can make an essential contribution to energy security and independence from the significant price fluctuations of fossil fuels. This is of particular importance in countries that are faced with a sharp rise in energy demand or whose energy supply is highly dependent on imports. According to IEA estimates, global energy demand will rise by 32 percent by 2040 (IEA 2015a: 53). While energy consumption is stagnating in many parts of Europe, Japan, Korea and North America, demand is rising sharply in the rest of Asia, in the Middle East and in Latin America. Asia will account for 60 percent of the global increase in demand. While China will remain a central engine of growth for global energy demand until the year 2030, it is expected that as of 2030, India, Southeast Asia, the Middle East and sub-Saharan Africa will take over this role (IEA 2014b: 53 ff.).

For many countries, reducing the reliance on energy imports is also a concern from a security policy standpoint. Renewable energy that is generated domestically can, for example, reduce the political dependency on energy exporting countries as well as the vulnerability due to possible interruptions of supply. The European Union, for example, has a high degree of import dependency with regard to oil and gas supply. Over 80 percent of oil and over 60 percent of gas resources consumed by EU member states are imported. Additionally, around two thirds of gas imports come from only two countries – Norway and Russia. Reducing the demand while simultaneously increasing the use of renewable energy presents an important opportunity to reduce this dependency (Blandow et al. 2010).

In India – as has so far been the case in China as well – a steep rise in energy demand goes hand-in-hand with an equally steep increase in import dependency. The import share of fossil fuel consumption increased between 1990 and 2012 from 15 percent to nearly 40 percent. Here, the expansion of renewable energy can help to diversify the energy mix and utilize domestic energy sources. While in the past India has primarily been importing oil, for several years now coal imports have been increasing sharply, and by now make up 23 percent of domestic coal consumption (McKinsey 2014). This increasing import dependency and the associated foreign exchange risk are seen as the central obstacle to future economic growth (Dubash 2011; Mallet 2013; Quitzow, Libo and Jacob 2013).

5.5 Contributions to local environmental protection and health

Renewable energy sources, compared to fossil fuels and nuclear energy, also make a positive contribution to reducing local environmental damage and risks, as well as to avoiding associated health problems.

In many regions of the world, poor air quality is a significant concern (Schmale/Kuik 2013). Estimates put the number of people who die in major Chinese cities each year due to the effects of urban air pollution at around 650,000 (Jing 2014). The main causes are traffic and coal-based electricity production. Already in the late 1990s, countless Chinese cities introduced measures to reduce emissions in the transport sector; these included banning motorcycles operating on conventional fuel or restrictions for the use of personal vehicles. Recently, the Chinese government decided to close the last coal-fired power plants in Beijing by the year 2016. This is part of an initiative to reduce the annual coal consumption by 13 million tons by 2017, relative to the base year 2012 (Bloomberg 2015). In the year 2014, in fact, the consumption of coal fell by 2.9 percent, and declined further during the first half of 2015 (China Climate Change Info-Net, 9 Nov. 2015; BloombergBusiness, 9 Nov. 2015).

Another benefit of renewables is the significant contribution they can make to sustainable water use. Wind power and photovoltaics, for example, significantly reduce water consumption and water pollution as a result of electricity production (Roehrkasten, Schaeuble and Helgenberger 2016). This is of particular significance for regions suffering from scarcity of water. The relevance of an energy supply system which conserves water will increase substantially in the future. According to the World Water Report, 40 percent of the global demand for water will not be able to be met by the year 2030 (UNESCO 2015).

Nuclear energy carries with it the well-known safety risks as well as the still unsolved problem of permanent storage of radioactive waste. An additional drawback of a fossil fuel-based energy supply is the significant environmental impact that the extraction of fossil fuels has. These include in particular emissions of mercury or arsenic, which have only recently entered the public debate. This further adds to the environmental benefits offered by wind and solar power.

Renewable energy is certainly not free of environmental impacts. The IPCC (2011) conducted a differentiated assessment of this question in a special report. The expansion of renewables should therefore build on local potentials and challenges and take these into consideration in a holistic assessment of various expansion paths. This also holds true for the economic and the social aspects of the expansion of renewable energy. The postulate of higher energy efficiency applies – not least of all in the interest of conserving resources, but also in light of new user groups such as electromobility users - also when dealing with renewable energy sources.

The International Renewable Energy Agency (IRENA) is a strong voice for the wordwide deployment of renewables. Germany initiated its founding in 2009.

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6. Potentials and challenges of an international energy transition policy

6.1 More ambition in the global expansion of renewable energy is needed

Despite the diverse advantages of renewable energy, its broad-based expansion at global level remains a challenge. Even in some of the European pioneering countries, a slow-down of the expansion path of renewable energy is clearly evident. In particular in Italy and Spain, new deployment has, after a phase of explosive growth, now come to a virtual standstill. In Great Britain – a climate policy pioneer in its own right – the funding of renewable energy sources has recently been subject to such drastic cuts that some are predicting a period of very slow growth for the sector in the future.

Also in Germany, the deployment of solar energy has experienced a significant slowdown in recent years. In the wind energy sector, annual capacity additions in Germany remain among the ambitious globally. A high level of ambition for the future deployment of renewable energy remains indispensable, if Germany seeks to retain its role as an international frontrunner. This in turn will be crucial for sustaining the important signaling effects of the German *Energiewende*.

Furthermore, international climate protection goals are not attainable if renewable energy merely complements conventional energy sources. What is instead necessary is an increased *substitution* of conventional energy sources with renewables. Although global coal consumption may have reached its peak in 2013/14, the global energy balance remains dominated by fossil energy. Even if the global use of renewable energy has increased significantly since the turn of the millennium, its share of the worldwide primary energy mix to the year 2013 has not increased to a significant extent. From 2000 to 2012, it remained relatively constant at around 13 percent, before reaching 14 percent in 2013. Even in the area of electricity supply, only a slightly positive trend is evident: The share of renewables increased from 19 percent in 2000 to 22.8 percent in 2014 (REN21 2015; IEA 2015a: 348; IEA 2014b: 242; IEA 2010: 279).

In other words, the accelerated expansion of renewable energy has in the past been accompanied by a corresponding expansion of fossil energy sources. Many emerging and developing economies, which in the future will be the key drivers of a growing global demand for energy, are continuing to plan for new deployment of fossil fuel capacities and nuclear power. Unlike in the saturated markets of industrialized countries, the expansion of renewable energy sources in these countries will not automatically be accompanied by a reduction or substitution of conventional energy sources. In these countries, renewable energy sources are for the most part seen not as replacement for, but rather as a supplement to the already existing supply of conventional energy sources.

6.2 Global trends are also crucial to the success of the German *Energiewende*

Not only from a climate policy standpoint, the success of the German *Energiewende* depends largely on how developments in Germany can contribute to a global expansion of renewable energy. The economic success of the *Energiewende* is also significantly influenced by international developments. Furthermore, the *Energiewende* and the international attention that it attracts can serve to strengthen Germany's international reputation and its "soft power." Against this background, the international commitment of the German government in the context of the energy transition takes on increasing significance. It offers numerous opportunities for strengthening multilateral and bilateral cooperation with other pioneering countries and strategic partners in the energy sector.

As outlined above (see Chapter 3.2), there is already a broad portfolio of activities and approaches that promote cooperation with partners in the energy sector, in particular in the area of renewable energy. This not only forms a strong foundation, but also a wealth of experience that can benefit the further development and the expansion of Germany's international energy transition policy. Specific experiences have already been evaluated and translated into corresponding political programs, for example the Renewable Energies Export Initiative. Only recently, Germany's international *Energiewende* policy has become the subject of scientific and policy papers (see e.g. Hirsch 2015; Huebner 2013; Jaenicke 2013; Messner/Morgan 2013; Roehrkasten 2015; Roehrkasten/Westphal 2013; Steinbacher 2015; Steinbacher/Pahle 2015; Taenzler/Wolters 2014; Westphal 2012). The increasing dynamic of the global expansion of renewable energy and the worldwide innovation drive that is accompanying it offer an important opportunity for additional analysis and discussion.

6.3 Recommendations for a further strengthening of Germany's international *Energiewende* policy

As this study has outlined, Germany still plays an important role as pioneer of a global transformation of the energy system. However, other countries are also assuming pioneering roles in this area, increasingly also emerging and developing economies. This not only offers significant market opportunities outside of Germany, it also means that these innovation and transformation processes will give new impetus to the transformation of the global energy system. An international energy transition policy for Germany must therefore not only ensure that German impulses continue to play a central role in the international arena, contributing to a further acceleration of the expansion of renewable energy and the decarbonization of the energy supply system. It must also ensure that developments in other pioneering countries are seized upon within Germany.

In the future, an international energy transition policy must to a greater degree promote mutual exchange and the transfer of knowledge with other countries. Only then can the innovation processes and the technological changes associated with the German *Energiewende* retain their international relevance. The German *Energiewende* should not be seen as a model for other countries and regions. Instead, it must be continuously developed as a successful and dynamic strategy in exchange with other countries. This is the only guarantee of its successful implementation in Germany and Europe, and the only way a German success story will serve as an international impetus for change.

The bilateral cooperation, for example in the form of energy partnerships, is thus not only an opportunity to "export" the German *Energiewende*, but also to "import" international experience and trends. In order to support this dynamic, an international energy transition policy should increasingly contain mechanisms that systematically incorporate international developments into national discussion processes. This not only helps to link technological innovations to broader international trends, it also constitutes an important basis for engaging in a fruitful policy dialogue with international partners. Constructive engagement at the international level requires a serious examination of the approaches of other pioneering countries – extending beyond the electricity sector as well. Corresponding successes should be incorporated both into the international communication strategy as well as into national discussions. The German *Energiewende*, for example, could benefit from the experience of international pioneers of an energy transition in the transport sector (see Chapter 4.3). The existing energy partnership with Brazil could be increasingly utilized to advance the development and use of 2nd generation biofuels and biofuels for aviation in Germany as well (Roehrkasten 2015b). Other examples of areas that can offer added value for the German *Energiewende* are the

Danish experience with civic participation (Gotchev 2015), the Italian experience in the area of smart meters (Erlinghagen, Lichtensteiger and Markard 2015) or lessons on steering flexible loads (demand response) from the Unites States (Bayer 2014).

In the area of development cooperation, the German *Energiewende* and the associated policy instruments can serve only as a general point of orientation. The applicability of individual elements depends on the respective objectives and on the country-specific context. With more and more experiences from developing and emerging economies, there is a growing spectrum of practical lessons which can be more appropriate to the challenges that partner countries face. This includes, for example, innovative approaches to reduce investment risks (derisking) for the greater mobilization of private capital (Schmidt 2014) as well as the promotion of economic value creation and employment in the renewables sector (Jacob et al. 2014). In order to ensure suitable policy advice and the successful support of transformation processes in developing and emerging markets, there must be a continuous exchange with these countries and a dedicated evaluation of the experiences made there. In conjunction with a country-specific analysis and assessment of the locally relevant benefits of renewables, this presents a way to develop effective strategies for the accelerated expansion of renewable energy sources.

To this end, IRENA, SE4All, REN21 and the IEA can prove to be useful forums. However, certain parts of these organizations are still too strongly dominated by the interests of industrialized countries. The IEA, which is still the leader in the analysis of international energy markets, has only OECD states as members. Even in those organizations that do involve industrialized, emerging and developing economies, the perspectives of industrialized nations frequently prevail. In the Global Futures Report published by REN21 (2013b), for example, nearly 80 percent of surveyed experts came from Europe, the U.S. and Japan (Roehrkasten 2015a).

Finally, an international energy transition policy should to a greater degree encourage the development of alliances that promote the global energy transition at the highest political levels. Only through the targeted cooperation with international partners can Germany effectively advance the acceleration of a global energy transition in key international forums such as the G7 or G20, or within the framework of the European Union. In this context, greater cooperation with European electricity neighbors is an important step. But at many other levels as well, the fostering of political alliances can make an essential contribution to strengthening the German as well as the global energy transition. For Germany this also means that its international energy transition policy should be pursued at the highest political level.

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IASS Study
March 2016

Institute for Advanced Sustainability Studies Potsdam (IASS) e. V.

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DOI: 10.2312/iass.2016.009

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