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Deep Decarbonization in Germany
A Macro-Analysis of Economic and Political Challenges of the 'Energiewende' (Energy Transition)

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List of Abrevations

BAFA	Federal Office for Economic Affairs and Export Control
BMBF	Federal Ministry of Education and Research
BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
	(since December 2013: Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety BUMB)
BMVBS	Federal Ministry of Transport, Building and Urban Development
BMWi	Federal Ministry of Economics and Energy
CCS	Carbon Dioxide Capture and Storage
CDM	Clean Development Mechanism
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
CO_{2equ}	Carbon Dioxide Equivalent
DDPP	Deep Decarbonization Pathways Project
dena	German Energy Agency
EEG	Renewable Energy Act
EJ	Exajoule
EnEV	Energy Efficiency Ordinance
EnWG	German Energy Act
ErP	Energy-related Products
EU	European Union
EU ETS	European Union Emissions Trading System
FiT	Feed-in Tariff
GDP	Gross Domestic Product
GHG	Green House Gas
GW	Gigawatt
GWh	Gigawatt-hour
HH	Households
ICT	Information and Communication Technology
IECP	Integrated Energy and Climate Program
JI	Joint Implementation
KfW	Reconstruction Credit Institute
kW	Kilowatt
kWh	Kilowatt-hour
MSR	Market Stability Reserve
NAPE	National Action Plan on Energy Efficiency

NEP	Power Grid Development Plan
PJ	Petajoule
PV	Photovoltaic
R&D	Research and Development
RES	Renewable Energy Sources
SDSN	Sustainable Development Solutions Network
SME	Small and Medium-sized Enterprise
TSO	Transmission System Operators
TWh	Terawatt-hour

1 Executive Summary

With the goal of limiting the rise in global temperature to two degrees, the developed countries agreed to reduce greenhouse gases (GHG) compared to 1990 by 80% to 95% until 2050. Germany also adopted this target. Germany's GHG emissions in 2013 were estimated at 954.7 million tons of CO_2 equivalents, the largest emission of a single country in the EU. This constitutes an increase compared to 2011 and 2012 levels, but a reduction of about 23.5% compared to the base year 1990. Thus, the target reductions defined in the Kyoto protocol (21% for 2012) have been more than fulfilled. Nevertheless, in order to achieve the long-term reduction target of 80% to 95% by 2050, further efforts are required.

In the year 2010, the German government initiated a new Energy Concept for a substantial transition of energy use to reduce carbon emissions in all sectors simultaneously, which adjusts previous strategies and climate policy packages. Moreover, after the nuclear catastrophe in Fukushima in 2011 a societal and political consensus was reached to completely phase out nuclear electricity generation in Germany within ten years.

In several areas, additional sub-targets have been set, including energy savings, renewable energy development and reductions of GHG emissions by 2020 and on the pathway through 2050. The whole concept is known as *Energiewende* and aims at an overall change of the complete energy system. In addition to the transformation of the power sector, the continued decarbonization of non-energy industrial processes, buildings, agriculture, heat, and transport is also envisaged. Furthermore, an accelerated upgrade of relevant infrastructures has been adopted as complementary goal.

In addition to its contribution to GHG emission reduction, the *Energiewende* is associated with several economic, technological and social co-benefits. Most important in the political debate is the creation of jobs. According to government figures, from 2004 until 2013 371,400 new jobs have been directly created by the roll-out of renewable energies. Effects on employment in the economy as a whole are calculated with macro models that show also net employment increases. The numbers for net employment effects by renewables are estimated at 80,000 in 2010 and 100,000 in 2015.

Moreover, GDP growth is estimated to increase by around one percent through 2030 due to the *Energiewende* compared to a Current Measures Scenario as found by a tailored model assessment. Correspondingly, it is also expected that the *Energiewende* creates jobs on top of those induced by the measures in place before 2012. The biggest amount of additional jobs will be created in the labor intensive construction sector (102,000 new jobs by 2030) followed by trade and services (50,300), and manufacturing (22,300). By contrast, the number of jobs in the energy sector is projected to decline by 44,000.

The *Energiewende* is also associated with technological innovation and increased competitiveness in related sectors due to first mover effects. This is demonstrated by the German wind turbine industry, which appears to be highly competitive if its world trade share is considered: Between 2004 and 2012 it rose from 10 to almost 50% according to a recent estimate. With regard to overall market shares, the German manufacturers Enercon (9.8%), Siemens (7.4%) and Nordex (3.3%) belonged to the top 10 wind turbine manufacturers in 2013. A particularly strong position of German manufacturers is indicated by their world market shares in offshore-wind turbines. Here, Siemens and BARD clearly led the world far-shore segment with regard to both number and electric power of installations in 2013. In contrast, the German solar PV industry has lost its international competitiveness. Its world trade share is decreasing since 2008 (15%) and fell back to its pre-2005 level of below ten % in 2012.

A strong German position in renewable energy and energy efficiency related innovative activity is also indicated by the country's top position in related patent applications and a high effectiveness of R&D expenditures. While in 2011 total German expenditure on R&D in the field of energy amounted to 0.028% of GDP only, German patent applications in the fields of renewable energies and energy efficiency are on the same level as US and Japanese applications. At the same time, the sector gains international relevance as sharply increasing numbers of total patent applications suggest.

Another co-benefit is due to the positive impact of renewable energies and energy efficiency on local air quality and human health and productivity. By the displacement of fossil fuel use they lower the related external costs of energy provision. Black carbon as well as sulfur dioxide emissions are projected to significantly decline together with fossil fuel combustion.

Hence, import demand for fossil fuels is also expected to decrease, which contributes to a lower exposure to their volatile international prices. This corresponds directly with increased energy security and less vulnerability imposed by energy imports. Furthermore, fossil fuels are limited resources and their protection by efficient use and their substitution by renewable energies increases the potential for non-energy use in sectors where substitution is more costly or impossible.

New opportunities for investment and respective returns for municipal entities and private households are frequently discussed as further co-benefit of the renewable energy policy, since this approach of micro-generation and micro-ownership improves acceptance for new energy technologies in the society. Today, about half of renewable-energy capacity is owned by citizens, -most often individuals or farmers.

Finally, an international co-benefit reaching beyond Germany is associated with the roll-out of renewables: Existing support schemes have led to significant market size of renewable energy technologies in Germany, initiated competition among technology suppliers, and induced economies of scale and learning effects, which lower the costs of renewables. Hence, support towards creating and upscaling a renewable energy market has helped to make the technologies affordable even for consumers in countries with lower income levels than Germany. In this, the German renewable energy law with its pioneering introduction of the feed-in-tariff concept has played a critically important role.

Regarding its main goal of GHG emission reduction, the *Energiewende* delivered mixed results over the last years. The second Monitoring Report on the implementation of the *Energiewende* delivered by the end of 2014 states that in 2012 GHG emissions were reduced by 24.7% compared to 1990, but increased slightly compared to the previous year. In 2013 emissions increased further. Although projections show that a reduction of 35% would be achievable until 2020, additional measures need to be implemented in order to reach the envisaged 40% goal.

Although some success was observed concerning reduction of primary energy consumption and gross electricity consumption, energy productivity improvement still lags behind the necessary transformation pathway implied by the adopted target. Until 2013, primary energy consumption fell by just 4.0% compared to the base year 2008. Recent estimations show that depending on assumptions on economic growth rates and on primary energy productivity a gap of around 9.9% to 12.8% remains for compliance with the target of 20% primary energy consumption reduction until 2020.

Buildings are central for energy efficiency improvements and show positive results. Although the building stock increases due to higher living standards and increased living space per person, heat consumption in residential buildings fell by 20% over the period 2000-2012. In case the current development continues, the 2020 targets for residential heat consumption seem achievable. However, the refurbishment rate of buildings has to increase to 2% annually to facilitate such development.

Towards this aim, the government offers long-term soft loans including subsidization of repayment rates for energy efficient refurbishment in buildings, which are managed by the state-owned KfW bank. Since 2006 about 1.6 billion EUR for loans have been provided, which triggered investments worth almost 118 billion EUR. In order to achieve the doubling of the refurbishment rate, the CO_2-Refurbishment Program was expanded in May 2012. A sum of 1.8 billion EUR annually is provided from 2012 until 2014 compared to about 936 million EUR previously. The National Action Plan on Energy Efficiency (NAPE) approved in December 2014 further increased the amount of financial support provided by this Program to up to two billion EUR annually from 2015 on.

A remarkable development was observed in the electricity sector. Electricity consumption peaked in the years 2006-2008 due to rapid economic development. However, since 2007 electricity consumption decreased and a trend reversal was achieved. Moreover, the use of renewable energies in Germany has made substantial progress, and the targeted share of 18% renewable energies in total final energy consumption in 2020 seems to be achievable. By 2012 the share reached already 12.5%. As most important driver, renewable electricity generation has been for the first time the most important source in gross electricity generation, and contributed 25.8% to gross electricity consumption in 2014.

However, the rapid expansion of renewable energies has led to decreased wholesale electricity prices, and an increased net export to neighboring countries. Correspondingly, it has limited the substitution of German conventional energy generation. Hence, German emissions are not reduced proportionally to renewable energy extension. The government currently considers additional measures that would reduce the overall allowed emissions of the electricity sector by 22 million tons, i.e. some eight percent.

At the same time, private households and other non-exempted sectors were burdened in 2014 by a differential costs of renewable electricity support of 20 billion EUR compared to a procurement at the dampened wholesale prices. Despite these costs, the backing of the population continues to be high. Around 70% of Germans agreed with the Energiewende in 2014 according to an opinion poll. However, industrial consumers that do not pay the surcharge enjoy the full reduction of wholesale prices, which is estimated at about 10% or five EUR per MWh. On the one hand, this concerns about 100 TWh of industrial consumption and creates an annual advantage for the industry from the merit-order effect of about half a billion EUR. On the other hand, the four major energy utilities in Germany - E.on, RWE, Vattenfall and EnBW - struggle with decreased market values for electricity, and the expected cost of dismantling their nuclear fleets.

The *Energiewende* is to be seen as work in progress backed by the framework setting of the ruling government and by the consensus of the public. In the long run, until 2050, new challenges will emerge which have to be solved in order to keep on track. The most relevant of them, which potentially affect the political backing, are linked to an expectation of a rise in the costs of the *Energiewende*. They are spurred by potentially more than proportional increases of costs for electricity grid extension, storage and curtailments of renewable energies with increasing renewables in the electricity sector, increasing costs of nuclear waste disposal, changes in the support for renewable electricity leading to higher investment risk, and potentially unfavourable developments of the international framework.

2 Introduction

With the goal of limiting the rise in global temperature to two degrees relative to pre-industrial levels, the global community agreed to try to halve GHG emissions (vis-à-vis the level in 1990) by 2050. In order to achieve this ambitious target, developed countries ought to contribute profoundly to the reduction of GHG emissions by 80% to 95% in 2050 compared to their 1990 level. This requires coordinated efforts for a successful transition into a low-carbon economy. Against this backdrop, in the fall of 2013, the Deep Decarbonization Pathways Project (DDPP) was launched under the auspices of the UN Sustainable Development Solutions Network (SDSN). The project includes disaggregated pathway modeling exercises for twelve countries as well as complementary qualitative assessments of the country-specific political settings and transformation strategies. Within this framework, this report contributes a qualitative assessment of the political economy of decarbonization efforts in Germany. The paradigm shift in Germany focuses mainly on a comprehensive energy transition that is also known as *Energiewende*. This narrative will demonstrate the complexity of policy measures undertaken, assess their effectiveness and bottlenecks as well as emerging conflicting targets and will include a discussion of intended solutions and future challenges.

3 Decarbonization targets in Germany

Germany is not only the leading economy within the EU, but also the biggest GHG emitter among the EU member states. In order to contribute to the envisaged overall GHG emission reductions for developed countries of 80% to 95% by 2050 compared to 1990, this target has been set also as a national target for Germany (BReg, 2010).

In 2013, Germany's GHG emissions were estimated at 954.7 million tons of CO_2 equivalents, whereof carbon dioxide emissions had a share of almost 88% (Ziesing 2014, 90).

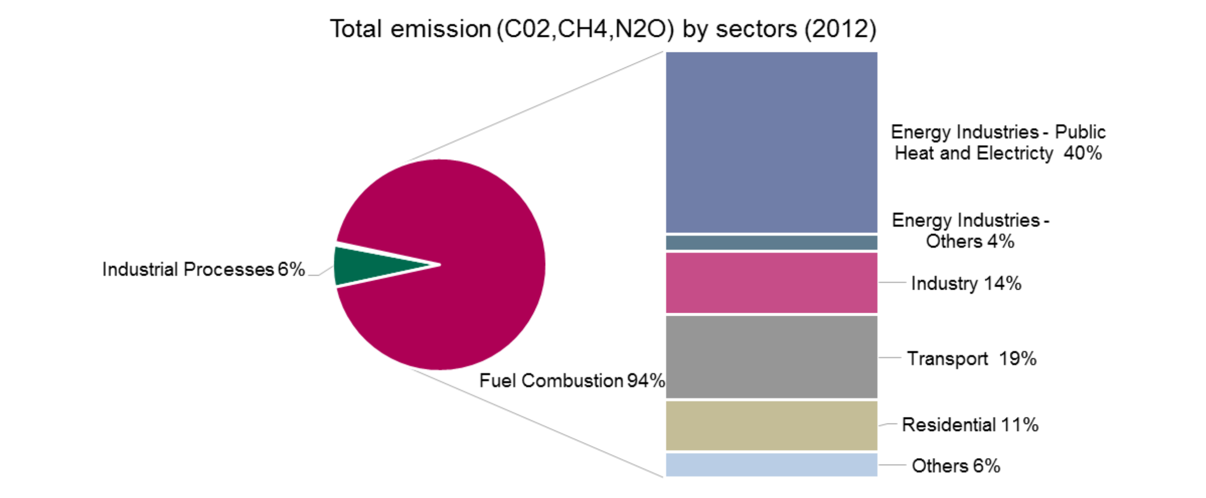
This development constitutes an increase compared to 2011 and 2012 levels, but a reduction of about 23.5% compared to the base year 1990. Thus, the target reductions defined in the Kyoto protocol (21% for 2012) have been more than fulfilled.

Nevertheless, in order to achieve the ultimate reduction target of 80% to 95% by 2050, further efforts are required.

For many years the mitigation of climate change has been an important policy issue in Germany. The Integrated Energy and Climate Program (IECP) of 2007 – the so-called "Meseberger Programm" was an important milestone, which gave an overall framework for climate friendly energy supply in Germany and features explicit sectoral emission reduction targets until 2020.

Most of these efforts focus on fuel combustion, which is the source of more than 90% of overall domestic carbon emissions (in 2012, see Figure 3-1), and offers substantial reduction potentials with comparatively low mitigation costs (McKinsey (2007); DIW (2007)). Within fuel combustion the production of public heat and electricity account for more than 40% of emissions, followed by the transport sector (22%), electricity and heat production in industries (15%) and in the residential sector (11%). Process emissions in industry are about 6%.

Figure 3-1
German CO2 emissions by sector, 2012



Source: DIW Econ based on UNFCCC (2014): National emissions inventory – Germany. Figures on carbon emissions exclude emissions from land use, land-use change and forestry.

In the year **2010,** the German government initiated a **new Energy Concept** for a substantial transition of energy use to reduce carbon emissions in all these sectors simultaneously, which adjusts previous strategies and climate policy packages. An additional policy push came after the nuclear catastrophe in Fukushima. A societal and political consensus in Germany emerged, which assessed the risks of nuclear energy and the burden of final storage of nuclear waste as too high. Although in 2010 nuclear power accounted for more than 22% of Germany's electricity, in July 2011 (three months after the Fukushima disaster) the German government decided to completely phase out nuclear electricity generation in Germany within ten years. Since that time the nuclear phase-out is an integral part of the German *Energiewende* – the transition to carbon neutral energy supply.

The concept aims at ensuring “a reliable, economically viable and environmentally sound energy supply” – the “energy policy triangle” - and is connected to the following targets:

- Complete nuclear phase-out until 2022.
- Significant increase of energy efficiency in all sectors resulting in pronounced energy savings.
- Substantial increase of the share of renewable energies in the provision of final energy consumption.
- Reduction of CO_2 emissions by 40% until 2020 compared to 1990.

In public debates, the *Energiewende* is often narrowly associated with a power sector transformation. De facto the *Energiewende* aims at carbon neutrality of almost the whole economy. Thus, relying on the **political priority of decarbonization,** the concept is directed towards an overall change of the complete energy system to facilitate sustainable climate protection. Stimulation of economic growth based on new, low carbon technologies constitutes one of its key motivations and drivers. Decarbonization of non-energy industrial processes, buildings, agriculture, heat, and transport is also considered. Therefore, an accelerated upgrade of relevant infrastructures has been adopted as complementary goal.

The Energy Concept of the German Federal Government of 2010 and the subsequent decisions set specific decarbonization targets that are consistent with the overall GHG emission reduction target of minus 85% to 90% in 2050 (seeTable 3-1). These targets and the **phasing-out of nuclear** energy are treated as **overarching goals** supported by different subordinated goals and policy measures (Löschel et al. 2014, 9).

Table 3-1
Ambitious targets versus status quo

	2013	2020	2030	2040	2050
GHG emissions (compared with 1990)	-22.6%	-40%	-55%	-70%	-80% - -95%
Renewable Energies					
Share in gross final energy consumption	12.0%	18%	30%	45%	60%
Share in gross electricity consumption	25.3%	35%	50%	65%	80%
Energy Efficiency					
Primary energy consumption (compared with 2008)	-4.0%	-20%			-50%
Energy productivity (final energy consumption)	0.26% p.a. (av. 2008-2013)	2.1% p.a.			
Gross electricity consumption (compared with 2008)	-3.3%	-10%			-25%
Thermal refurbishment of residential buildings	~1% p.a. (2012 value)	2% p.a.			
Final energy consumption of transport sector (compared with 2005)	1.0%	-10%			-40%

Source: BMWi (2014a) and Löschel et al. (2014b).

In detail, the shares of renewables in both energy and electricity consumption are expected to increase to 60% and 80% respectively by 2050. In the same period, overall primary energy consumption ought to decrease substantially by 50% and electricity by 25% respectively, while at the same time energy productivity is expected to increase by 2.1% per year. More precisely, until 2050 a nearly carbon-neutral building stock shall be in place. Following the first monitoring report, the government added three additional targets (BMU/BMWi, 2012, p. 16):

- A 20% reduction of heat demand in the existing building stock until 2020, and
- The reduction of primary energy consumption of buildings by about 80% until 2050.[1]
- A rise of the thermal refurbishment rate of the existing building stock to 2% per year.

In addition, in the transport sector reductions of energy consumption of 10% and of 40% are set for 2020 and 2050 respectively. E-mobility is considered to be an important pathway and therefore the increase of electric cars up to at least one million in 2020 and six million in 2030 is a further declared goal. Moreover, gross electricity generation by combined heat and power (CHP) plants should increase from 17.3% in 2012 to 25% in 2020.

Implementation of Carbon Capture and Storage (CCS) is not a target of the *Energiewende*. Initial optimistic views of the "bridging technology" CCS mostly turned into pessimistic ones, not least because of the fact that no demonstration project has been successfully realized until today. Reasons for the discrepancy between expectations and reality are underestimations of transport and storage costs as well as overoptimistic expectations towards cost reductions. Large amounts of auxiliary energy are needed in the carbon capture process, which in turn leads to a significant decrease of net efficiency of power plants (Schröder et al. 2013). Herold and Hirschhausen (2010) assume a reduction of efficiency by about one quarter, a number that also describes the status quo of the technology and which is expected not to decline significantly. However, the investment costs that substantially contribute to the unfavorable economics of CCS were assumed to drastically decrease according to a projection of the EU. An assessment of the model PRIMES assumed that the investment costs of

[1] Both heat demand and primary energy consumption in this case do not include renewable energies (Löschel et al., 2014b, Z-13). Therefore, the use of renewable energy facilitates achievement of both indicators, what is reasonable from the point of view of the GHG emissions reductions.

3,300 EUR/kW in 2005 would drop to below 2,000 EUR/kW in 2050, which implies an annual digression of fix costs of 1.3%. This turned out to be too optimistic in the context of CCS (Hirschhausen et al. 2012). By contrast, increasing estimations of future fixed costs and limited power plant flexibility further reduce the suitability of the technology for the transition towards fluctuating renewable energy sources. Finally, there is much uncertainty about leakage rates – especially for longer periods. In fact, large quantities of leaking carbon dioxide would substantially harm the population and the environment. This gave rise to the protests of citizens living near potential CO_2 storage areas. In densely populated Germany such protests had stopped pilot storage projects.

One should note that the described pathways only serve as indicative targets into a low carbon future and should neither be mistaken for complete trajectories nor be understood as a central planning of the *Energiewende*. Impact and effectiveness of measures and instruments need to be assessed with regard to the major energy policy triangle. Public debates about targets and instruments to reach the overall goals may initiate a social learning process.

The *Energiewende* is understood as a challenge, indeed a ‘transformative project’ for the society as a whole. The German government convenes a permanent **political dialogue** on implementation of the concept. It includes several working groups and discussion platforms to involve all relevant stakeholders. In addition, a National Forum on Energiewende (energy council) is planned for consultation of the German parliament (Bundestag) and the government on this topic.

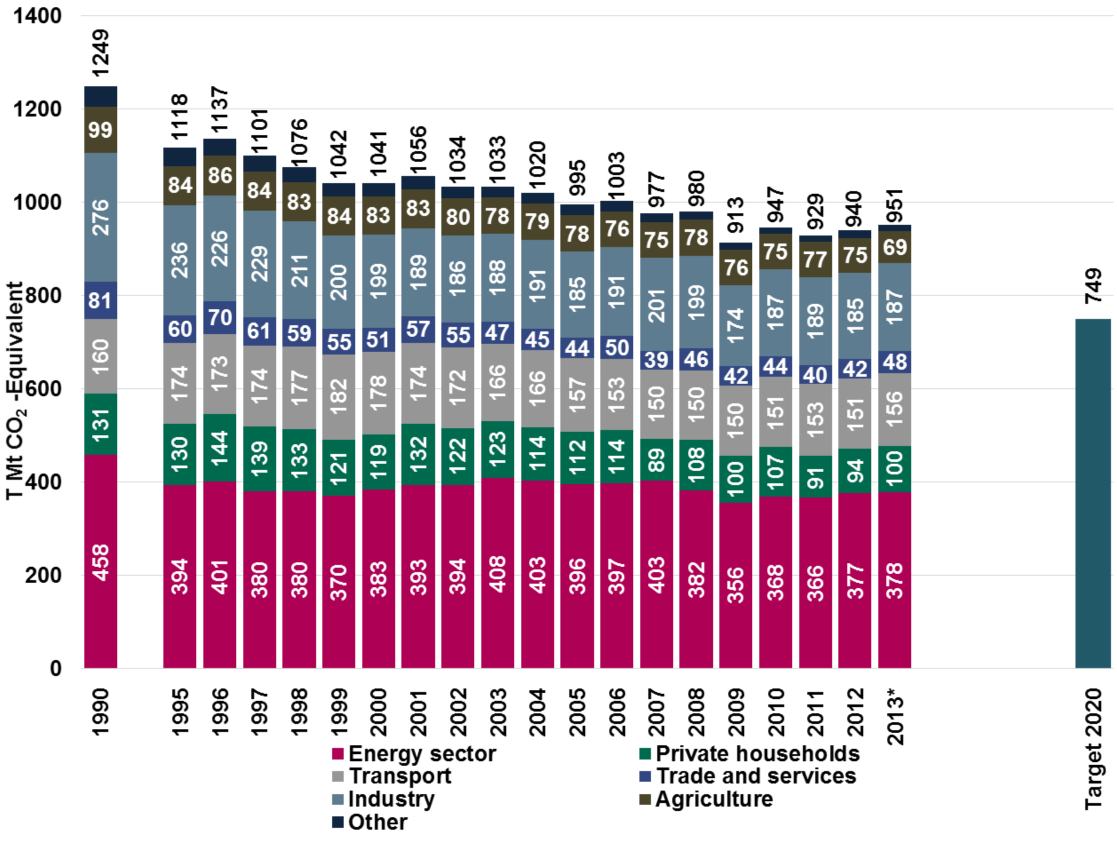
Since 2012, the progress made towards the targets and the status of implementation is monitored annually. The corresponding process was set up by a cabinet decree in 2011. Every three years an overall report on the status of implementation of the concept will be prepared, which might propose new measures and policies to be implemented if necessary. In addition, the monitoring process is being assessed by an independent scientific expert commission. The new government already effected two fundamental changes in the EEG, the core *Energiewende* policy: quantity targets and tendering of funding.

Furthermore, energy model studies are frequently commissioned by the Ministry for Economic Affairs and Energy to provide impact assessments of policies and measures, and to identify new instruments and measures to bridge possible gaps for target achievement.

4 Results at present

The 2nd Monitoring Report of 2014 on the implementation of the *Energiewende* provides an overview of the achieved progress in several dimensions. In 2012 GHG emissions were reduced by 24.7% compared to 1990, but increased slightly compared to the previous year (Figure 4-1). In 2013 emissions increased again. Although projections show that a reduction of 35% would be achievable until 2020, additional measures need to be implemented in order to reach the envisaged 40% goal.

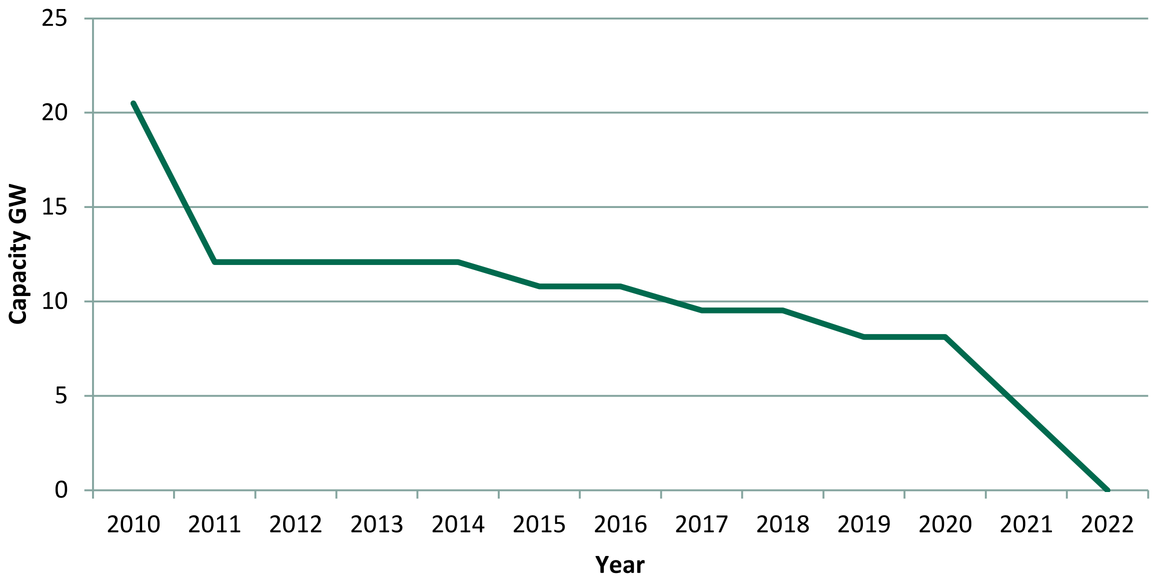
Figure 4-1
GHG Emissions in Germany by sector from 1990 until 2013 (in million t CO2equ.)



Source: Agora (2014).

The nuclear energy phase-out is regulated by two amendments of the Law on nuclear energy (BGBL 2010a and b[2]; 2012 BGBL 2011[3]) and is currently on track. By 2022, nuclear energy is scheduled to be fully decommissioned in Germany. Compared to 2000, total electricity generation capacities will accordingly shrink by 22.1 GW that contributed 26% of German electricity supply at its maximum output. In 2014, already 43% of nuclear generation capacities have been decommissioned (corresponding to 9.4 GW). The further pathway of phasing-out nuclear energy is shown in Figure 4-2.

Figure 4-2
German nuclear phase-out timeline



Source: BGBL 2011.

In 2012 renewable energies were already the second most important source of electricity generation and in 2013 a new record of 25.3% of renewables in electricity generation (AGBE, 2014, 29) was achieved. The rapidly increasing renewable electricity generation and increasing market competition triggered significant economies of scale and technological learning, and led to reductions in feed-in tariffs for new renewable power plants. However, the EEG

[2] Elftes Gesetz zur Änderung des Atomgesetzes vom 8. Dezember 2010, Zwölftes Gesetz zur Änderung des Atomgesetzes vom 8. Dezember 2010.

[3] Dreizehntes Gesetz zur Änderung des Atomgesetzes vom 31. Juli 2011.

surcharge levied on consumption increased over several years and reached 5.3 Eurocent/kWh in 2013, i.e. about one fifth of the price of final household consumption, due to a rapid rollout of mainly photovoltaic installations. (For an overview of the basic characteristics of the EEG see Box 6-1 in Chapter 6.2.1.)

Regarding the aggregated energy sector, primary energy consumption decreased slightly and overall energy productivity improved. However, a closer look at current results reveals that there are still huge challenges to adjust the measures and instruments currently in place.

A large number of sectoral and technological factors contribute to the *Energiewende's* success. The following overview provides a brief outline of the results for the agreed quantitative targets.

4.1.1 Energy consumption and energy efficiency

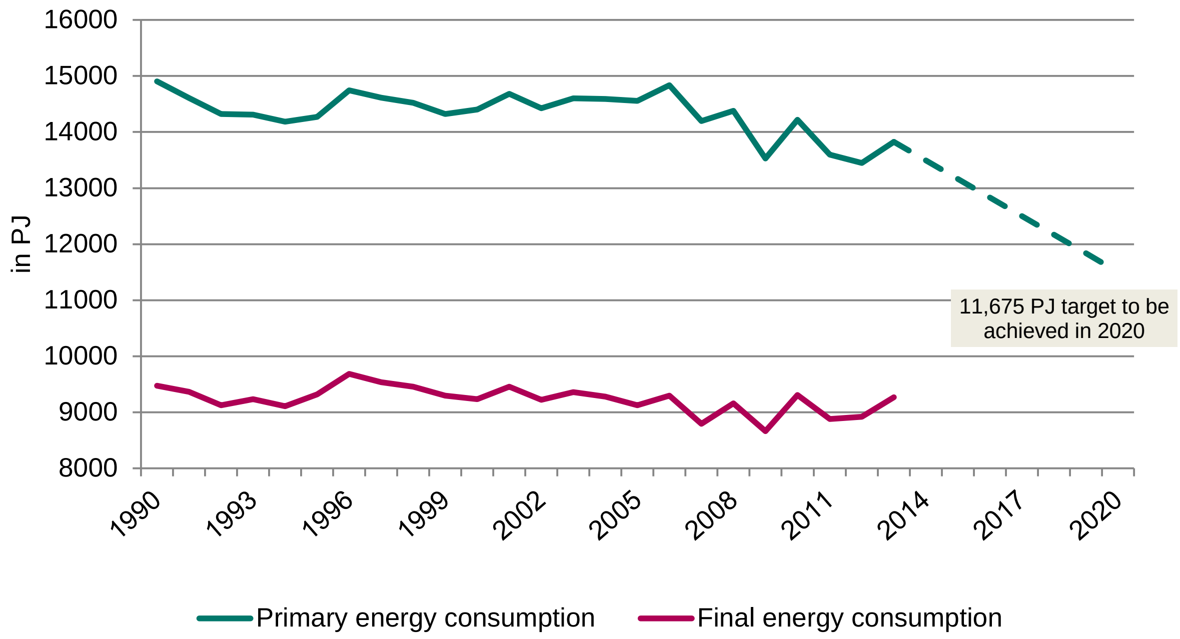
Energy efficiency improvement is crucial for the *Energiewende*. It reduces energy consumption and fuel costs and, in many cases constitutes the least cost option for GHG emissions reduction. Energy productivity measured as price-adjusted GDP per unit of domestic energy consumption is the key indicator to measure progress as it relates physical use of energy to economic performance of the whole economy. It can be related to primary energy or to final energy. For assessment of energy efficiency improvement, final energy productivity is more appropriate as this indicator is adjusted for fuel mix and mix of different electricity generation plants.

Although some success was observed concerning the reduction of primary energy consumption and gross electricity consumption, energy productivity improvement still lags behind the adopted target. Until 2013, primary energy consumption fell by just 4.0% compared to the base year 2008 (Löschel et al., 2014b, Z-6). Recent estimations show that depending on assumptions on economic growth rates and on primary energy productivity a gap varying between 9.9% and 12.8% (or 1,445 and 1,751 PJ)[4] remains for compliance with the 20% primary energy consumption target until 2020 (Fraunhofer ISI, 2014, 10). Final energy consump-

[4] The basis is temperature adjusted primary energy consumption of 14,594 PJ in 2008. (Fraunhofer ISI et al. 2014, 9)

tion increased by 1.19% in the same period (see Figure 4). Therefore, the necessary further decoupling of energy consumption from GDP growth needs a more pronounced increase of energy productivity to reach the envisaged targets. The improvement of energy productivity in the economy, measured as GDP per unit of final energy consumption, has to increase at an average annual rate of 2.1%.

Figure 4-3
Primary and final energy consumption development (in PJ)



Source: BMWi (2014c).

Final energy productivity performed differently across time periods. While average energy productivity grew by 2% from 1990 to 2000 and by 1.3% from 2000 to 2004 the increase was even more substantial between 2004 and 2008 (up to 2.6%). However, from 2008 to 2012 the rate of energy productivity improvement slowed down to an average rate of 1.1%. In order to comply with the 2050 target, from 2012 on, an annual average energy productivity increase of about 2.6% until 2020 would be necessary (Löschel et al, 2014, 43).

Structural changes in the economy, e.g. prices, sectoral and sub-sectoral composition of GDP etc., have a significant impact on both, GDP and energy consumption. The aggregated indicator is exposed to these factors as well. Hence, changes in the overall indicator are difficult to interpret and the success of policy measures aiming at energy efficiency increases is difficult to disentangle from other factors. Therefore, it is necessary to monitor energy efficiency improvements at a disaggregated sectoral level.

The commercial and service sector performed best (3% energy productivity improvement annually since 1991) followed by road freight transportation (2.3%), individual road transportation (1.5%), industry (1.3%) and private households (1%) (Löschel et al, 2014, 50). For industry, which accounts for 29% of total final energy demand in Germany, a future rate of 1.3% annual energy productivity increase has been stipulated in negotiations between government and industry over CO_2-tax reliefs (see Chapter 7.1). While the less energy intensive service sector, which also includes the public sector, is less affected by business cycles, industry is generally more influenced by market developments. Therefore, energy productivity in industry was decreasing in 2003 and 2009, years with low market demand for industrial goods and low utilization of existing capacities.

In total, energy productivity has improved since 1991. The growing use of CHP plants and technological progress has contributed positively. Another reason for this development is the growing importance of less energy intensive sub-sectors within industry.

Moreover, buildings are central for energy efficiency improvements and are showing positive results. Although the building stock increases due to higher living standards (increase of living space measured in m²/person), heat consumption in residential buildings decreased over the whole period 2000-2012 by around 450 PJ or 20% (Schlomann et al., 2014, 23). In 2013 heat demand increased slightly due to a harsh and long lasting winter. Temperature adjusted specific heat demand per m² declined by 10.8% in 2013 compared to 2008 (BMWi 2014g, 32), i.e. even more pronounced. In case the current development continues the 2020 targets for residential heat consumption seem achievable if the refurbishment rate of buildings will be increased to 2% annually as targeted (Löschel et al, 2014b, Z-13). However, it needs to be considered that additional efficiency improvements in buildings during the coming years will be more challenging and therefore more costly the higher the achieved efficiency level is. The even more challenging target for 2050 to reduce primary energy demand in the building sector by about 80% will need substantial increase of investment into this sector.

With regard to envisaged energy savings in the transport sector, the target appears to be quite ambitious: 10% reduction until 2020 compared to 2005. In 2012 the achieved reduction was only 0.6% compared to the reference year. At the same time, transport services[5] for passenger and freight traffic increased by 4% and 9%, respectively. Therefore, energy consumption related specifically to passenger and freight traffic which decreased by 2.9% per year was more than compensated by the overall increase of transport services. More into details, the various subsectors of transport performed quite differently:

- Energy consumption of road transport declined by almost 2% in the same time and that of rail transport decreased even faster (4.6%).
- By contrast, shipping (2% increase of energy consumption) and aviation (including tank contents of international flights) increased by almost 8%.

A remarkable development was observed in the electricity sector (see Figure 4-4). Electricity consumption reached its peak in the years 2006-2008 with around 620 TWh. This is due to the rapid economic development in Germany during these years. However, since 2007 electricity consumption slightly decreased resulting in a gross electricity consumption of 581 TWh in 2009 during the financial crisis. That means the continuous increase of gross annual electricity consumption persisting until 2007 reversed and gross annual electricity consumption slightly decreased since 2008 to around 600 TWh (see Figure 4-4).

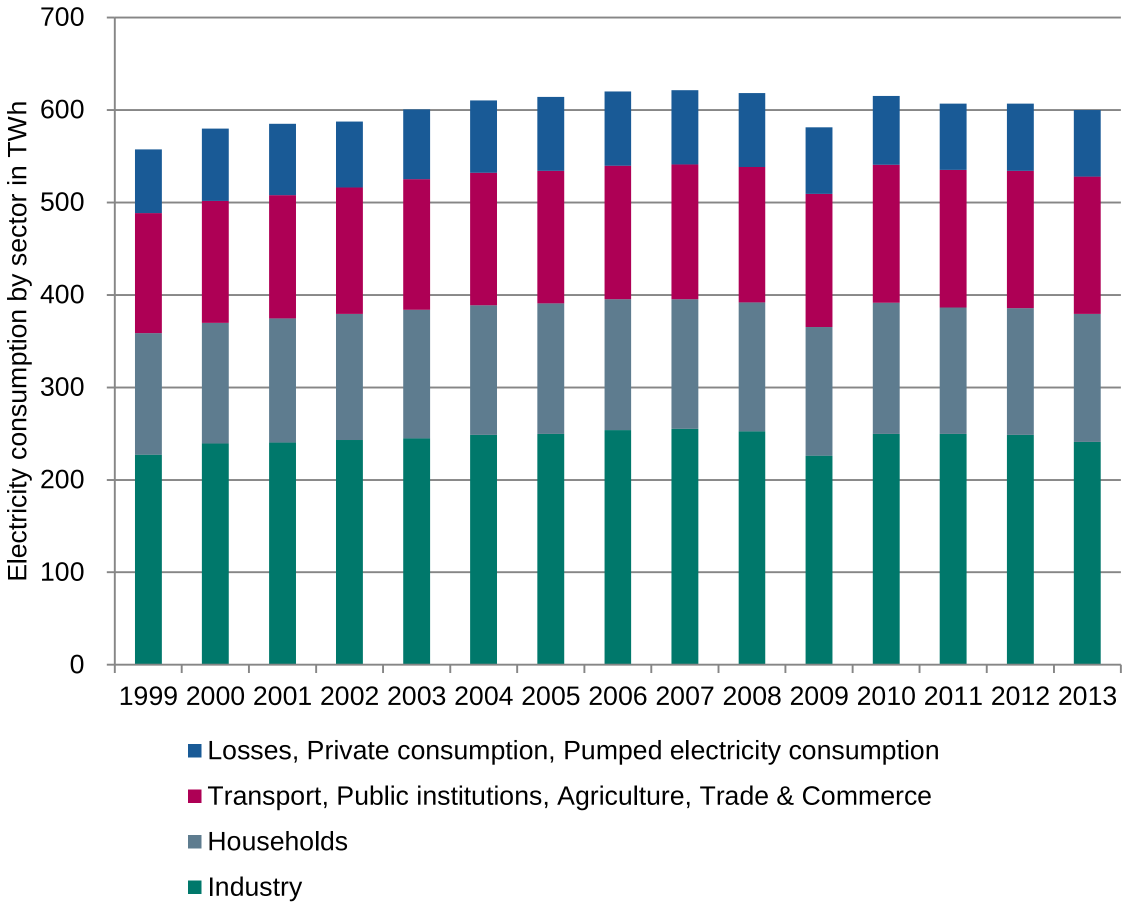
Although the average annual decrease from base year 2008 till 2013 was about 0.55% this rate needs to be doubled to 1.1% annually in order to reach the 2020 reduction target of 10% (Löschel et al, 2014, 45). This task is also challenging. Private electricity consumption shows a decreasing trend but at the same time electricity consumption in sectors like transport is still increasing compared to 1999.

Against the background of an economic development as assumed by the energy scenarios calculated for the government, growth in electricity productivity needs to accelerate to 1.6% annually. This corresponds to an increase of 0.2 percentage points compared to the average annual productivity increase of about 1.4% that was experienced from 2008 to 2013 (Löschel et al., 2014, 46). Although considerable progress in energy efficiency improvement was

[5] Services are measured in persons-kilometers and tons-kilometers respectively.

achieved in recent years, present results also indicate a need for efforts that strengthen the current trend of energy productivity increases to achieve the 2020 goals.

Figure 4-4
Development of total gross electricity consumption

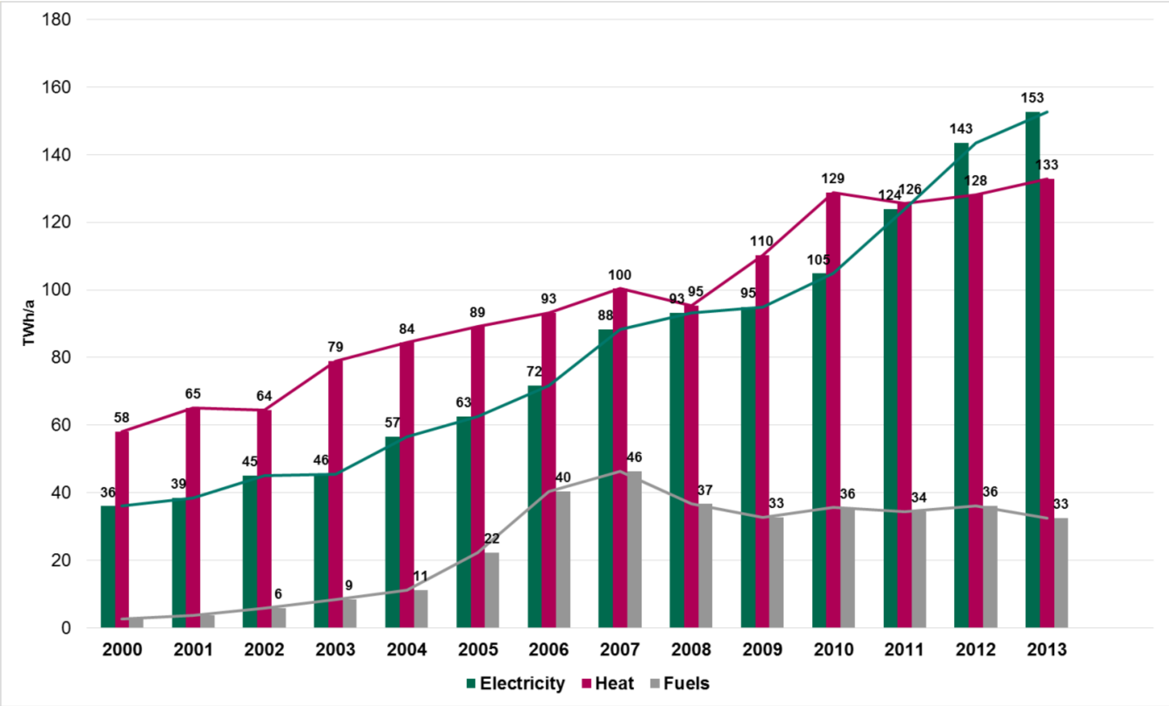


Source: BMWi (2014c).

4.1.2 Renewable energies

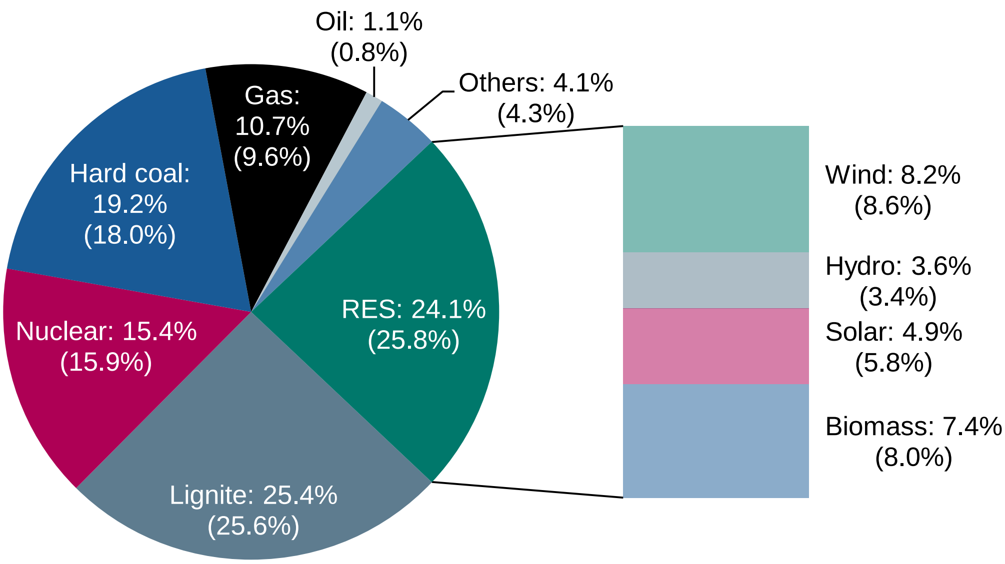
The use of renewable energies in Germany has made substantial progress (see Figure 4-5), and the targeted share of 18% renewable energies in total final energy consumption in 2020 seems to be achievable. By 2012 the share reached already 12.5% (12% in 2013). In 2014, for the first time renewable electricity generation has been the most important source in gross electricity generation (see Figure 4-6). Its share in gross electricity consumption amounted to 25.8%.

Figure 4-5
Gross provision of renewable energy by sectors



Source: BMWi (2014h).

Figure 4-6
Share of renewable energies in gross electricity generation 2013 (provisional data for 2014 in brackets).



Source: BMWi 2014c

The current support mechanisms for renewable electricity (for details see Box 1 in 4.2.1.) therefore proved to be effective with regard to quantitative development. The fixed feed-in tariffs (FiT) on the one hand and generous exemptions of industries from grid charges, EEG surcharges and taxes on the other hand, led to increased electricity prices for households. The overall surcharge imposed on consumers to finance the feed-in tariff increased continuously and amounted to almost a fifth of German household prices in 2013 (BMWi, 2014, 27).

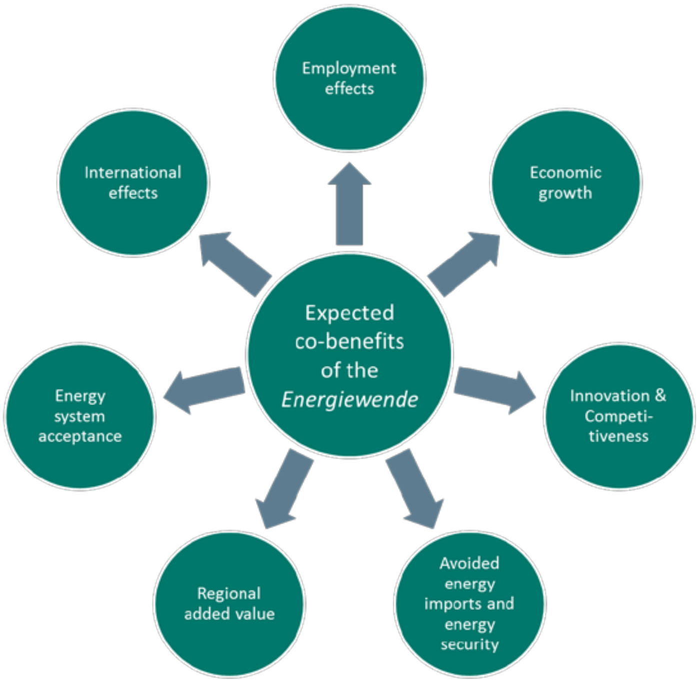
By 2013, heat had a share of more than 50% in total final energy consumption, whereof renewable energies contributed a share of about 9.1%, which corresponded to 133 TWh. These figures suggest that the 14% target for 2020, set in the Law on renewable heat, may be reached (Löschel et al. 2014, 85), although the respective growth was comparatively weak since 2010. The bulk of heat (61%) is used in buildings, whereas the rest is process heating. In the industrial sectors, renewable heat is often sourced from wood in the paper and wood processing industries. However, the main potential for renewable heat lies in the building sector, which accounts for the dominant share (83%) of German heat already today. However, only 6% of existing buildings covered their total heat demand by renewables in 2010 and 13% used renewable heat partly. Biomass is so far the main source of renewable heat (82% in 2012), whereas solar thermal energy, geothermal heat and biomass in municipal waste accounts for about for 5%, 6%, and 7%, respectively.

The reduction of heat consumption in buildings remains a challenge also in view of the target of 14% renewable heat in overall heat consumption in 2020. In case no substantial reduction will be achieved, it is estimated that heat supplied by renewables would need to grow up to 190 TWh. If in addition the predominance of biomass in the renewable heat mix persists, the sustainability of biomass could be called into question (Löschel et al. 2014, 87). In the transport sector, the use of renewable energies is stagnating since 2008. It seems that additional efforts and new approaches need to be developed for this sector. As all targets for the use of renewable energies are relative targets, achievability depends very much on overall development of energy and electricity consumption. This relationship is especially important for the heat and the transport sector, where so far mainly biomass is used as renewable energy source. However, the biomass potential is limited.

5 Expected co-benefits

In addition to the contribution to GHG emission reduction and effects on long-term costs of mitigating climate change by technological advances, the *Energiewende* is associated with a significant number of co-benefits (see Figure 5-1). These include the creation of jobs in the renewable energy and energy efficiency sectors, the stimulation of economic growth, technological innovation and increased competitiveness in related sectors due to first mover effects and improvements of energy security, local air quality, regional income distribution, asset value of buildings, disposable income, and international options for energy provision and mitigation of greenhouse gases. In the following we shed some light on these effects.

Figure 5-1
Expected co-benefits of the Energiewende



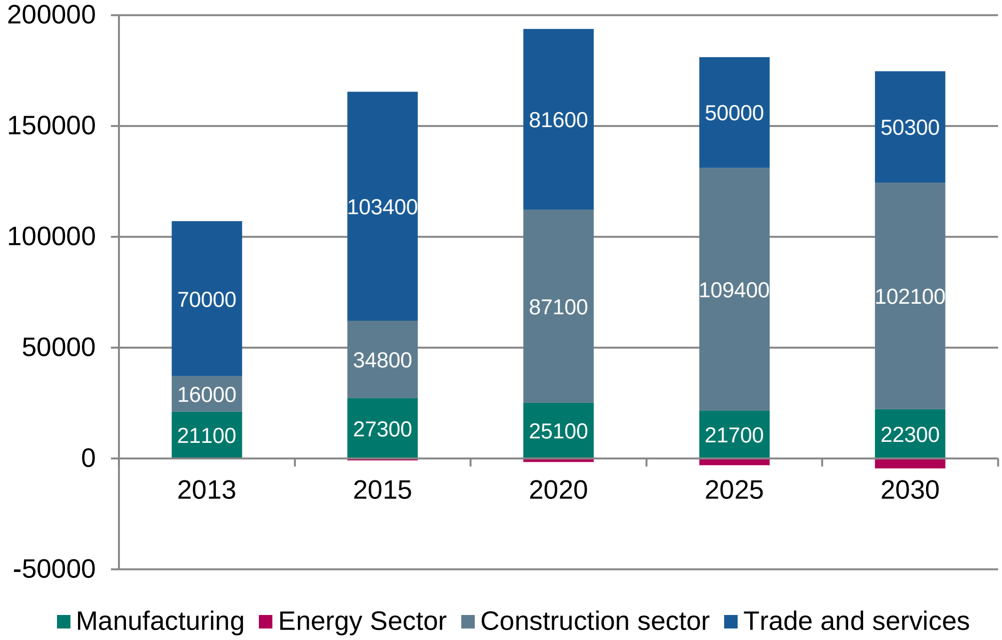
Source: DIW Econ.

The focus on **additional jobs** assumes priority in the political discussion, as this is thought to be the most "visible" benefit in an economy where unemployment is a major concern. Two indicators can measure employment effects of the *Energiewende*: The gross job effect resulting from energy efficiency and renewable energies and the corresponding net job effect.

While the former measures the number of direct and indirect jobs needed for the implementation of energy efficiency measures and for the increased use of renewable energies, the latter refers to the total employment effect in all sectors of the economy compared to a baseline without such development. For estimation of the latter, economic modeling approaches are used.

From 2004 until 2013 371,400 new **jobs** have been created **by renewable energies**, which is a decrease compared to 2012 (almost 400.000 jobs) mainly due to the decrease in the solar PV sector. Most of them (about 137,800) were in the wind energy sector. Biomass provided 126,400 jobs and solar energy added some 68,500, which was substantially less than in 2012 (113,900) as the growth rate of solar energy installations slowed down. The rest of the new jobs were generated in hydro energy, geothermal energy as well as public administration and R&D (BMWi, 2014i). These jobs originated from a growing number of new, specialized companies, but also from many incumbent industries producing components and delivering services. In order to estimate net employment effects several modeling exercises had been carried out, showing positive effects. Due to varying model assumptions, the estimated effects differ. The PANTA RHEI model shows considerable positive annual net effects for 2010 (80,000 net new jobs), 2015 (about 100,000), 2020 (about 35,000) and 2030 (about 160,000) (ifeu und gws, 2012, p.7), where the reduction from 2015 to 2020 is due to the assumed decline of additional photovoltaic installations. Job effects are observed for non-energy sectors as well. A comparison of the full Energy Concept (Energy Transition Scenario) with a Current Measures Scenario that includes all measures which already had been undertaken until 2012 sheds light on major impacts. The biggest amount of additional jobs will be created in the labor intensive construction sector (102,000new jobs in 2030 after a peak of 109,400 in 2025) followed by trade and services (50,300), and manufacturing (22,300). By contrast, the number of jobs in the energy sector will decline by 4400 (Lehr et al. 2013, 27). This could be due to the fact that, for example, new PV installations will decrease and the corresponding creation of additional jobs will largely be completed by 2030. Furthermore, the number of jobs in the conventional energy sector will decrease.

Figure 5-2
Employment effects by sector – Deviation of the Energy Transition Scenario from the Current Measures Scenario



Source: DIW Econ based on Lehr et al. (2013).

Assuming the continuation of existing support schemes and reaching the targets for **renewable energies** development, the modeling results also show **positive effects on GDP** growth. These stem from additional investment, its multiplier effects, and from operation and maintenance of new installations that create value added in the respective regions. Although costs of renewable energy generation at present are mostly higher than for energy generated by conventional power plants, in the long run costs will decrease and will lead to lower electricity and heat costs.

Additionally, ambitious **energy efficiency** measures are expected to induce a growth of **employment** and **the overall economy**. These effects are measured by the comparison of an “ambitious efficiency” scenario with a “frozen efficiency” scenario that includes no additional efficiency increases. Positive effects originate from additional investment replacing energy consumption, which is assumed to be financed by private households and by the state budget. Implementation of the ambitious efficiency scenario is assumed to require 12 billion EUR of additional investment during 2010-2020 and about 18 billion EUR during 2020-2030. According to modeling results the enhanced energy efficiency increase may result in a 0.4%

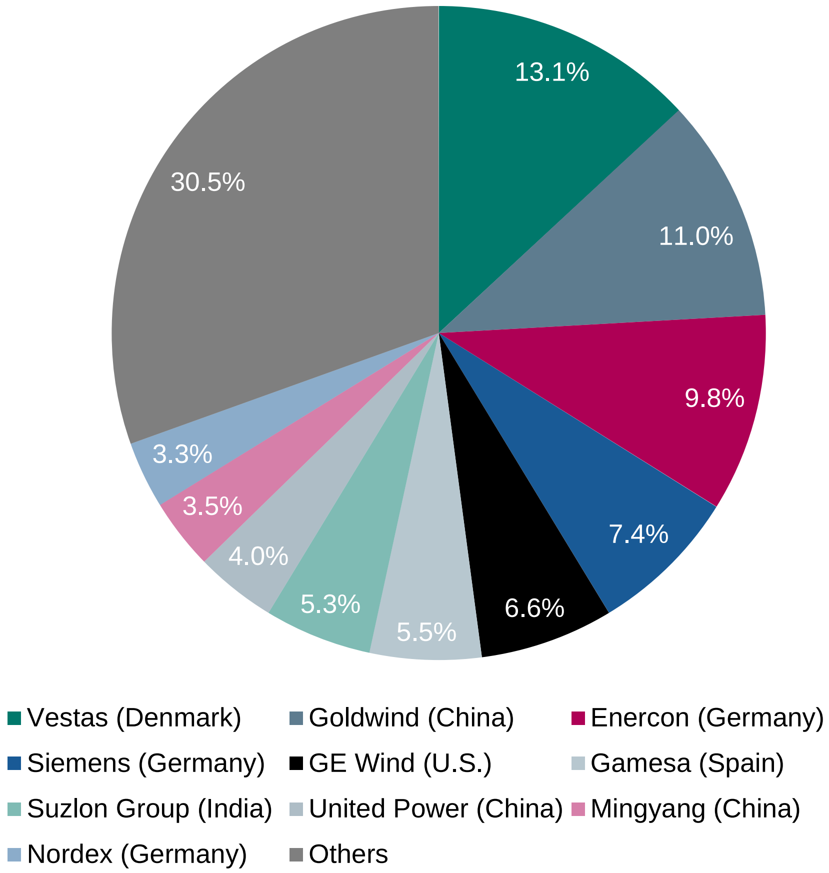
(2015) up to 0.8% (2030) additional GDP growth and 0.2 to 0.3% additional jobs (ifeu und gws, 2012, p.9). Other scenarios estimate additional GDP growth due to the *Energiewende* compared to a Current Measures Scenario as 0.9% (2015) and 1.1% (2030) (Lehr et al. 2013, 26).

Although the support mechanism for renewable energies has helped German firms to spur investment into innovative technologies, the development has led to a controversial political debate. However, firms may benefit from the first mover effect, i.e. a sustained competitive advantage on international markets due to realization of economies of scale and/or the realization of experience effects. These advantages will gain particular importance if the global initiatives for climate change mitigation will gain momentum. A sector where German companies won significant importance is the production of wind turbines. By contrast, in photovoltaic manufacturing German companies have not sustained their market position.

The German wind turbine industry appears to be highly competitive if its world trade share is considered: Between 2004 and 2012 it rose from 10 to almost 50% according to Pegels and Lütkenhorst (2014). With regard to overall market shares, the German manufacturers Enercon (9.8%), Siemens (7.4%) and Nordex (3.3%) belonged to the top 10 wind turbine manufacturers in 2013 (see Figure 5-3). Market leader is the Danish wind turbine manufacturer Vestas which regained its market leading position in 2013. The loss of market share by the U.S. wind turbine manufacturer GE Wind, the market leader in 2012, is mainly due to the weak development of the U.S. market (REN21 2014).

For the evaluation of the competiveness of German wind industry, the location of production sites has to be accounted for. Due to various international mergers and acquisitions of wind turbine manufacturers and their multinational activities, market shares of companies cannot always be related to market shares of countries. Siemens Wind Power, for example, with headquarters established in Hamburg (Germany) mainly emerged out of the Danish company Bonus Energy A/S and still has manufacturing plants in Denmark.

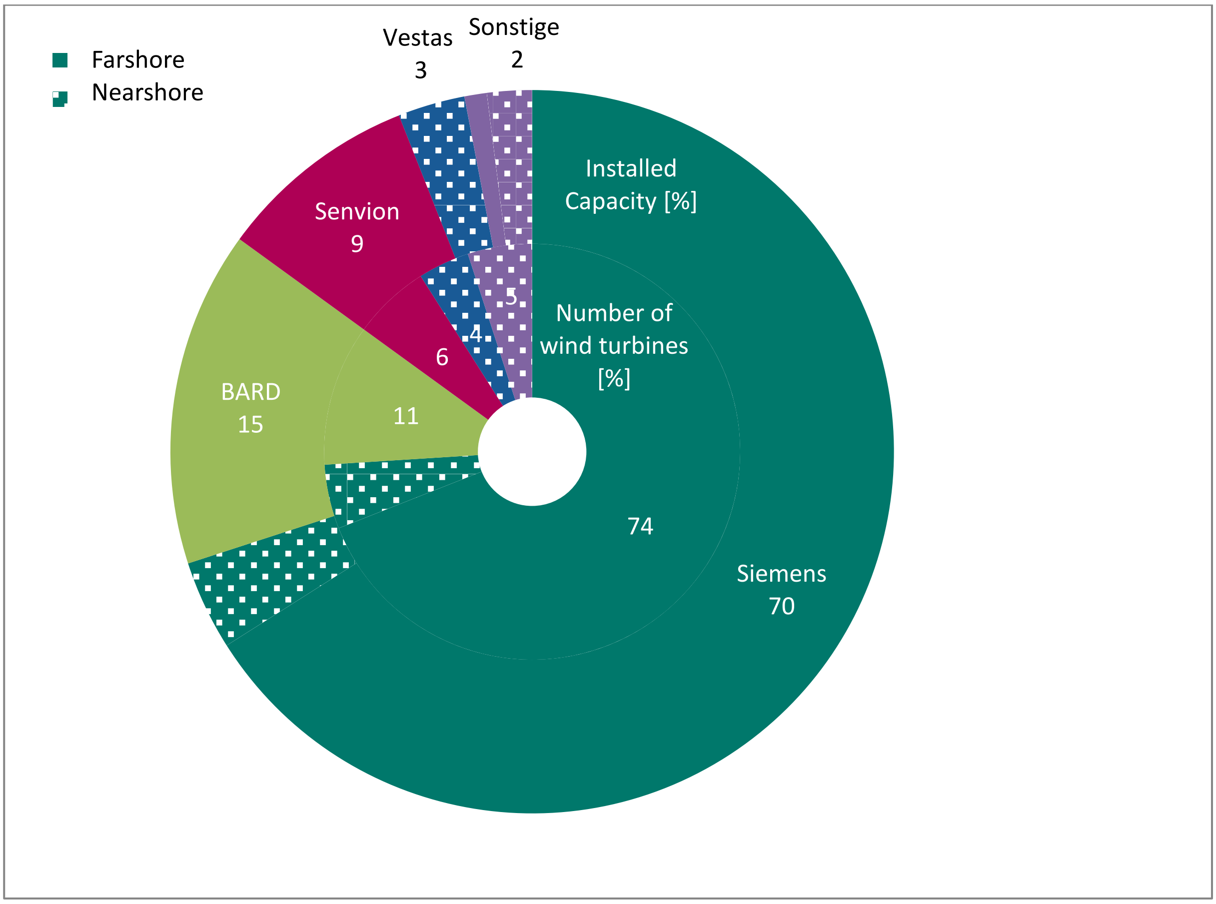
Figure 5-3
Market shares of top 10 wind turbine manufacturers in 2013*



Source: DIW Econ based on REN21 (2014).
*Percentage share based on total sales of ~37.5 GW.

A particularly strong position of German manufacturers is indicated by their world market shares in offshore-wind turbines. Here, Siemens and BARD clearly led the world farshore segment with regard to both number and electric power of installations in 2013 as documented in Figure 5-4.

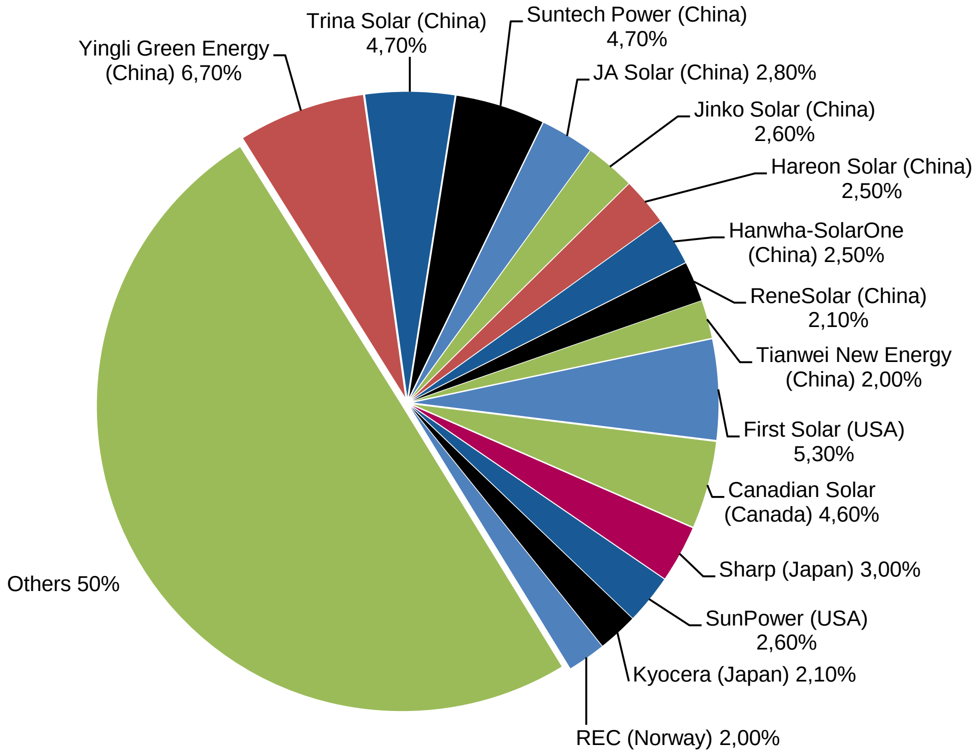
Figure 5-4
Manufacturer market share of the new offshore wind turbines*



Source: DIW Econ based on Fraunhofer IWES (2013)
*Installed worldwide in 2013.

In contrast, the German solar PV industry has lost its international competitiveness. Their world trade share is decreasing since 2008 (15%) and falls back to its pre-2005 level of below ten% in 2012 (Pegels and Lütkenhorst 2014). More and more Chinese manufacturers enter this market (see Figure 5-5) which is a highly political market subject to significant government interventions.

Figure 5-5
Market shares of top 15 solar PV module manufacturers in 2012*



Source: DIW Econ based on REN21 (2014).
*Percentage share based on 35.5 GW produced in 2012.

With increased use of renewables and improved energy efficiency, imports of fossil fuels are expected to decrease. Therefore, another co-benefit is the lower exposure to volatile prices of fossil fuels. This corresponds directly with increased **energy security** and less vulnerability imposed by energy imports. Furthermore, fossil fuels are limited resources and their protection by rational use and their substitution by renewable energies increases the potential for non-energy use in sectors where substitution is more costly or impossible.

Moreover, renewable energies and energy efficiency lower fossil fuel combustion and, thus, have a positive impact on **local air quality and human health and productivity.** Correspondingly, they lower the related external costs of energy provision. Black carbon as well as sulfur dioxide emissions are projected to significantly decline together with fossil fuel combustion.

The replacement of brown coal by renewables in the mid-term facilitates the preservation of **historical housing areas and landscapes** in several regions of Germany, which otherwise would be destroyed by the development of opencast pits.

Another co-benefit of renewable energies is widely debated at present: spurring decentralized energy supply and creating opportunities for investment and respective returns for communal entities and private households. By 2014, almost 1.5 million (1,470,445) photovoltaic installations of different size were installed in Germany. The bulk of them were built by private households, which turned into decentralized energy suppliers. Many wind farms and biomass facilities have been built in communal or local collective ownership. About 50% of renewable-energy capacity is owned by citizens, often individuals or farmers (Renews Kompakt, 2014). This approach of micro-generation and micro-ownership – so-called '**prosumer' model**[6] – **creates acceptance** for new energy technologies in the society. By providing additional income to communities and private households, such decentralized investment opportunities mobilize private households and local communities. They support renewable energies not only by financing but also by providing the necessary space on land or roof tops and are engaged in electricity sales via direct marketing. Driven by these developments, some major utility companies in Germany are starting to change their strategies and are trying to position themselves as service providers for the prosumers. RWE and E.ON, for instance, provide a new service for the typical house owner to help them construct their own PV system on the roof, and to combine it with a small-scale battery. RWE also provides support to an open citizen cooperative (Bürgerenergie e.G.) which aims at investing in renewable energy, providing services on energy efficiency and increasing the amount of cooperatives in this field. Although the new activities are still of minor significance for overall output and revenues of the big electricity suppliers, they indicate a heightened awareness of the growing relevance of public acceptance of the new electricity infrastructure.

Energy efficiency improvement in buildings will reduce energy bills and potentially improve their **asset values**. Due to the long life cycle of buildings equipment, embodied heat costs are an important aspect of the decision to purchase a private house or building. Investment

[6] The term prosumer describes a consumer who simultaneously is a producer. Research is carried out currently on understanding the new role of prosumers and their impact on implementation of the Energiewende. See: http://www.prosumer-haushalte.de/

into heating systems is costly and long-term and creates lock-in effects. This fact was often underestimated in the past due to a lack of awareness. The implementation of energy passports for buildings indicating the building's energy consumption class makes these costs more transparent. This may improve the nexus between asset value and energy efficiency level, and might help to limit effectively the user-investor dilemma (principal agent problem between house owner and user). In addition, leasing "*green*" space is an opportunity to demonstrate a commitment to sustainability and is more and more popular among start-ups and companies focusing on their green and pro-climate image. Many service companies in the buildings market have already included the respective certification services in their service portfolio. Furthermore, there is an important number of energy efficiency measures which imply negative lifetime costs, and investment into these measures will more than pay off. Thus, the *Energiewende* can be expected to **increase disposable income** of private and public households in the long-run.

Last but not least, an international co-benefit reaching beyond Germany is associated with the roll-out of renewables: Existing support schemes led to significant market size of renewable energy technologies in Germany and initiated competition among technology suppliers, and induced economy of scale and learning effects, which lower the **costs of renewables**. This is especially the case for wind and solar energy. Today former niche technologies have emerged as large-scale options in global markets. Support of the market development by German consumers helped to make the technologies affordable even for customers in countries with lower income levels than Germany.

6 Main current policy instruments applied and their effectiveness

Experience in developing renewable energies and energy efficiency has shown that both need to become a profitable business to enable the achievement of the ambitious targets of the *Energiewende*. Experience also demonstrated that due to several market and behavioral failures policy instruments are necessary to achieve preferable outcomes. To spur and to manage the transition process towards deep decarbonization, policies need to adjust to the different stages of the transition and to take different time horizons of investors into account. Moreover, challenges imposed by the political economy of distributional effects are to be considered and policies should avoid the creation of lock-in effects related to long-term investment.

The EU policy package, which focuses on mitigating climate change, enhancing energy efficiency improvement and the use of renewable energies, forms the basis of the respective German policies. On the one hand, bottlenecks or dysfunctions of European policies create dysfunctional results also in Germany. An example is the flagship climate policy of carbon pricing through CO_2 emission trading – the EU ETS - which has failed to generate a sustained price signal to give investors certainty. On the other hand, the EU initiated a lot of important policies and initiatives, which generated positive results. This is the case, for example, with the EU energy efficiency directive as well as with the eco-design directive.

The following analysis will focus mainly on policies for which special design and decision making by the German government was crucial. Thus, these policies add special design elements to the European policies in place or are additional to EU policies. Most of these policies are not completely new. Rather, they result from manifold government initiatives on climate change mitigation prior to the invention of the term *Energiewende*. In general, they follow the stick-and-carrot approach combined with information and communication.

6.1 Cross-sector policies as basic instruments

There are some sector-neutral policies in place aiming at setting incentives for energy efficiency by trying to internalize external costs of fossil fuel combustion and therefore, making private energy consumption more expensive. A basic instrument which was introduced in

1999 is the so-called **ecological tax (eco-tax)**, which is levied on electricity consumption, but also applies to fossil fuels. This tax modifies the previously existing tax on mineral oil products. Between 1999 and 2003 the eco-tax rates were increased annually. Since 2006, the tax is harmonized with respective EU fuel tax requirements. However, the economic effects of the tax are considered to be quite low. Firstly, there are manifold tax exemptions, which made the instrument less effective than intended. Secondly, the overall level of the tax is not sufficient to initiate deep transformation down to the level of private households. In addition, the eco-tax has been introduced in parallel with the liberalization of the electricity market, which at that time led to declining electricity prices, so that the effective economic impact of the new tax at the household level was not perceived as significant. However, it was a starting point to make customers aware of instruments incentivizing the rational use of energy.

The EU ETS, in force since 2005, introduced carbon pricing by setting caps on CO_2 emissions for selected industries. Although in fact the ETS is a policy instrument ensuring that an absolute emission cap is achieved, it was also intended to raise carbon prices up to levels which could spur technology development for decarbonization. The ETS covers roughly 45% of all European CO_2 emissions and is regarded as the key instrument for emissions reductions.

The ETS design is characterized by generally fixed quantity targets. This leads to a dependence of the carbon price signal on the realization of several developments that could hardly be expected at the time of the set-up of the emission reduction pathway. Consequently, the unexpectedly huge amount of certificates created from project related mechanisms (CDM and JI), the particularly strong rollout of RES by additional support mechanisms, and the economic crisis in Europe led to surplus allowances in the market and therefore dampened carbon prices far below originally expected levels. In reaction to these shortcomings, in January 2014 the European Commission announced the introduction of a Market Stability Reserve (MSR) from 2021 onwards. The proposed MSR is designed to respond to unforeseen events by adjusting the supply of allowances based on pre-defined rules. By monitoring ‘Allowances in Circulation' the MSR either feeds permits into or releases permits from a reserve such that the permit surplus is maintained within a certain band. In addition to quantity based thresholds, the MSR is also activated via a price based trigger (Acworth, 2014). Thus, important carbon price increases within the ETS are conceivable only post 2020 when caps will be sharpened and possibly result in a scarcity of allowances (ewi et al., 2014, p. 15).

There is another shortfall as well. While the ETS complies with CO_2 emission reductions targets for the industry at international (EU) level, the *Energiewende* sets targets at national level. Within the ETS the German industry is allowed to purchase additional allowances for compliance, and therefore may not reduce GHG emissions at home to the extent necessary for the achievement of German national targets. Thus, the ETS could create a need for additional regulation that in part offsets the effects of its rigidity.

Although a successful reform of the ETS depends on a common decision of EU member states and not on German government's policy alone, the consequences of a dysfunctional ETS are substantial for the success of the *Energiewende.* Low carbon prices have a negative influence on investment into new low carbon technologies as their abatement costs are still high. Consequently, many emission reducing investments in power generation and other ETS sectors have been postponed. To the contrary, the current switch to coal, and particularly lignite coal fired electricity generation increases GHG emissions, and could have been avoided by higher carbon prices. In addition, low carbon prices are reducing the available financial support for energy efficiency provided by the national Energy and Climate Fund, which is sourced from the national auctioning of CO_2 allowances.

The national **Energy and Climate Fund** was implemented by law in 2010 and is scheduled to allocate three billion EUR annually. Given the huge investment required for a successful transition to a carbon-neutral energy system, the Fund provides financing for a prominent part of public R&D promotion and for efficiency measures. The latter are applicable to a variety of sectors including municipalities, industry, SMEs and consumers. The fund focuses on investments into energy efficient refurbishment of buildings, R&D for renewable energies, and new electricity storage technologies. Since 2012 all income generated from auctioning of CO_2 allowances for the ETS is to be used by this Fund. Currently, the financing of this fund is fluctuating at a low level due to very low and volatile prices for CO_2.

Energy efficiency is the basis for the business model of ***energy performance contracting***. Investment that is financed by a third party is re-paid by reduced energy costs of the customer. This lowers the financial burden on the customer. In addition, the energy efficiency service company provides competence on identification of energy efficiency potentials and implementation of appropriate energy efficiency measures. Thus, it helps to overcome two major energy efficiency barriers: lack of financing or of access to financing and lack of information. So far, the model is mainly used for efficiency investment in energy supply systems, in development of energy efficiency potential in energy intensive industries and, to a certain extent, in public and residential buildings. Barriers to a wider application of this approach especially by municipalities and small and medium size companies are related to risks for the contractor linked to long contracting periods and the lack of guarantees etc. The National Action Plan on Energy Efficiency of 2014 aims at helping to secure these risks by widening the current guarantee offers in place. The guarantee level per loan was raised to two million EUR for a period of three years (BMWi, 2014f, 30).

6.2 Power sector policies

6.2.1 Renewable Energy Act

The Renewable Energy Act (EEG) is the mainstay of providing incentives for the expansion of renewable energies in the electricity sector. For better understanding of the adjustments made to the law over time the following analysis of its development is split into two phases.

Phase 1

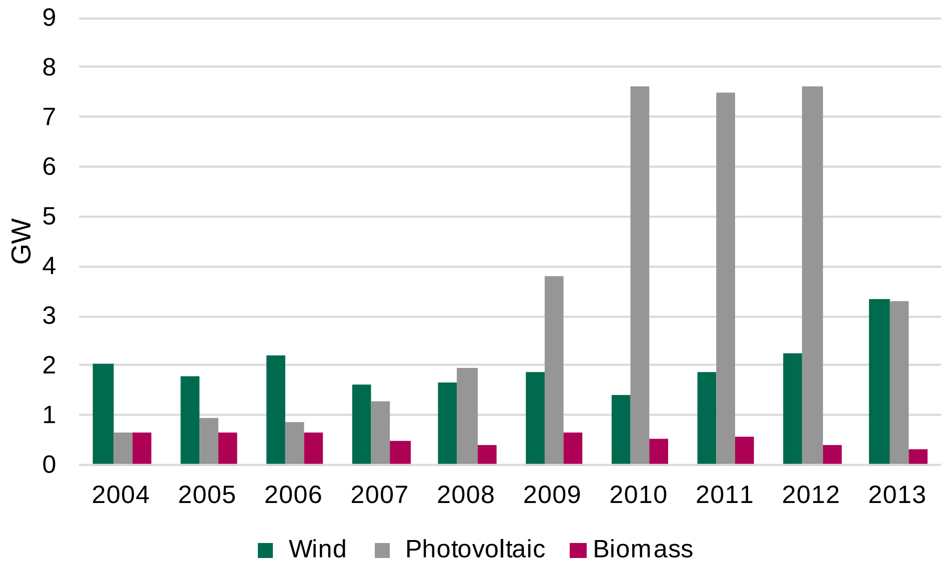
Implemented in 2000 and subsequently altered and modified in 2004, 2009, 2012 and 2014, the Renewable Energy Act (EEG) is the most important instrument of providing incentives for the expansion of renewable energy-based electricity. The law is designed to trigger and broaden the diffusion of these technologies while limiting excess profits of investors by a differentiated tariff structure.

These administratively set tariffs for supplied energy are guaranteed for predefined periods of usually 20 years. Furthermore, the EEG establishes a priority dispatch and obliges grid companies to connect new units to the electricity system.

The tariffs for new installations are reduced annually to reflect cost reductions that are for instance due to economies of scale and technological learning effects. Therefore, the tariff-system is clustered into broad source types, e.g. wind, sun, and biomass, and further differentiated according to size and type. For instance, tariffs for new investments in solar power distinguish between ground mounted and roof-top modules, which are further clustered in five sizes.

The German feed-in tariff (FiT) has resulted in a fast roll out of a variety of technologies. The net capacity additions in the dominant renewable energy technologies of the last decade are summarized in Figure 6-1, which shows the comparably stable development until 2009 across technologies. However, it also exhibits an unprecedented increase of solar power capacity in the following years with yearly installations of more than seven GW annually in the years 2010-2012. This accelerated roll-out was halted by several reductions of the photovoltaic feed-in tariff, which brought down the installation of new panels to around three GW annually.

Figure 6-1
Capacity additions of renewable energies in the electricity sector

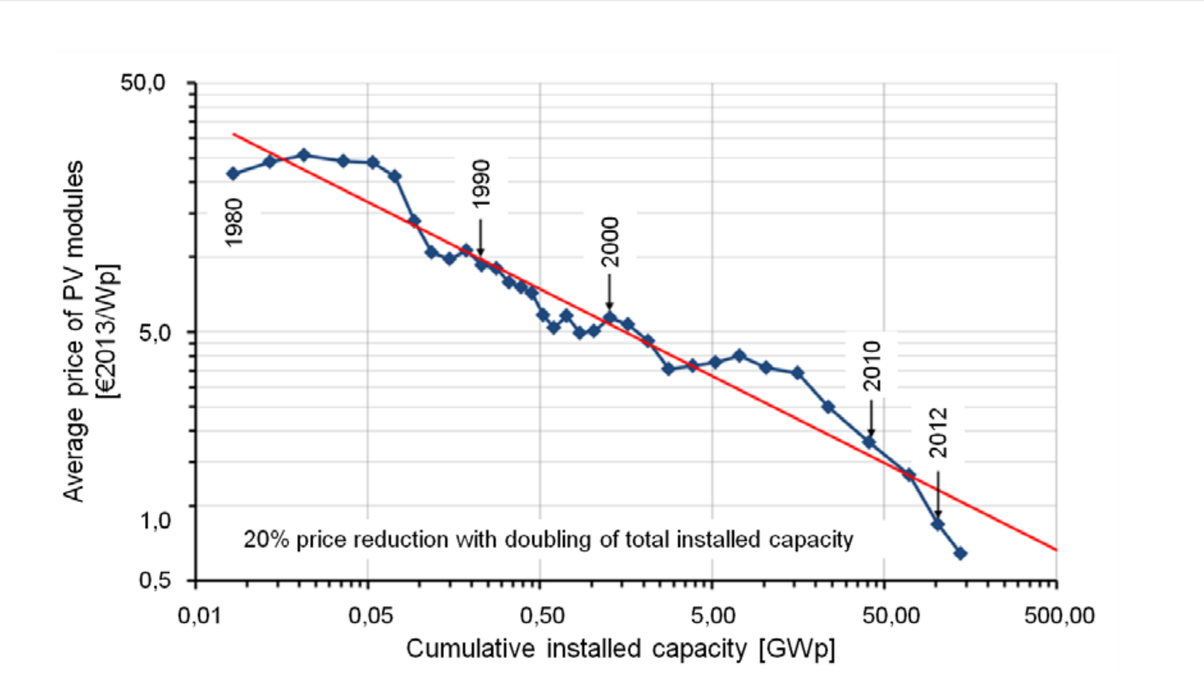


Source: BMWi (2014c).

In the fourteen years prior to 2013, Germany was seven times the largest market for PV-modules worldwide (EPIA 2014) and leads in cumulative capacity. At the same time, Germany is number three in global installed capacity of wind power with a share of about 11% of all installations and a cumulative capacity of almost 36 GW. Only in China and the US higher absolute values are achieved. Since the introduction of the EEG in 2000, the share of renewable electricity in German electricity generation has increased from less than 10% to more than 25% in 2013 (BMWi 2014d).

The rapid technology diffusion of particularly wind and solar power is linked to a strong cost decrease. Figure 6-2 shows the average price for PV-modules in relation to cumulated worldwide capacity and implies a cost reduction of about 20% per doubling of installations.

Figure 6-2
PV-module cost development versus total capacity



Source: Wirth (2014).

Arguably, these cost dynamics resulted in high rents for investments in PV at good locations. In turn, a further acceleration of deployment was induced. This development implied a strong increase of the total volume of support to renewables, and led to a sequence of increases in electricity prices that were halted most recently only.[7] Although solar power had a share in total supported energy of 20%, it has been responsible for more than 40% of the surcharge in 2013.

[7] The renewable surcharge calculated for the following year was reduced for the first time in 2014.

The surcharge recovers the differential costs of the supported energy in comparison to procurement costs at the electricity exchange and is passed on to consumers' electricity bills. However, similar to the eco-tax it allows generous exemptions for industrial consumers in order to sustain international competitiveness of electricity intensive production processes. Thus, the instrument does not significantly burden almost a quarter of German electricity consumption. By contrast, the so-called merit-order effect, i.e. the wholesale price dampening effect of renewables, benefits exempted industries currently by at least ten % of energy procurement costs.

In comparison with other support schemes like quota systems, historically the per-kWh-cost of promoting specific technologies in Germany has been below those in other European countries that promoted renewables with other schemes. We can explain this by two facts. First, a central characteristic of guaranteed tariffs is the creation of preferential investment conditions. In essence, the German support system transfers the major part of the normal investor's risk, the price risk, to the consumer. Since only the performance risk remains, the total risk is reduced which contributes to low financing costs and relatively low guaranteed tariffs. Secondly, a high technological differentiation of cost related tariffs prevents excessive windfall profits. Whereas a pure technology-neutral quota system promotes all technologies with the same support and creates windfall profits for low costs sites, the tariff differentiation is adjusted to reflect these cost advantages. As a result, the average support is lower than under a unified tariff that achieves the same deployment but would lead to higher total transfers to investors than necessary. Moreover, if technologies are expected to experience significant cost reductions in the future and are at the same time necessary for the achievement of long-term climate targets, an especially high support may be justified for a short transitory period. Such high support had also to be granted to cheap technologies, for instance onshore wind power, in a technologically indifferent system.

Hence, in the last decade the overwhelming majority of countries decided to introduce a feed-in tariff or feed-in premium.[8] In Europe, 25 of 28 countries used this mechanism in

[8] A premium grants a second income stream in addition to market revenues. It is essentially identical to a feed-in tariff if it completely fills the gap between a guaranteed tariff and the average market revenue. This is called direct marketing (Direktvermarktung) in the German system, and is profitable for renewable energy generators if the realize higher than market average revenues. However, a premium can also be designed as a fixed premium independent from the market outcome.

2013 (DIW 2012, European Commission 2011, Ecofys et al. 2011, Klessmann 2014, Fraunhofer ISI / RISO / VUT 2007).

Box 6-1
Central characteristics of the German renewable energy support scheme.

Feed-in Tariff
• Fixed tariff per renewable energy unit granted usually for 20 years, i.e. revenues are independent from electricity prices. • Differentiated by technologies and transparently decreasing with the time of first grid connection, i.e. later installations receive less support per energy than older ones. • Grid companies are obliged to connect new installations and to grant priority to purchases of renewable electricity. • Differential costs due to the difference between remunerated tariffs and wholesale market prices are allocated to consumer electricity bills by the renewable energy surcharge. • Exemption of energy intensive industries from the surcharge

Phase 2

After the extraordinary rollout of PV from 2009 to 2012 and corresponding increases of the surcharge and thus electricity prices, several policy modifications were implemented to stabilize the deployment, increase market integration and limit the surcharge. Starting as a price instrument, already the 2012 version of the EEG introduced several quantitative elements. Today, the digression of support for new investments is linked to the deployment level of the corresponding technology in the previous period, and total supportable PV installation as well as annual supported biomass fired power plant erection is restricted by absolute ceilings. Furthermore, the latest version of the law paves the way to a switch from administratively defined tariffs to a tendering of support grants. The first pilot tender will determine the support for ground mounted PV already in 2015. By 2017, the law foresees that all support will be granted by tendering.

Most importantly, the EEG revisions will enable to control the renewable energy rollout in the electricity system and to comply with the envisaged targets. For that aim, the EEG 2014 defines a quantitative trajectory to achieve by 2025 an at least 40 to 45%, and by 2035 an at least 55 to 60% share in gross electricity consumption. On the one hand, this promotes a stable investment perspective for complementing installations of the electricity system, and the tendering is expected to promote intra-technology competition. On the other hand, investor risks are likely to increase since an estimation of competing offers has to be the basis of a successful competitive bid. Moreover, a penalty to limit underbidding and the effects of the so-called winners curse has to be introduced to prevent bids that are not cost covering. The additional risk that is introduced to renewable energy investment projects is likely to increase financing costs and may lead to an increase of market concentration since larger companies are able to hedge risks through portfolio optimization. It remains an open question whether intra-technology competition outweighs these effects.

6.2.2 Electricity grid initiative

Today, the German electricity system has a very high reliability standard and one of the smallest interruption rates worldwide (BMWi 2014a, 63). However, following the liberalization of the energy market in Germany in the1990s, a more efficient utilization of and lower tariffs for the grid service have been achieved by the introduction of an incentive regulation, while comparatively little reinvestment in grid infrastructure took place. The continued restructuring of electricity generation, particularly the rollout of renewable energy and the phase-out of nuclear energy, as well as the integration of national electricity markets induce changing requirements for the electricity grid infrastructure. New fluctuating wind resources are added to the system mostly in the northern part of Germany, while Photovoltaic electricity generation is concentrated mainly in the south. At the same time, the major part of the remaining nuclear power plant fleet is located comparatively close to the centers of consumption in the south.

In response to these requirements, the government adopted the Energy Line Expansion Act and the Line Expansion Acceleration Act, which provide the necessary political framework for the expansion of the transmission grid.

The federal Grid Development Plan and corresponding grid requirement plan intend to structure and to accelerate the planning of the German legislation on electricity grid development.

Four transmission system operators (TSO) are in charge of the inter supra-regional provision and the transmission of electricity. By law of the EnWG, the four TSOs have to submit a single Grid Development Plan, which describes the effective measures that are necessary for a secure and reliable grid operation in the next decade (EnWG, NEP 2014, Chp. 1).

Based on the so-called scenario framework which defines in a first step central figures for the future requirements under different possible evolutions and up to two decades in advance (generation mix, expected demand and their regional distribution), simulations are carried out with up-to-date methods and programming tools to define in a second step a draft of the grid development plan. In a third step, the draft is put forward to public and expert consultation, revised and redrafted. Finally, together with an environmental report the revised draft is brought forward to the legislator who develops the requirements plan for acceptance and approval in parliament. The planning approval of the federal requirements plan constitutes a legislative act and approves public interest and the according grid development requirement is therefore hardly contestable in legal process.

6.2.3 State support program for solar electricity storages

Small electricity storages are considered to be a key option for the integration of grid connected small solar electricity installations. These storages help lowering peaks of solar electricity supply into the grids and therefore have the potential to relieve the grid in critical situations. This could reduce the necessary grid investment and the curtailment of renewable energy supply. In order to provide incentives to private owners of PV stations a new investment subsidy program was set up in May 2013. It applies to installations with maximal available capacity below 30 kW that is installed from January 2013. The program is managed by KfW and offers a subsidy for up to 30% of the eligible investment cost, and maximal 600 EUR/kWp PV capacity. In addition, the bank provides loan repayment subsidies in case an additional loan is required (KfW, 2013). (See chapter 6.6.1 for further information on storages)

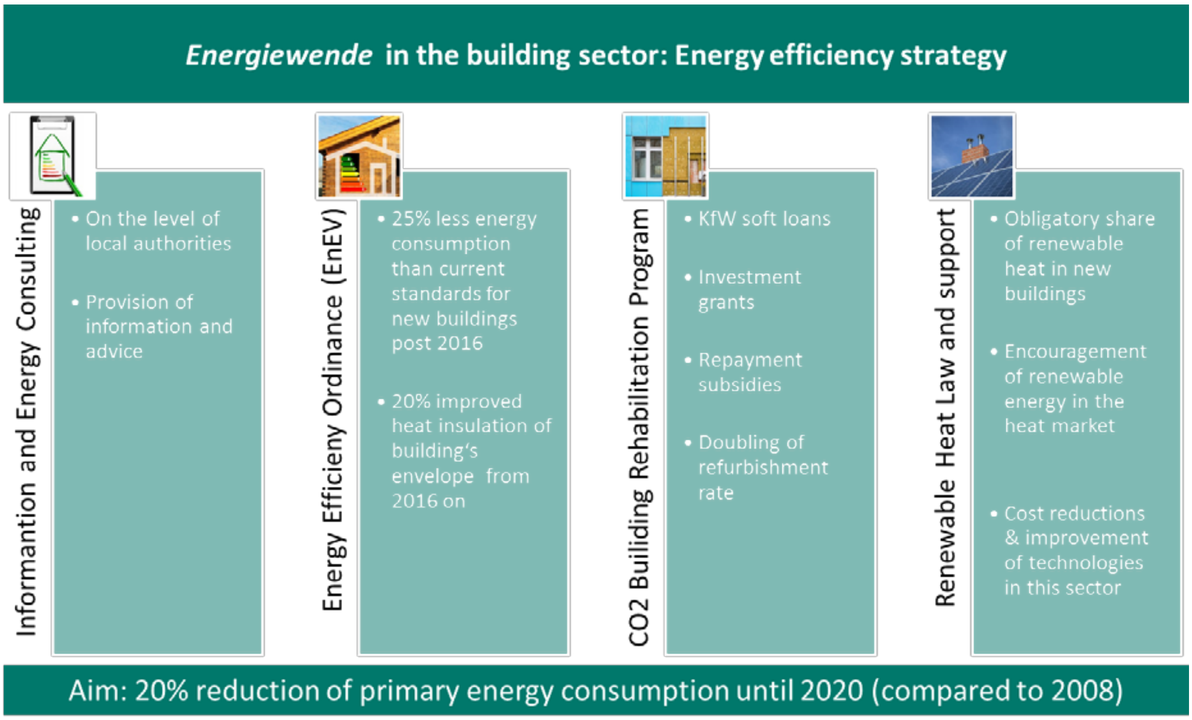
6.3 Policies in the Building sector

Energy consumption in residential and commercial buildings represents more than 40% of total final energy use and contains the bulk of the identified energy saving potential on the demand side (Fraunhofer ISI, 2014, 14). Therefore, buildings need to contribute substantially in order to reach the estimated targets of primary energy reduction and of final energy productivity increase. Buildings differ widely by type, age, owner and user. Their final energy demand is mainly driven by heating and cooling, hot water supply and lighting. These drivers are in turn heavily depending on heat losses through the building envelope (roof, walls, cellar, windows and ventilation) and the energy standard of the equipment in place. Measures to reduce energy consumption therefore need to focus on all these elements.

As market failures, information problems and behavioral failures are major barriers for the success of respective measures, a variety of appropriate policies is needed to overcome a bundle of obstacles. Divergences between home owners and experts' assessments of energy refurbishment's economic viability give additional explanation why the estimated rate of possible refurbishment differs from the rate of practical implementation (Albrecht and Zundel, 2010). Thus, a viable approach for this sector integrates different demand and supply side policies, such as improving appropriate standards for insulation and heat production and combines them with financial assistance and raising awareness. For new buildings, the obligatory use of renewable energy for heat is an additional requirement that is combined with efficiency standards.

The current building stock in Germany consists of about 18 million residential buildings and of about 1.5 million non-residential buildings. Although small by overall number, the non-residential buildings consume 35% of the energy used in the buildings sector. 41% are accounted for by about 14 million single- and/or two- family houses, whereas the remaining 24% are consumed by four million multi-family buildings (VdZ, 2014).

Figure 6-3
Measures and policies for climate friendly buildings.



Source: DIW Econ based on BMWi;
http://www.bmwi.de/DE/Themen/Energie/gebaeude.html

The Energy Concept of 2010 aimed at kick-starting a modernization campaign for buildings and led to the implementation of a package of different measures and instruments involving the business sector. Policies in force can be grouped into the following broad classes:

- Administrative law
  - Creating minimum standards for the energy performance of new and existing buildings and their energy equipment combined with subsequent tightening of these standards over time by ordinances and laws. This approach also includes the use of renewable heat in accordance with technical availability and economic viability.
  - Regular inspection of heating and air-conditioning systems.
  - Introducing changes in the principal agent relationship (building owners and tenants). In May 2012 the government amended the tenancy law in order to split advantages and costs between landlords and tenants to facilitate refurbishment. Landlords are

now allowed to increase rents up to 11% per year to cover the cost of energy renovation.

- Obligatory use of renewable heat in new buildings.

- Economic incentives
  - Public financial assistance to the building owners by provision of soft loans and subsidies herewith reducing liquidity constraints.

- „Soft“ instruments
  - Providing information and advice concerning reduction of energy consumption levels of building by energy consulting and by labelling buildings (energy performance certificates) in order to reduce informational market barriers and to reveal potential savings related with high energy efficiency standards.
  - Information and awareness raising campaigns.

However, tax incentives for energy efficient refurbishment had not been approved mainly because of opposition by the Federal State governments (see chapter 7.2). What remains in place are tax breaks (up to 1,200 EUR/a) for owner-occupiers that invest in energy-savings without recourse to public funding.

Experience shows that the existing measures are effective for new buildings, since standards are enforceable during construction licensing procedures. The more challenging part of the buildings sector is the existing building stock, where owners cannot be forced to implement energy efficiency measures or the measures might not lead to the desired effects. Although modernization takes place and standards of modernization are well defined, the transformation of the building stock turns out to evolve much more slowly than expected.

Respective EU directives and communications, which set up the framework and have been adjusted over time, lay the basis for German policies. The EU-Directive on Energy Efficiency of 2012 (Directive 2012/27/EU) is the most recent document, which had to be transposed into national law. Its implementation has been incorporated into Germany's Energy Efficiency Ordinance.

6.3.1 The Energy Efficiency Ordinance - EnEV

The EnEV constitutes the basic legal act for the support of energy efficiency development in buildings in Germany. The ordinance applies to all buildings which use energy for heating or cooling and for all facilities and technologies used in these buildings for heating, cooling, ventilation, lighting and hot water supply. It sets minimum efficiency requirements for the buildings envelope and the equipment used for heating and cooling. The ordinance also imposes retrofitting requirements for major components which have to be met. The standards and requirements have been tightened over the last years in continuously updated versions of the ordinance. The current EnEV, effective since May 2014, aims at contributing to reach the energy efficiency targets in the building sector and setting the right course for having an almost climate-neutral building stock in place in 2050.

The EnEV is based on the Energy Savings Law in force since 2002 requiring avoidance of unnecessary losses and the installation and operation of energy saving appliances in new buildings. It prescribes rules for the pass-through of operation costs such that the energy consumption of the final customer is appropriately measured and accounted for in energy bills.

The updated ordinance of 2014, as an instrument of administrative law, imposes the following:

- More ambitious efficiency requirements for **new residential and non-residential buildings** including:
    - The annual primary energy demand of heating and cooling installations related to reference types of building. These types are usually based on the relation of the envelope of the buildings to heatable volumes in m^3. From 2016 on, more ambitious energy efficiency standards for new residential buildings are valid requiring 25% less primary energy consumption than current standards for new buildings (EnEV, 2014, Annex 1 to §§ 3 and9)).

- Heat insulation of the building's envelope (20% better from 2016 on)
- Heat shield – summer heat insulation
- Airtightness of the building's envelope
- Minimum air exchange in the residential building.

From 2019 on all new public buildings have to be in line with low energy building standards and from 2021 on the same requirement is valid for new private buildings (residential, office buildings etc.)

- Compliance with final energy demand standards may be fulfilled by the use of renewable energy. In case a building generates renewable electricity which is used by the building itself, the total energy demand that is subject to the ordinance can be reduced by the amount of predominantly self-supplied renewable electricity.

- Requirements concerning refurbishment of existing buildings:
  - In case of changes in the building's envelope the refurbishment measures need to be in line with energy efficiency standards for new buildings. These requirements are mandatory if changes apply to more than 10% of the envelope's space.
  - Decommissioning of heat boilers for liquid or gaseous fuels and with nominal capacity between 4-400 kW that are installed before 1 October 1978. Boilers installed until end of 1984 lose their operation license after 2015, and boilers installed in 1985 or later are not allowed to operate longer than 30 years.
  - Insulation of heat pipelines, of controls and instruments for heat and hot water supplyand of the ceiling of the last floor is mandatory.
  - Obligatory insulation of roofs or ceilings of heated space below the roofs.

- Obligatory building certificate (buildings passport) if buildings or flats are sold, aiming at increased transparency of costs to improve pricing in this sector.

6.3.2 Soft loans for energy efficient refurbishment and energy efficient construction (CO2 Building Rehabilitation Program)

Since 2001 the government offers long-term soft loans including subsidization of repayment rates for energy efficient refurbishment in buildings, which are managed by the state-owned KfW bank. Since 2006 about 1.6 billion EUR for loans have been provided, which triggered investments worth almost 118 billion EUR. Roughly three million flats and 1,400 communal buildings have been refurbished or newly constructed (BReg, 2014). In order to achieve the doubling of the refurbishment rate, the CO_2-Refurbishment Program was expanded in May 2012. A sum of 1.8 billion EUR annually is provided from 2012 until 2014 compared to about 936 million EUR/a previously. The National Action Plan on Energy Efficiency (NAPE) approved in December 2014 further increased the amount of financial support provided by this Program to up to two billion EUR annually from 2015 on (BMWi, 2014f, 21).

The Program supports energy efficient construction and refurbishment of the existing building stock. Support is related to efficiency classes of buildings. The classes for refurbishment of the existing stock range from EH-55 standard – i.e. “passive” house standard - reaching a level of 45% energy demand reduction against current efficiency standards for new buildings, to EH-70, EH-85 standards with demand level reductions of 30% or at least 15% respectively. New buildings may be supported in case they reach EH 70, 55 or 40 standards.

Guidelines of energy efficient refurbishment until 2050 provide information for landlords and house owners that show how refurbishment measures can lead to lowest energy consumption. Buildings of the Federal Government should become role models for energy efficient refurbishment.

In order to provide tailor-made financial support for different types of buildings, building owners and specific technologies, the program includes several targeted sub-programs. In addition to refurbishment of the residential building stock and construction of new residential buildings other sub-programs include amongst others:

- CO_2-refurbishment program for municipalities with a focus on 300,000 existing buildings of communal and social infrastructure, which allocates up to 50 million EUR starting in 2012.
- Refurbishment of heating systems supporting renewable heat (see chapter 7.3.3).

- Refurbishment of buildings of non-commercial organizations and churches, of communal enterprises like public swimming pools and conference halls etc.

Until recently, the bulk of support was absorbed by refurbishment of the existing stock. Moreover, about 50% of new residential buildings have been supported by the program. Correspondingly, half of the new buildings have been constructed complying with higher efficiency standards than required by the previous EnEV 2009.

Information and advice are crucial to overcome informational gaps. The program supports the identification of measures that reach appropriate efficiency standards. The support program of the Federal Ministry of Economy and Energy on in-house counseling as an advisory service allows for involving qualified energy advisors in the development of refurbishment plans; 650 helpdesks presently operate.

6.3.3 Legal regulations for renewable heat combined with financial support

Financial support schemes for renewable heat have been in place in Germany since 1993, but have not been sufficient to reach the targets. Although analysis often shows favorable economics of renewable heat installations, higher up-front investment and volatility of oil and gas prices have frequently been identified as a barrier for choosing renewable heat (BMU 2012b).

Therefore, in summer 2008 the **Renewable Heat Act** was approved within the frame of a “package” of laws targeting climate change. It aims increasing the share of renewable heat and cooling in total final energy demand to 14% until 2020. In force since January 2009, the act is obligatory for all new buildings and has three main pillars:

- The obligation to use renewable heat in all new buildings. All types of renewable heat can be used, also in combination with each other. Alternative measures can be a 15% more ambitious insulation of the building’s envelope as required by the current energy efficiency standard for buildings or heat supply by district heating or CHP.
- Financial support through extension of the market incentive program for renewable heat up to 500 million EUR annually.

- Municipal administrations are allowed to make access to and use of heat grids obligatory.

In contrast to the EnEV's technological neutrality, the Renewable Heat Act aims at incentivizing technology development.

First results show a more stable development of renewable heat in new buildings than before the implementation of the new law. In 2011, new buildings pulled a share of 60% of newly installed heat pumps and about 66% of the new biomass-central heating systems implemented in buildings. This development proves the success of the law in the segment of new buildings. However, as the overall dynamic in construction of new buildings was slow and respective improvements are still insufficient, market expansion of renewable heat is still moderate. Annual renewable heat supply in new buildings amounted to about 0.6 to 0.7 TWh/a between 2009 and 2012. The law also triggered an increase of connections to district heating, which was declining before the law came into force (BMU, 2012b).The legal approach has been combined with the **Market incentive program for renewable heat** financed by of the Federal Government. The goal of the program is to encourage the production and use of renewable energy in the heat market, to reduce costs, and to improve profitability of technologies in the sector (BMWi, 2014b). The program in its new design was set up in 2009 in parallel with the Renewable Heat Act, and is now focusing on support for renewable heat predominantly in the existing buildings stock. Various technologies and innovative processes are supported

The program provides grants as well soft loans and repayment subsidies. The grant part is managed by the Federal Office for Economic Affairs and Export Control (BAFA) and provides the following support:

- Investment grants for small solar thermal installations (up to 40 m²) usually appropriate for single family houses;
- Extra (bonus) support for innovative renewable heating technologies or combinations of different technologies;
- Investment grants for process heating installations up to 50% of net investment;
- Investment grants for biomass installations and for refitting of existing biomass installations for heat supply.

The second part of the program is managed by KfW, the German state-owned development bank, and offers the following:

- Repayment subsidies of up to 50% of investment for big solar collectors (above 40m²), generation process heat or solar cooling;
- Soft loans and repayment subsidies for heat pumps of 100 kW capacity and larger, biogas pipelines, and deep underground geothermal installations for heat and for electricity generation.

In addition, large companies may receive low-interest loans for projects in this sector through KfW's renewable energy “premium” program. These loans cover up to 100% of a project's net investments costs up to a maximum of 10 million EUR per project.

Up to 500 million EUR annually have been made available for support of renewable heat from 2009 until 2012. Means provided by the subsidy part of the program increased over the last three years from 229 million EUR (2011) to 321 million EUR (2013). Overall private investment triggered by the program was 1.23 billion EUR in 2013.

Within the second (loan) part of the program (KfW part) about 2,695 soft loans had been secured with a total volume of 289 million EUR. The major part of the loans (1,677 loans of about 191 million EUR in total) had been spent on heat grids followed by biomass installations (705 loans), heat storages (190 loans), and on big solar thermal installations (59 loans; BMWi, 2014b).

However, the market incentive program seems not to be sufficient to trigger the needed transformation to renewable heat in the existing building stock. Out of the 500 to 600 thousand heating systems being annually refurbished almost 90% are still carried out as fossil fired systems. This probably leads to a lock-in effect at least until 2030 and corresponding high long-term embodied emissions.

In order to change the renewable heat dynamic in the existing building stock, new approaches are under discussion (see chapter 7.2).

6.3.4 Information and awareness raising campaigns

The German Energy Agency (dena) runs an information campaign "Zukunft Haus" (Future Building) based on a special internet platform (http://www.zukunft-haus.info/). Exemplary projects are exposed as "Low Energy House in the Housing Stock" with ambitious efficiency standards and innovative technologies to demonstrate best practice. 375 buildings have been renovated reducing their energy demand by 87% on average. Different projects for energy efficient buildings, energy efficient municipalities, energy performance contracting and advisory services offer background information and working tools to tenants and landlords. They provide information with respect to energy passes, energy standards and innovative technologies. In 2014, the new campaign "Hauswende" (buildings transformation) started. The campaign aims at pushing the refurbishment process and provides help for house owners to manage the complex energy efficient refurbishment process. It supplies information and advice for the identification of potential measures, for the financing of investments (screening available means and programs), the planning of the refurbishment process (including selection of qualified service providers, cost assessment) and its implementation.

The projects and campaigns address the lack of information on the side of potential investors and consumers, and initiate a learning process by demonstrating new technologies and construction techniques together with existing support programs.

6.4 Policies in Industry

A large part of the German industry is export-oriented and heavily exposed to international competition. Not surprisingly, international rules are therefore dominant and energy efficiency policies in industry are mainly driven by European legislation. Apart from the EU-ETS, which covers a large part of German industry, the EU policies for industries focus on two main directions:

- **Technology driven activities**: Development and introduction of energy efficiency standards developed for energy-related products (ErP) by the 2009 EU Directive establishing a framework for the setting of eco-design requirements for energy-related products. The directive defines minimum standards for energy using products applied in all sectors. It sets implementing regulations for various type of products. Examples include power transformers, water pumps, industrial fans, and electric motors. The Regulation for electric motors serves as an example:

- The EU Motor Regulation (640/2009) defines the requirements relating to the environmentally-compatible design of electric motors and the use of electronic variable-speed drive control. There are four international efficiency classes for induction motors.
- The European Energy-related Product standard EN 50598, which focuses on the drive system as a whole and defines requirements placed on energy-related products (energy efficiency, eco balancing) for drive systems in electrically-driven machines

- **Process driven activities**: Introduction of energy management tools like voluntary and obligatory energy audits at regular intervals for all non-SME companies as well as introduction of energy management systems in accordance with ISO 50001 standards. These systems provide a means by which companies and organizations establish the necessary systems and processes for the achievement of operational control and continued improvements in the energy performance. Energy consulting for SMEs is supported by public finance.

In addition to the EU rules in 2012 the German government concluded an **agreement with the German business community on energy efficiency improvements** until 2022 (BMWi, 2012). The Agreement reacts to the decision within the energy concept of 2010, which extended the exemption of energy intensive industries from the eco-tax (see 5.1) since 1999 under certain conditions. The conditionality was linked to a verifiable implementation of energy management systems in accordance with ISO 50001 starting from 2013 combined with an agreement on increasing targets for energy efficiency that is binding from 2015. The following efficiency targets have been agreed on: 1.3% energy efficiency increase in 2013 in order to apply for eco-tax exemption in 2015. For the following years the targets are 2.6% in 2014, 3.9% in 2015 and 5.25% in 2016 for application of respective tax exemptions. Monitoring by an independent economic institute will be implemented and targets for tax exemptions in 2019-2022 will be established by 2017.

The agreement is to assure that energy efficiency improvement keeps on track with overall target after having slowed down to 1% annual improvement between 2008 and 2012 providing tax exemptions as financial incentive.

6.5 Transport sector policies

The transport sector is the second most important sector consuming almost 29% of total final energy and at present it is not in line with the targets for 2020. Due to the diversified structure of the sector a package of policies is needed to improve the sectors climate performance. The Mobility and Fuels Strategy of the German Government in place since June 2013 takes the difficulties of the sector into account, and aims at being not an overarching mobility strategy but rather an initial, concrete contribution to achieving the targets in the transport sector (BMVBS, 2013b, 5).

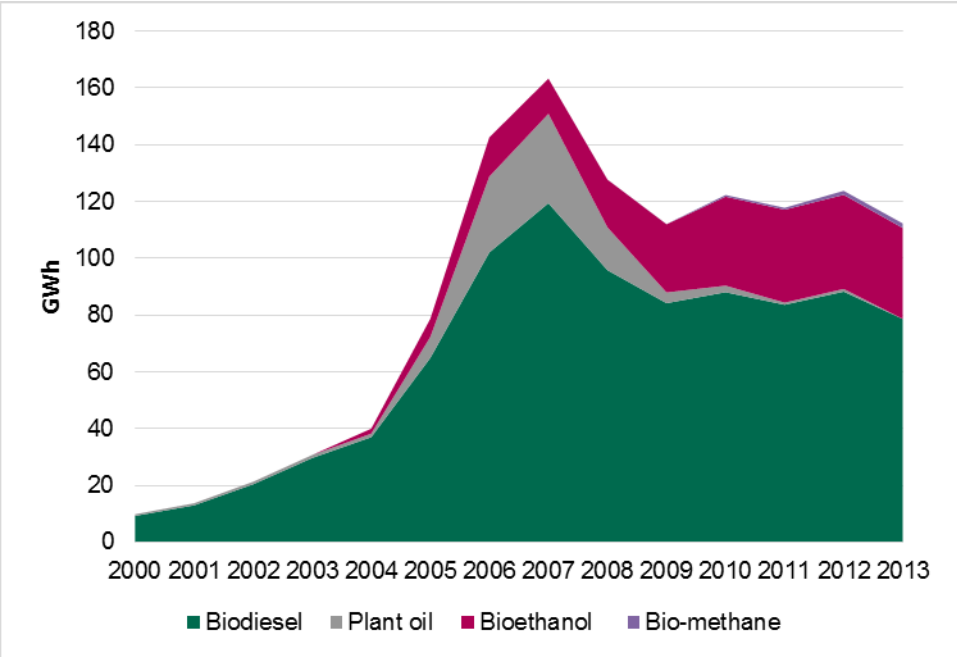
The major share of energy used in this sector is consumed by road transportation (82% in 2012). Therefore, the policies focus mainly on this sector and concentrate predominantly on fuel switch and technology improvement aiming at lowering fuel consumption of vehicles. The latter is incentivized by the vehicle-tax.

A cornerstone of the Transport Sector policy of the Federal Government is the process engaged with the Mobility- and Fuel-Strategy that tries to give an overview of options for energy and fuel provision for different transport modes. It also aims to contribute to knowledge and awareness of specific problems in the field of transport, to analyze the current framework, to prioritize targets, and to show ways to realize the *Energiewende* in this sector by a learning strategy. Central part of this process concerns the fuel strategy, whereof renewable fuels play the most prominent role.

6.5.1 Renewable fuels

The share of biofuels in the transport fuel mix experienced a pronounced increase since the beginning of the century and reached more than seven % in 2007. Figure 6-4 shows the corresponding development of biodiesel, plant oil, bioethanol and biomethane in Petajoule. Since 2006, however, biodiesel and plant oil for fuel use is taxed with annually increasing rates that culminated in the current taxation, which today is comparable to that of conventional fuels. By 2007, the government effectively replaced the law by an obligation that prescribes a biofuels quota for the fuel supplying industry.

Figure 6-4
Development of biofuels in the transport sector



Source: BMWi (2014c).

Following the adjustment of the policy, the use of biofuel decreased significantly due to a pronounced reduction of biodiesel and plant oil until 2009. A subsequent increase in the use of bioethanol primarily until 2010 did not compensate these reductions. Consequently, since 2010 the share of biofuel stagnated as indicated by the development of total biofuel use shown in Figure 6-4, and a stable total fuel use in the transport sector in the last years.

Although the quota system formally obliges the fuel industry to provide increasing shares of biofuels in their overall supply that should reach eight % by 2015, less than six % were achieved by the end of 2013. Several obstacles come into play that prevent a further diffusion. These concern technical problems, acceptability, sustainability and the overall regulation framework. First of all, blending ten % ethanol into gasoline turned out to be either not possible for technical reasons or not acceptable for many car users. As a new product that was intended to reach the quotas, E10 is supplied in Germany and stands for ten % ethanol fuel content. However, it is not feasible for all gasoline cars older than the newest generation to use E10 without risk of engine damage. Only after its introduction, car manufacturers provided lists of cars that are in principle able to use E10, and often still do not guarantee a riskless use. Moreover, the economics of E10 are not convincing since the energy content is lower than in ordinary gasoline fuel and the discount offered at the gasoline stations does not always compensate for perceived risk and reduced range. Second, due to imports from third countries, sustainability of bioethanol production is questionable and hard to control. Therefore, an acceptable biofuel regulation has to ensure also the sustainability of supplies in order to achieve sustainable consumption structures.

6.5.2 E-mobility

Consequent introduction of e-mobility is one of the most important long-term carbon-neutral transformation strategies for individual traffic (BMU, 2014b). In the Governmental Program on E-mobility of 2011, the Federal Government outlined that the country should not only become a leading market for e-mobility technologies but aims also at becoming a leader in offering e-mobility in practice. A major focus in the Program is set on further R&D, which is carried out within the National Innovation Program for Hydrogen and Fuel Cell Energy (see 6.6.2).

As the technology is new and the respective infrastructure (charging stations) is not yet developed all over the country many activities focus on research on implementation of the e-mobility concept, awareness raising, and setting up pilot regions, so-called regional “show windows” for e-mobility. That latter approach is aiming at linking the e-mobiles with the traffic system and energy supply and at testing various technical and practical solutions.

The following pilot regions have been selected for financial support by the Federal Government (180 million EUR) which is to be leveraged by private funding of the participating industry and by regional public funding:

- "Living Lab BW E-Mobil" (Baden-Württemberg)
- „International show window e-mobility" (Berlin/Brandenburg)
- "Our horse power will become electric" (Niedersachsen)
- "E-mobility links" (Bayern/Sachsen)

In the framework of the regional show windows also car sharing initiatives relying on e-mobiles are supported.

In addition, several incentives have been discussed in order to support market introduction of e-mobiles.

- Measures to ease the use of e-mobile in road traffic such as:
  - Special parking areas for e-mobiles
  - Exempting e-mobiles form bans which had been introduced for conventional motor vehicles (manly vans and lorries)
  - Opening up of special bus lanes for e-mobiles

- Financial incentives such as:
  - New e-mobiles are exempted from motor vehicle tax for five years. From 31 January 2015 on new e-mobiles and mobiles with CO_2 emissions below 50gCO_2/km will be exempted from motor vehicle tax for ten years (BReg, 2011, 49).
  - Adjustment of the rules for taxing company and staff cars taking into consideration the environmental advantages of e-mobiles.

Current development of e-mobility lags behind targets. Relatively higher costs and the chicken-and-egg causality dilemma concerning the amount of e-cars and charging stations are some of the reasons. Many players operate charging stations and create so-called island solutions. Only own clients may use the stations by concluding a respective contract. But drivers of e-mobiles require similar open use of charging stations as it is the case with conventional filling stations.

However, lacking market acceptance (individual preferences are extremely important for purchasing new cars), lack of economic incentives and lack of unified technical standards are additional reasons for slow market development. Furthermore, certain measures which were outlined in the Governmental Program on E-mobility have not been implemented so far. This is true for labeling e-mobiles which is necessary for recognition of e-mobiles and letting them benefit from the already existing privileges in road traffic and for the new traffic rules themselves. The law on traffic privileges for electric vehicles approved on 24 September 2014 (BMU, 2014a) aims at solving these issues. However, the Law does not grant the privileges directly but leaves the respective decisions with the municipalities. In general grating privileges to e-mobiles in road traffic are assessed positively. However, opening up of special bus lanes for e-mobiles may conflicts with another goal making public transport more attractive and may lead to lower acceptance of e-mobiles by the population. In the National Action Plan for Energy Efficiency the government plans to introduce further tax relieves and a public procurement action for e-mobiles (BMWi, 2014f). Public procurement is seen as a driver to raise awareness and being an example for other consumers. 50% of the costs of e-mobile staff cars will be tax deductible during the year the car was purchased (BEM, 2014a).

In light of lagging behind the target even for 2014, the current rules and initiatives are not sufficient and tend to defend interests of the German automobile industry related to technical standards. At least two approaches may be important to create trust in current e-mobility market development (BEM, 2014b):

- Erection of an area-wide structure for non-discriminating access to rapid-charging stations for all types of e-mobiles in the market
- Introduction of standardized compatible cash- and billing systems

Non-discriminating standardized access to rapid-charging which is a main precondition for further market development should particularly be addressed by pilot regions.

There are initiatives emerging like the e-mobility network "econnect" (www.econnect-germany.de) which unites seven municipal electricity generators with manufacturers and research units that are trying to develop and test a rooming platform (e-clearing.net) for access to different owners' charging stations to overcome the cash- and billing bottleneck. Big electricity supply companies as well as ICT-service provider Mitsubishi Motors Automobile have shown interest in cooperation in case the platform is operational. The requirement of the EU Directive on Clean Power for Transport that all EU member states have to organize a filling and charging infrastructure for alternative fuel until end of 2016 will certainly add a push to overcome this barrier.

6.6 R&D and innovation

Germany has a long tradition in the support of energy technology research and development and increased these efforts significantly over the past years. From 2006 to 2013 the annual budget of the federal energy research program was increased by more than 100% to 809 million EUR. Dominant fields of support are energy efficiency and renewable energy with shares of around 37% each, which have also experienced the strongest increase in public expenses with 170 and about 150% increases in the mentioned period respectively. In addition, the Federal States (Länder) granted research promotion of 253 million EUR in 2012.

6.6.1 6th Energy Research Program of the Federal Government

Federal support for energy research is predominantly organized within the 6th Energy Research Program of the Federal Government (BMWi, 2011) and complemented by additional funding from further sources.

Most prominent funding areas of the federal research include in descending order of funding volume Photovoltaics, Energy Storage, Energy Efficiency in Buildings and Cities, Wind Power, Bioenergy, Energy Efficiency in Commerce, Industry, Service and Trade (BMWi, 2014j, Tables 3 and 4).

Research funding for photovoltaics had a volume of 81 million EUR by 2013 with main research foci on crystalline silicon, thin film technologies, and also basic research.

In 2013, the actual payments for 342 ongoing projects in the field of photovoltaics amounted to 63.59 million EUR. In that year, the federal budget also committed 49 million EUR for new projects. Additional government funds for photovoltaics were spent on other solar-based technologies, e.g. photonics. However, the total payments for research support in 2013 were reduced by five % compared to 2012.

In recent years, PV technology experienced significant cost reductions on both the system and component level (see Figure 6-2). To further promote this development and to realize the expansion potential of photovoltaics efficiently, the target is to improve efficiency and realize existing potentials for cost reductions. In the current situation, the major share of funding supports the German photovoltaics industry, the mechanical engineering industry as well as industries that develop innovative and competitive solutions. Correspondingly, the government favors collaborative projects with industry participation. At the same time, the program also facilitates initial research, which should pave the way for German research institutions to provide the industry with assessed and tested concepts for photovoltaic electricity.

The second largest funding goes to the support of energy storage R&D. Payments for storage research promotion totaled more than 61 million EUR in 2013, and increased by almost 60% compared to 2012. A most significant initiative related to the development of storage technology is Germany's "Förderinitiative Energiespeicher" or Development Initiative for Energy Storage. As part of Germany's 6th energy research program, the initiative is coordinated among three ministries, the Federal Ministry of Economics and Energy (BMWi), the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), and the Federal Ministry of Education and Research (BMBF) and is funded with 200 million EUR. Project participants have to share in at least 50% of the costs.

Promoted projects include electricity storage via the synthesis of hydrogen and methane, tests of hydrogen capture in geological formations, thermal storage including the use of new materials and in combination with solar thermal facilities. In addition to the investment in test projects for specific technologies, the project also aims to contribute to system analysis, simulation, cost reduction, and to foster the communication within the international research community as well as cooperation between business and science (PTJ, 2010).

In addition to basic funding, participants may receive a "combination bonus"[9] for a combination of various measures such as solar thermal heating and heat pumps, an "efficiency bonus"[10] for projects that achieve cost savings due to lower primary energy needs from the use of renewable energy, or an "innovation bonus" (Bonhoff, 2009, 8) for especially innovative applications.

6.6.2 The National Innovation Program for Hydrogen and Fuel Cell Energy

This Program combines resources of industry and science "to speed up the process of market preparation of products" in addition to projects supported by the 6th framework program. This is accomplished by research, development, and demonstration projects related to hydrogen and fuel cell technology. The program began in 2006 and is funded with 1.4 billion EUR until 2016. 500 million EUR of this amount has been funded through the former Federal Ministry of Transport, Building and Urban Development (BMVBS), the Federal Ministry of Economics and Energy (BMWi) provides 200 million EUR and the other half (700 million EUR) is provided by industry participants.

The initiative is organized into four program areas: transport and hydrogen infrastructure, hydrogen provision, stationary energy supply, and special markets. While all the projects relate to the production and storage of hydrogen, the most relevant program areas are stationary household energy and hydrogen production.

Following on the third place in regard to payments for R&D support, energy efficiency in buildings and cities received almost 57 million EUR, whereof about 45% was granted for solar optimized building.

With a volume of payments of about 53 million EUR in 2013, wind technology was the fourth most prominent field of federal innovation support. This equaled an increase of 37% against 2012. Moreover, grants for new projects totaled 37.3 million EUR. Major parts of funding are

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[9] For instance, 500 EUR for solar and biomass or solar and heat pumps (BMU, 2012c).

[10] For instance, EUR 90/m2 for solar hot water heating or EUR 180/m2 for solar hot water heating with heat support. (BFA, 2012)

devoted to the development of general generation technology, offshore wind, and the category of "Logistics, Installation, Maintenance and Operation" (BMWi, 2014j, Table 2). Major topics of funding are manufacturing and design of wind turbine blades, and the foundation of offshore windmills.

By 2013, further funding posts promoted:

- "Bioenergy" (42.7 million EUR),
- "Energy Efficiency in Commerce, Industry, Service and Trade" (36.2 million EUR), and
- Innovations in the field of electricity grids (30.95 million EUR).

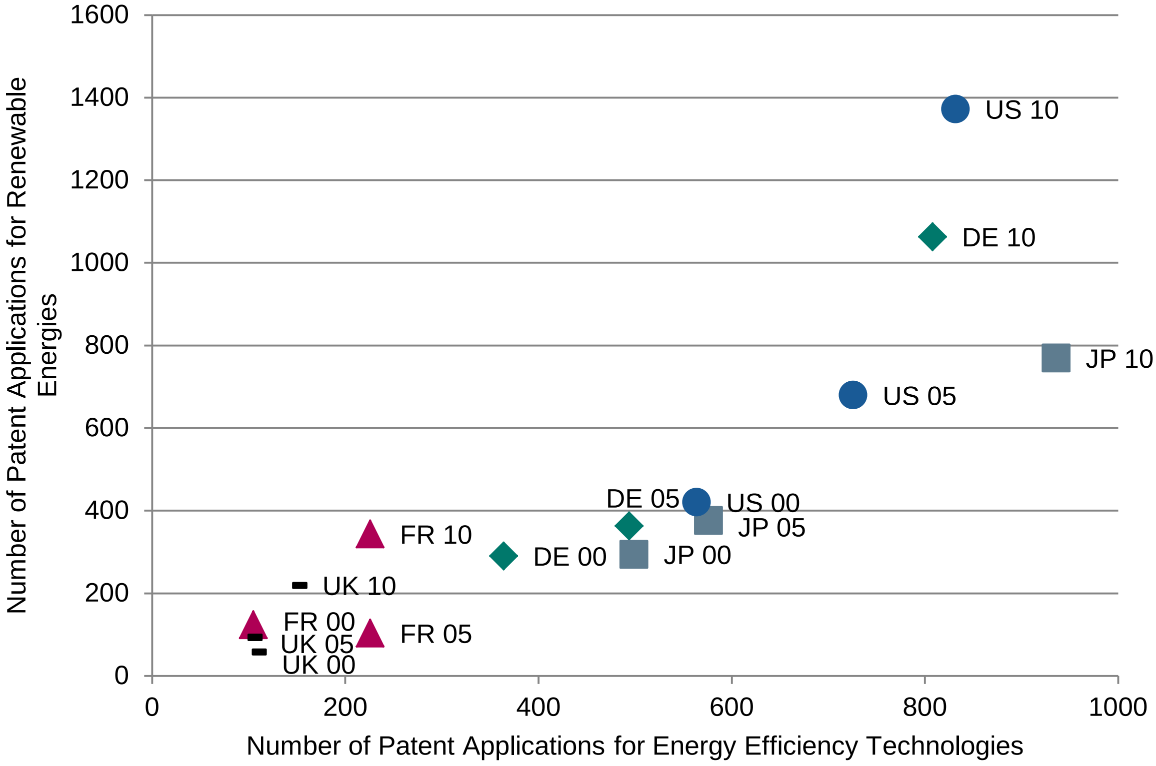
Effects

The effects of the promotion of innovation by the *Energiewende* and the associated R&D are assessable on an aggregated level only. Today, the different influencing factors on innovation can hardly be disentangled. However, it is possible to compare the aggregated impact of research activities in the fields of overall patents for energy efficiency and renewable energies. Although in 2011 total German expenditure on R&D in the field of energy amounted to 0.028% of GDP only,[11] German patent applications in the fields of renewable energies and energy efficiency are on the same level as US and Japanese applications (see Figure 6-5). Löschel et al. (2014a) come to a similar result and underline that at the same time especially in the US the volume of spending on R&D is higher than in Germany. Furthermore, expenditure on R&D in the fields of renewables and efficiency per patent application is notably lower in Germany (276,000 US dollar) than in Japan (702,000 US dollar) and the US (902,000 US dollar). An overall trend also shown in Figure 6-5 is the clear increase of applications in the fields of energy efficiency and renewable energy. This trend even accelerated towards the year 2010, the latest year with available patent data from the European Patent Office. These figures suggest that R&D spending is particularly effective in Germany and that the respective technology developments are increasingly useful, as is clearly indicated by the patent application dynamics shown in Figure 6-5.

[11] For the average OECD country this amount equals to 0,046 percent of GDP.

Figure 6-5

Patent Applications in the fields of energy efficiency and renewable energies at the European Patent Office (2000, 2005 and 2010)



Source: DIW Econ based on data from the European Patent Office (EPO 2014).

7 Challenges

Although energy savings via energy efficiency increases and a transformation towards accelerated use of renewable energy sources for heat and power provision are clearly defined objectives, the implementation of the complete *Energiewende* concept proves to be rather complex. The targets should be achieved at affordable costs neither harming competitiveness of the economy, nor losing the acceptance of the population, and ensure a properly functioning, and environmentally sound energy supply system.

Investment in the energy sector as well as the insulation of buildings and heating systems are often long-term and may therefore create lock-in effects for many decades to come. Appropriate sequencing of policies and measures is therefore an important aspect of optimal governmental decision making on pathways. This proves to be a formidable task, since currently the impact of the development of new technologies on economic and ecologic costs of the achievement of climate goals are unclear. Hence, due to long gestation periods of new technologies optimal solutions for the goal attainment are time-dependent. By contrast, the mobilization of private capital calls for a stable regulatory framework, to create predictable returns on investments.

Currently, a plethora of targets exists for different legislative levels. From the internationally agreed Kyoto targets regarding GHG emissions to European targets for energy efficiency down to targets for renewable energy roll-out in individual Federal States (Länder).

Instead, an integrated approach is called for if targets contradict each other. For instance, the electricity grid optimally develops differently if based on the renewable energy targets of the German regions or on the respective federal targets alone. The combined Länder targets are in total more ambitious compared to the federal rollout plan. Furthermore, the public perception of *Energiewende* is by now mainly focused on transition electricity and renewable energy, which are of high visibility. However, significant GHG reduction potentials in the buildings and transport sector have to be realized for ultimate GHG target achievement. Public awareness needs to be raised on these targets in order to mobilize respective private investment and public funding.

The new National Action Plan on Energy Efficiency which is estimated to lead to additional 390 to 460 PJ of primary energy reductions (see Table 7-1), is still not sufficient to bridge the existing GHG emissions reduction gap of about 1,445 and 1,751 PJ (see 2.2.1).

Table 7-1
Key Measures of the National Action Plan on Energy Efficiency (NAPE)

Measure	**Predicted Reductions by 2020**	
	Volume of Reduction in PJ	GHG in Mt CO_2-equivalent
Immediate measures		
Quality assurance and optimization of the existing energy consultations	4.0	0.2
Tax encouragement of energy-saving redevelopment	40.0	2.1
Further development of the CO_2 Building Renovation Program	12.5	0.7
Introduction of a competitive tendering scheme	26-51.5	1.5-3.1
Promotion of contracting (incl. deficiency guarantee)	5.5-10	0.3-0.5
Further development of the KfW Energy-efficiency Program	29.5	2.0
Energy Efficiency Networks Initiative	74.5	5.0
Top-Runner-Strategy – on national and EU-level	85.0	5.1
Obligation for large-scale enterprises to conduct energy audits	50.5	3.4
National efficiency label for old heating systems	10.0	0.7
Further immediate measures of the NAPE	about 10	about 0.5
Sum of immediate measures	**350-380**	**21.5-23.3**
Further measures		
Measures starting in October 2012	43,0	2,5
Provisional estimator for the effect of the additional operating process	up to 40	up to 4
Total	**390-460**	**ca. 25-30**
Measures in the transport sector *(cf. Climate Action Program 2020)*	110-162	7-10

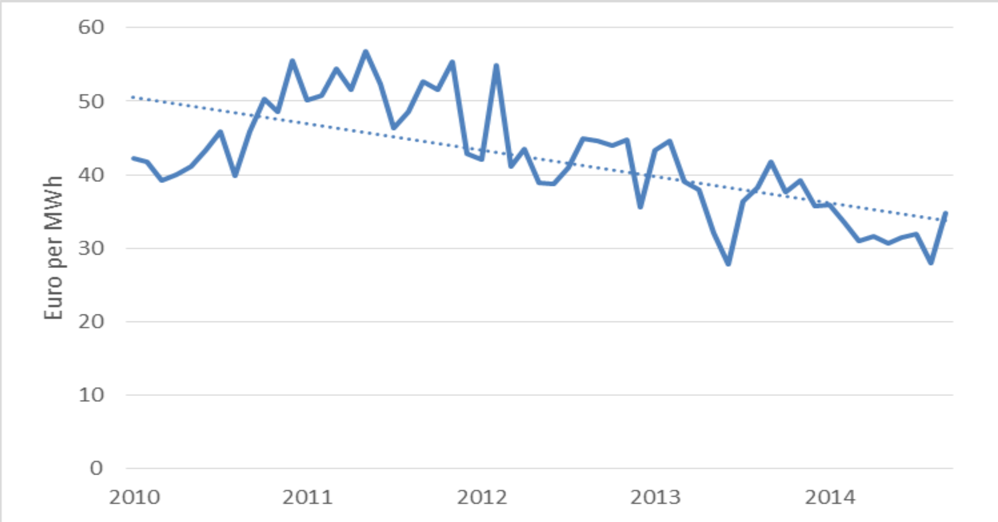
Source: BMWi, 2014f, 21.

7.1 Fundamental restructuring of the power sector

The focus on renewable energies as the main pillar to satisfy future energy demand requires a fundamental restructuring of the power sector. Prior to the liberalization process of the European power sector, the electricity sector in Germany was dominated by regulated regional monopolies, which provided a very high reliability of supply at a comparatively high price allowed by the regulator. Central power stations generated bulk electricity to satisfy a given demand projection that was assumed to be independent from prices. Usually, power plants were erected close to the regional consumption centers.

Since the end of the last century, the liberalization has increased efficiency of supply and dampened electricity prices. In the liberalized system, private investment in conventional power plants reacts to prices and their expected changes. Furthermore, consumers are free to purchase their electricity from a wide range of regionally and internationally dispersed suppliers. Today, electricity trade in central Europe is mainly organized by wholesale electricity markets and either price or market coupling. This has brought a high degree of market integration measurable in terms of price convergence and increasing utilization of international transmission capacities (ACER 2014). Together with the roll-out of renewables and a dampened demand, wholesale market prices decreased over the last four years by roughly a quarter despite significant fuel cost increases for conventional electricity generation. Figure 7-1 shows the development of the electricity spot prices on the German market.

Figure 7-1
Development of wholesale electricity spot market prices in Germany.



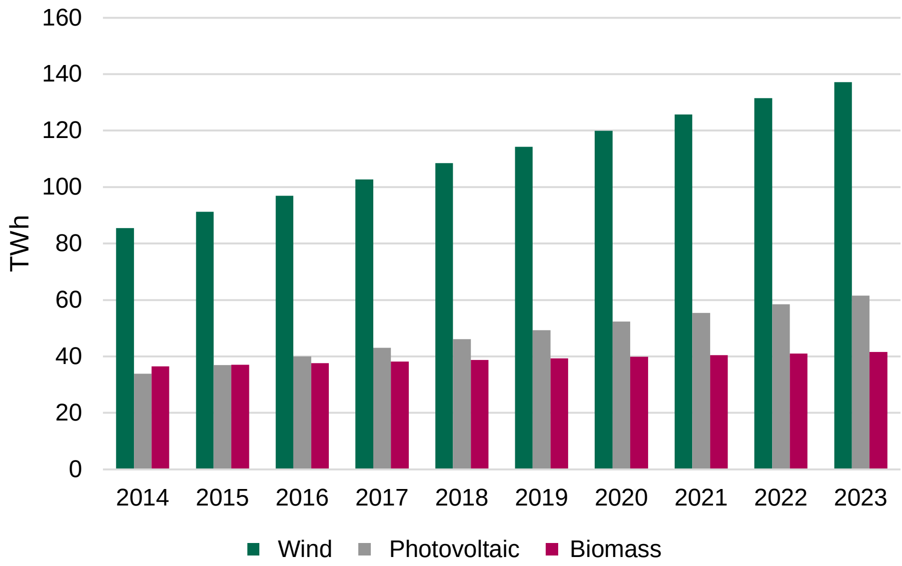
Source: BMWi, 2014c, Sheet 26a.

Against the background of substantial cost digressions of solar and wind power over the last decade, and their high resource potentials which allow for further substantial increases, onshore wind and solar power are the favored technologies of the restructuring of the power sector. This technological predominance prevails also in the current governmental plans for the next decade. Figure 7-2 shows the projected development of renewable electricity according to targets for capacity development in the renewable energy act[12].

According to these plans, by 2023 the dominant renewable electricity technologies will provide around 240 TWh of electricity, which is about 116 TWh more than in 2013. In the current decade this development alone more than compensates the effect of the nuclear phase-out, which translates into a further reduction of 90 TWh compared to 2013. Already by 2014, electricity generation of renewable energy will completely substitute the maximum nuclear generation of more than 150 TWh reported for 2006.

[12] Annual availabilities are in accordance with Netzentwicklungsplan (2014).

Figure 7-2
Projected development of electricity supply by renewable energies



Source: Own calculation based on EEG (2014) and NEP (2014).

Thus, the main technical challenge to the electricity sector posed by the *Energiewende* is not related to annual generation, but the fluctuation of availability of RES over the year and their regional distribution in the electricity grid vis-à-vis the distribution of demand centers. The question of reliability of electricity supply that depends on reliable power plants and/or flexible demand combined with sufficient grid infrastructure is one of the most debated questions concerning the German electricity sector.

Technical responses to these questions are often referred to as flexibility options.

Flexibility to cope with the gap between the time of natural supply of renewable energy and the time of electricity consumption can be provided by flexible thermal power plants, curtailment of supply, demand side response & demand side management, electricity storage, and power-to-heat with heat storage (EcoFys 2014; DIW 2013a). Only thermal power plants and energy storage provide possibilities to bridge longer supply gaps of fluctuating renewable energies.

While thermal power plants mostly use matured technology, some storage technologies are promoted by R&D policy measures to induce innovative technological developments. The diffusion of these options, however, depends on sufficient market revenues. Current market conditions do not support significant private investment into these technologies.

Capacity mechanisms

Traditionally, electricity utilities have planned reliability based on peak demand projections and derived target values for adequate capacities by targeting reliability standards such as “one interruption in ten years”. By contrast, on liberalized electricity markets it is the price and its projection that serves as the basis for investments. These prices can result from organized wholesale markets, bilateral contracts or balancing markets. However, the producer prices are currently not high enough to sustain pronounced investments in climate friendly power plants.

In Germany and elsewhere in Europe, e.g. France, UK, Italy, the introduction of capacity mechanisms is brought to the fore in discussions of energy policy. A capacity mechanism aims at ensuring a certain level of reliable capacity, which an insufficiently regulated ‘energy-only’ market assumedly does not provide. Since the complete targeted capacity is expected to be used for energy generation only, say, one hour in several years, it is assumed that companies do not sufficiently invest: energy market revenues will be extremely sporadic[13], at times extremely high and, therefore, under threat of opportunistic regulatory behavior. Several options for the electricity market design have been evaluated by studies commissioned by the BMWi. These studies have shown that the mechanisms induce extra system costs of 2 to 13 billion EUR per year to achieve an increased security level (BMWi 2014e). However, the ‘energy-only’ market design could achieve a comparable security level if it was complemented by strengthened requirements for balancing energy and the continuation of reserve capacity purchases by the transmission system operators. Moreover, these reserve capacities should be placed at important locations in order to relief stress of the transmission grid.

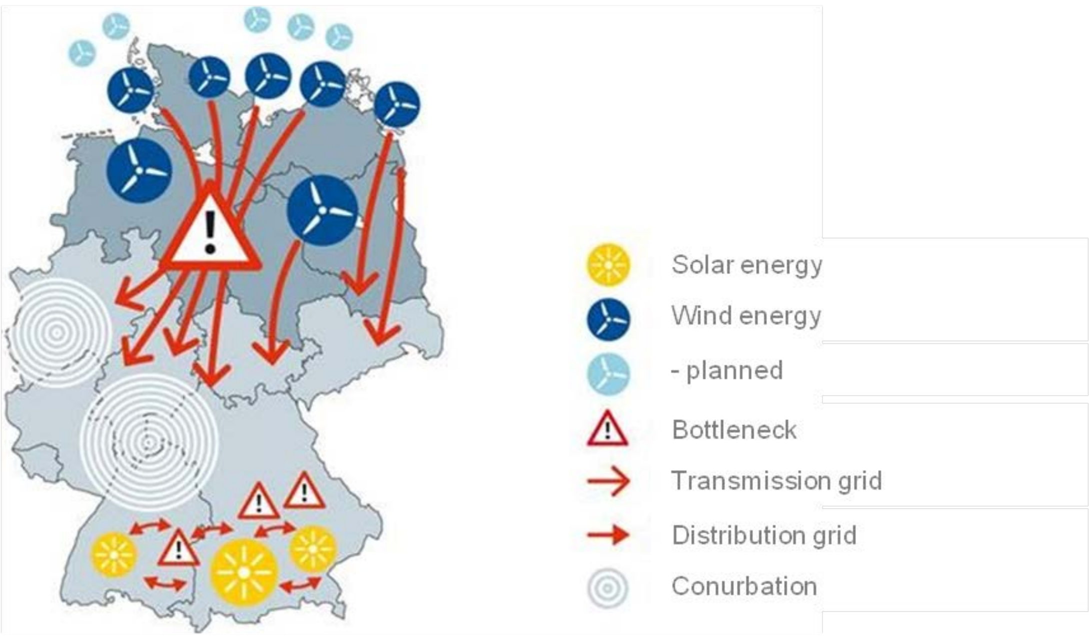
[13] For instance, a plant may have no revenues for several years in a row.

At the same time, the roll-out of renewable energies leads to an increase of supply mainly at favorable locations for the respective sources, while the scheduled nuclear phase-out concerns predominantly the southern part of Germany.

Transition to new power infrastructure

Mainly located in the southern regions, nuclear power stations are close to dense industry structures and high electricity consumption. In contrast, major renewable electricity sources are concentrated in the North of Germany. Both developments require adjustments and potentially the expansion of the electricity grid.

Figure 7-3
Geographic discrepancy of electricity demand and supply



Source: DUH (2014).

Figure 7-3 shows the principal geographic distribution of renewable energy sites and corresponding congestion of electricity flows.

The potential corridors for line expansion and the technical realization of grid enforcements are fiercely debated. Frequent changes in the details of line expansion with regard to starting and endpoints as well as the favored technology, underground vs. overhead lines; direct vs. alternating current, grid optimization vs. up-grade vs. newly built – show that optimal choices are contingent on the technological development, public discussion and the changing mix of projected renewable energy sources.

A major criticism questions the objectives of the grid expansion optimization. For that aim, the current Grid Development Plans build on the objective to integrate all expected supplies regardless whether they stem from coal, renewable or other sources without bottlenecks (DIW 2013). This does not provide an efficient development if the costs to integrate the last units of supply are higher than their valuation by consumers. Clearly, it is hardly justifiable by the climate targets of the *Energiewende* to expand the grid merely to facilitate situations where renewable and fossil fired units supply with maximum capacity to achieve record high electricity exports. It follows from the economic cost-by-cause principle that the beneficiaries, i.e. the exporters and corresponding importers, should finance these extensions.

Two challenges are linked to the current practice. First, line extensions that are built at the expense of German consumers and do not appropriately benefit them could question the public support for the *Energiewende* as a whole (Jarass 2013). Second, due to path dependency of the grid architecture an excessive grid expansion may prevent the connection of low cost renewable sites that are part of a cost minimizing energy mix in the future.

7.2 Additional instruments needed for refurbishment of the building stock

As mentioned above, the 2020 targets for residential heat consumption can be reached in case current trends of declining heat demand will continue and the 2% refurbishment rate will be achieved. However, although the NAPE has improved financial support for refurbishment of buildings and tax deductions are planned to be implemented more ambitious instruments are necessary to achieve the 2020 and the even more stringent 2050 targets. This is specifically due to the following challenges:

- Studies have estimated necessary additional annual investment of about 26.4 billion EUR to achieve the 2020 target. That would mean the current level of about 100 billion EUR of annual investment into buildings construction would need to rise to about 126 billion EUR (BMVBS, 2013a, 65). The question is how to incentivize private investors to generate such amounts of additional investment. Current policies and instruments (KfW soft loan programs) in place and even their scheduled upgrade by increased financial support appear to be insufficient.
- How to achieve higher energy savings today in order to avoid lock-in effects that possibly raise future mitigation costs (i.e. deeper renovation)? What national long-term rehabilitation scheme can assure the KfW-40 standard in a step-by-step progress?
- Another shortcoming is the observation that obviously the opportunities for refurbishment are not fully used. Although the refurbishment rate is about 1% p.a., by contrast 3% p.a. of the building stock is subject to some non-energy renovation. This indicates potentially missed opportunities for energy efficiency improvement (BPIE, 2014, 41). Similarly, how can it be assured that these opportunities will be used without posing a restraint for non-energy renovation by a connection with deep energy efficiency refurbishment mandates which need much higher up-front investment than non-energy renovation?
- By 2020, all refurbished and new heat systems should be in line with the 2050 targets since no additional refurbishments are expected for already refurbished buildings between 2020 and 2050 (BMBVS, 2013b, 103). The challenge is to incentivize exchange by modern and innovative systems in order to avoid lock-in effects.

Before discussing the specific opportunities and new or additional policies to solve the challenges, we first discuss some more fundamental issues. In particular, evidence points to a conflict between the refurbishment rate and projected heat demand reduction as sub-targets for the existing building stock, which requires a rethinking of the relationship of these sub-targets to the overarching target of climate change mitigation via the reduction of GHG emissions. The refurbishment rate and the heat demand reduction are sub-targets, which have been set in order to trigger the carbon-neutral development in the building sector with special policy measures. However, one of the two sub-targets would be sufficient.

The refurbishment rate can serve merely as a means to reduce heat demand rather than a target itself as long as there is no precise definition of the required scope and quality of the refurbishments, e.g. in terms of energy savings in case no public financial support would be required by the building owner.

In addition, there is also a problem with the definition of heat demand. This term does not differentiate between renewable and fossil heat. However, if heat demand is met completely by renewable energies, it satisfies the overarching national GHG emission reduction target and any heat reduction impact on climate change is nullified. Therefore, the introduction of the “net heat demand” (BMVBS, 2013a, 58), which considers renewable heat at “0” emissions and as reduction of total heat demand is more appropriate. Alternatively, targets for the building sector should be re-formulated in terms of primary energy demand in line with definitions under the EnEv law, which defines primary energy demand for buildings as “non-renewable primary energy demand” (Löschel et al., 2014b, Z-13). The positive effects of such an approach would be:

- Leaving more space for decision making to the building owners on least cost options for GHG emissions reductions, e.g. level of insulation vs. utilization of renewable heat.
- Lowering the necessary targets for CO_2-neutral refurbishment of the existing stock and therewith lowering the tremendous amount of investment estimated for that purpose.

Such an approach also fits the discussion on the extension of the Renewable Heat Law to the existing building stock. In case renewable heat in existing buildings would become obligatory or obligatory refurbishment measures could be offset by renewable heat the choice of measures would be more open and left to the house owner. The latter approach could trigger least cost solutions, which would become even more important at later stages of the transition of the building sector when additional, more ambitious insulation would become more costly.

Scenario analysis has illustrated that the “net heat demand” approach would help to achieve the 2020 targets with lower refurbishment rates and to a certain extend would lead to over-compliance with the implicit CO_2-reduction target in the building sector (BMVBS, 2013a, 59). Defining a CO_2-target for the building sector would certainly be an appropriate adjustment of targets for this sector. However, it is obvious that adjusted targets would not make further increasing efforts obsolete. It only dampens the need for increased efforts to lower heat demand in buildings, to attract higher private investment into refurbishment of buildings than today, and to overcome the respective obstacles. Pooling of the two main laws in the building sector - Energy Efficiency Ordinance (EnEv) and Renewable Heat Act, which is mentioned as an opportunity in the NAPE, seems an appropriate solution to make the legal framework more effective.

Apart from improved regulation in 2012, the principle-agent problem where the purchasing party (house owner) is not responsible for paying the energy bills (tenant) is still not sufficiently resolved. This issue is of special importance in Germany since about half of the flats are not owner-occupied. Balancing interests between house owner and tenant is crucial for undertaking energy efficiency investment. As the magnitude of increased costs for tenants due to refurbishment is a hotly debated political issue, further proposals have been made to solve the problem. For instance, the rent index representing a basic tool for determination of rents agreed on in new rental agreements is proposed to be adjusted to energy efficiency criteria of the flats (BMVBS 2013a, 145). Given that the rent index does not include costs for heating and hot water, flats with higher energy efficiency standards become more expensive, but tenants save energy costs. For non-energy efficient flats it is the reverse. However, such an approach would not solve the problem of social affordability of energy efficient homes for low-income households, which is already an issue of policy debates. Often benefits from saved energy costs for tenants pay off increased rental payments only after a quite long time. In addition, the current reform of accommodation allowance for the poor needs to take into consideration adjustment for affordability on energy efficiently refurbished flats (BMU, 2014b, 33).

A further important and unresolved barrier to energy efficient refurbishment of buildings is the tradeoff between lower life-cycle costs versus lower upfront costs (usually energy efficiency investment into buildings creates high up-front costs) that is additionally subject to high transaction costs. Demographic development – increasing share of elder people – also results in unwillingness to refurbish. These barriers also apply to economically attractive efficiency investment. Moreover, the fluctuation of budgets of many financial support programs is adversely influencing a steady market development in this sector.

Several proposals related to additional new policies and instruments are currently under discussion. The proposed measures aim to overcome the specific barriers and should be additional to the already existing mix of policies and instruments.

Further tightening of requirements set by the administrative law, EnEV, is possible, but its potential impact is limited. Due to high upfront costs it is not possible to implement insulation measures of the building's envelope and the heat supply systems at any conceivable time. In fact, such measures need to be implemented in combination with necessary repair and renovation measures. Depending on the preferences of the house owners, measures may be pushed or postponed, and to be carried out in packages or as single measures. Many other aspects - including the design of the building, its location, available technologies etc. - are also determining costs and therefore influence decisions. Administrative law is generally limited, and is not able to take into account all the different aspects.

Thus, economic incentives may achieve more appropriate results. Several approaches are discussed:

- The combination of ”positive“ incentives like **financial support** programs with “negative” incentives like **energy taxes**. This would allow for saving costs (including energy taxes) and gaining advantages in form of soft loans or repayment subsidies in parallel. In order to make this approach an effective support program, it needs to avoid fluctuation in order to grant a stable and reliable framework. Energy taxes on the other hand need to be related to energy consumption of buildings. The respective tax income could be used to boost financial assistance. However, a proposed overall primary energy tax of one Eurocent/kWh (BMVBS, 2013a, 106) does not provide a guarantee for the fulfilment of targets in regard to investment into buildings, but may rather be marginalized by overall fuel cost developments. In order not to dry out financial assistance based on primary energy tax income, the tax is proposed to be increased up to about 1.7 Eurocent/kWh from 2020 to 2030 (BMVBS, 2013a, 128). In consequence, the tax would create a negative impact on recently carried out refurbishment investment. They have already fulfilled ambitious standards and therefore lack opportunities to respond.
- As a completely new instrument a targeted fee on buildings is proposed, which could feed a financial assistance fund. Building owners would be charged, and could benefit at the

same time from access to support programs. However, there are considerable transaction costs related to the classification of buildings and to the collection of fees. In addition, during the start-up phase of implementation additional budget funding would be needed for the financing of the assistance fund.

- **Income tax deductions** are of special interest for home owners and could assure targeted investment into refurbishment of buildings. A draft law had been proposed by the German government in 2011 that proposed income tax reductions of about 10% of refurbishment costs. The rule was planned to be applicable to residential buildings that were constructed before 1995 and measures, which would substantially reduce energy demand. The draft rule was opposed by the Federal States' (Länder) governments. As income tax is a major source for the Länder budgets, they were not willing to accept the respective proposal (NBW news, 2011). The dispute settlement committee between parliament and council of the Länder did not succeed in finding a compromise. The National Action Plan on Energy Efficiency approved in December 2014 makes another attempt to introduce income tax deduction in order to incentivize energy consumers investing into energy efficiency. Tax deductions envisaged by the Plan sum up to one billion EUR annually (BMWi, 2014f, 25). However, a precise decision on that issue still needs to be agreed on between the Federal Government and the Federal States.
- Another proposal refers to introduction of an energy-based structure **of the real estate tax**. In combination with and based on a unified building certificate indicating the appropriate energy efficiency class of a building, the real estate tax is proposed to be geared towards energy efficiency classes of buildings (VdZ, 2014).[14] Owners of efficient buildings would benefit from a lower real estate tax. The instrument would focus on the existing building stock and therefore focus on achieving the targeted refurbishment rate. In contrast to state support programs of the KfW, which are assigned by the Federal Government, this instrument would influence public income of the municipalities. The current level of the real estate tax in Germany is quite moderate, and would have to be increased

[14] An analog example is the automobile tax, which is based on polluting emissions for the definition of the level of the tax rate.

in order to function as an economic incentive. However, social acceptability is questioned when home ownership of low-income groups becomes unaffordable.

- One of the options is the introduction of obligatory shares of renewable energies for refurbished heating systems. Some Federal States already gained experiences with this approach. The Renewable Heat Act in Baden-Württemberg of 2007 makes a 10% share of renewable heat obligatory, if the heating system of a residential building built before April 2008 is refurbished (Baden-Württemberg, 2007). In 2013, an extension of this obligation to public buildings, office buildings and hotels was proposed. This approach was opposed by the association of real estate owners. They argued that refurbishment may not be carried out at all in case too costly measures are being imposed. However, public hearings succeeded and an equivalent federal law will come into force in July 2015.[15]

As far as the 2050 goals are concerned, there is high uncertainty about basic elements shaping the future structure of the building sector. Examples are the development of the living space per capita, the amount of new buildings, the refurbishment progress in buildings of different age groups and the technologies applied for heating, cooling and ventilation. Some scenarios assume that about one third of the building stock in 2050 will be new buildings, and the remaining two thirds already exist today (Öko-Institut and Fraunhofer ISI, 2014, xi). In such a scenario, the focus on transformation of the building stock will continue to be most important. In parallel, a switch to renewable heating and cooling in the existing building stock would be imperative. Introduction of obligatory use of renewables in the building stock and in local and central heating is debated.

7.3 Potentially conflicting targets

Electricity consumption reduction versus new applications

Although reduction of electricity consumption is a target established by the Energy Concept this target may contradict targets and solutions in other sectors. The target does not differ-

[15] http://www.akbw.de/berufspolitik/land/novelle-ewaermeg.html

entiate between electricity generated by fossil fuels and by renewables, focusing mainly on cost savings by efficiency improvement. The target in absolute numbers, however, possibly needs to be adjusted. For example, the fuel switch envisaged for the transport sector and the heat sector will increase electricity demand to a large extent. In the transport sector an increase is expected due to electric mobility which replaces petrol and diesel, and by power-to-gas-technologies in the production of fuels (mainly Hydrogen) generated by electricity. Heat pumps that replace fossil heat in the building sector will further heighten electricity demand. Also CCS-technologies in industry in order to capture and store CO_2 will require more electricity. Depending on scenario assumptions electricity demand from such "new" applications may even overcompensate reductions in traditional spheres of electricity consumption. Recent climate change scenarios therefore propose to look at electricity consumption from different viewpoints and to distinguish between "classic electricity consumers" (in line with present applications) and "new electricity consumers" in order to avoid dealing with conflicting targets (Öko-Institut and Fraunhofer ISI, 2014, X).

Additionally, for some of the "classic electricity consumers" electricity consumption may increase in absolute numbers. Modal shift of fright transportation is envisaged from road to rail which would need not only an increase of rail road investment but also imply an increase of electricity consumption by rail roads.

The overarching goal of GHG emissions reduction will not be threatened by this development in case the additional electricity is generated from renewables, which is indeed assumed in the scenarios. From this point of view, refocusing of the current cross electricity consumption target on non-renewable electricity would be appropriate but should be accompanied by electricity productivity targets in order to achieve cost effectiveness and technological change.

CHP targets versus renewable heat and reduction of heat consumption in buildings

The target to increase the share of CHP in electricity generation to up to 25% in 2020 may or may not fit to the planned RES-targets for electricity generation and to the heat savings targets for buildings until 2050. Current scenarios estimate the following electricity generation development:

Table 7-2
Electricity generation in accordance with current scenarios (TWh)

	2020	2050
Gross electricity generation		
- Reference scenario	618	561
- Target scenario	576	459
Net electricity generation		
- Reference scenario	556	505
- Target senario	518	413

Source: EWI et al. 2014, 5 and own calculations.

Based on these estimations the CHP target would translate into about 130 TWh (target scenario) to 140 TWh (reference case) of CHP electricity to be generated by 2020.

As CHP installations combined with the respective local heat grids require substantial investment and have an estimated life span of at least 30 years it is assumed that the 140 TWh (130 TWh) will be in place also in 2050. Due to reduced electricity generation in 2050 CHP electricity will then amount to a share of almost 28% of net electricity generation. A potential conflict with the renewable energy target of 80% could open up unless major parts of CHP are provided by renewable sources.

Another aspect is related to heat demand. Heat generated by CHP plants is used for process heating in industries, for district heating and for local (decentralized) heating of buildings. According to the forecasts the share of process heating is expected to increase and to become the main driver of the overall increase of heat supply by CHP. District heating will decrease in share (from 70% to 35%) as well as concerning overall amount (from 110 TWh to 64 TWh) in the period of 2020-2050. Also financial assistance is currently provided to build local heat grids for residential buildings that are often appropriate for densely populated areas. In combination with renewable heat and process heat low temperature local heat grids could provide flexible heating options. The overall increase of local heating, however, is estimated to increase from 2.5 TWh (2020) to 5.8 TWh by 2050 (EWI et al. 2014, 219). Taking into consideration declining residual heat demand due to energy efficiency increase of buildings (insulation), additional competition with highly efficient heating technologies (for example condensing boiler), and renewable energies (heat pumps and solar heating) the CHP target is not likely to be met. If the bulk of CHP plants will rely on fossil fuels (natural gas) - the potential for biomass CHP is almost exhausted - then increasing CO_2 prices will lead to declining economic advantages of CHP (ewi et al., 2014, 218). In order to avoid CHP investments that result in stranded assets or lock-in effects, the existing approach towards the building sector needs to be adjusted.

7.4 International impact of national approach

International trade flows are very important for Germany and the *Energiewende*. So-called "dirty" energy imports or exports need to be avoided. Leakages in the form of relocation of energy intensive industries and input for production of investment goods or in form of increased food imports due to extended use of cultivable land for energy crops should not be considered "solutions" within the *Energiewende*. Such approaches could not be replicated by other countries.

Concerning biomass, which is currently the most important renewable source (196.2 TWh) providing almost 62% of all renewable final energy in 2012 (Löschel et al., 2014a, 95) there is consensus acknowledging the limitation of national biomass and biofuel potential and the need to avoid competition with food. The strategies for agriculture – no enlargement of cultivable land, even reduction of green lands and cultivable lands to wetlands, reduction of the use of multiple fertilizers - limit the potential for biomass/biofuels in Germany additionally. In contrast to results of some modeling exercises, which envisage an enlarged import of biomass (Öko-Institut and Fraunhofer ISI, 2014, xxvii) for reasons of international multiplication, the goals of the *Energiewende* should not be achieved by enlarged biomass imports.

On the power market, the rapid expansion of renewable energies leads to decreased wholesale prices. This so-called merit-order effect is estimated to amount to five to ten % of business as usual prices according to scientific simulations, and lead to an increased net-export to neighboring countries. Furthermore, it leads to a reduced substitution of German conventional electricity. Consequently, German emissions are not reduced to the extent that would arise from a one-to-one replacement by renewable energy extension.

Although increased export in turn reduces emissions abroad, it also tends to reduce the profitability of foreign power plants, e.g. in Poland and the Netherlands, and gives rise to political opposition. In addition, intra-German line congestions can lead to loop flows via neighboring countries, which may trigger line congestions abroad.

In Poland, the construction of phase-shifters at the border will facilitate the limitation of German exports and thus limit the integration of renewable energies and the integration of the European electricity market.

7.5 Winners and losers

Until today, the *Energiewende* has triggered important impacts on the electricity market. In particular, the renewable energy policy created distinct effects for both industry and final consumers.

- Exemptions from the renewable energy surcharge for large parts of the energy intensive industry have driven a wedge between electricity prices for these customers and other customers like households and the service sector. In addition, the merit-order effect of renewable energies on the wholesale market reduces the prices compared to a situation without renewable energy support. Therefore, **industries that do not pay the surcharge** enjoy the full reduction of wholesale prices, which amounts to about ten % or five EUR per MWh (BMWi 2014a). Since this concerns about 100 TWh of industrial consumption, the annual advantage for the industry from the merit-order effect is calculated to amount to half a billion EUR.
- By contrast, **private households and other non-exempted sectors** were burdened in 2014 with a surcharge of 62.40 per MWh, whereof about ten % should have been compensated by the merit-order effect of renewable energy, i.e. the reduction of wholesale prices by these sources. However, wholesale price reductions are often passed on to final customers only with a time lag, which indicates limited competition. Despite total extra costs of renewable energy supply of around 20 billion EUR in 2014 compared to a wholesale mar-

ket procurement, the support of the population continues to be high. By June 2014, 70% of Germans agreed with the *Energiewende* according to an opinion poll carried out by Allensbach, a German opinion research centre.

- The **four major energy utilities on the German market** E.on, RWE, Vattenfall and EnBW are considerably impacted by the *Energiewende*. Dampened electricity demand and a fast roll out of renewable energies have brought down electricity producer prices by about a quarter in the last four years alone (see Figure 7-1: Wholesale Electricity Prices). In addition, phasing-out nuclear energy reduces the market values of these companies due to reduced expected revenues from operation and due to the expected cost of dismantling their nuclear fleets, which are furthermore hard to predict. Only recently E.on communicated a proposal for a restructuring of its business in order to cope with the *Energiewende* (See Box 7-1).

Box 7-1
Adaption to *Energiewende* by an incumbent utility.

E.on company strategy shift

The electricity supply company E.ON, one of Germany's largest utilities, decided at the end of 2014 to address the rapid changes in the energy market with a new strategy: The group will split into two companies, with one focused on renewables, distribution and customer solutions and the new, independent one on conventional energy generation, global commodities and upstream activities. It is therefore also a separation between the "new" energy sector where renewables, peripheral generation, smart grids and the end customer business are becoming more important and the conventional energy sector, which contributes to security of supply by fossil fired plants.

After years of squeezed earnings, the management hopes for the renewables-focused E.ON SE to generate revenues with low volatility and to tap growth potential from the transformation of the energy market while the new company should provide investors with cash flows from the established energy portfolio in Russia and Europe.

To carry out the separation a majority of the new company would be spun off to E.ON shareholders in 2016, after a necessary approval of the new strategy at the shareholder meeting in the beginning of 2016.

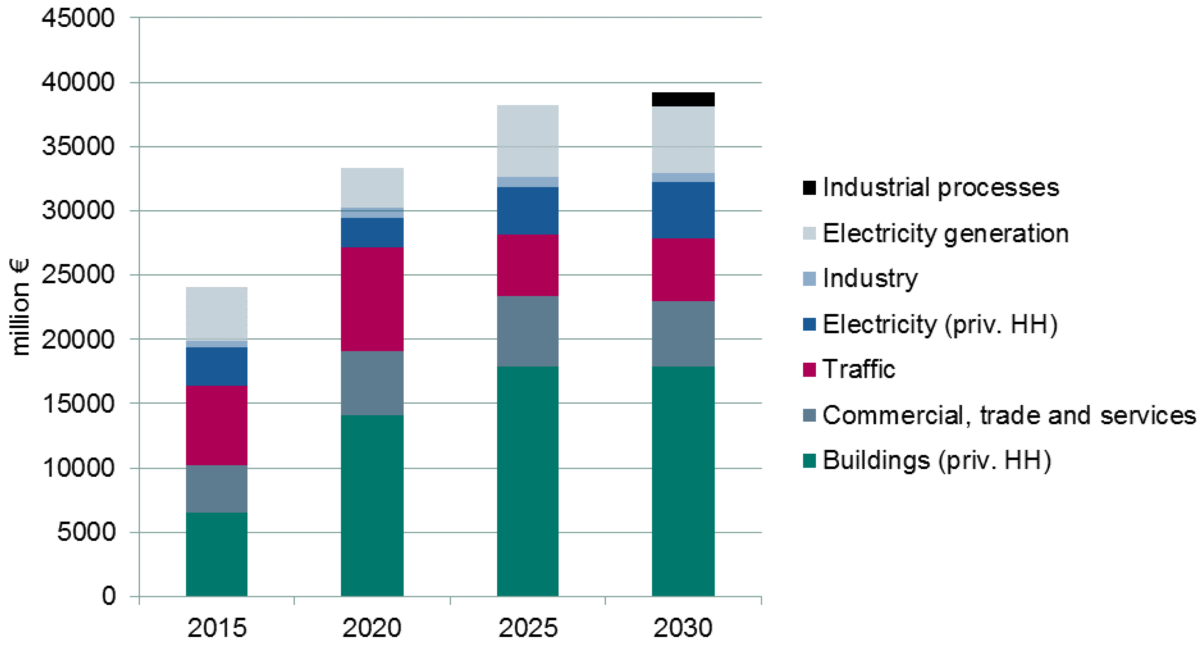
http://www.eon.com/de/presse/pressemitteilungen/pressemitteilungen/2014/11/30/new-corporate-strategy-eon-to-focus-on-renewables-distribution-networks-and-customer-solutions-and-to-spin-off-the-majority-of-a-new-publicly-listed-company-specializing-in-power-generation-global-energy-trading-and-exploration-and-production.html

http://www.eon.com/content/dam/eon-com/Investoren/141201_Strategy_IR-Charts_EN-final.pdf

- **Construction industries** benefit from huge additional investment into building refurbishment and into achieving higher insulation standards and renewable heating/cooling in private households and the commercial and service sector. Estimated total additional investment in 2025 and 2030 due to the *Energiewende* compared to a Current Policy scenario will amount to about almost 40 billion EUR annually. More than half of that investment needs to be directed into energy efficiency improvement of buildings (Lehr et al., 2013, 20). That would create a remarkable number of additional jobs and revenues (see Chapter 6) in the above mentioned industries and in the renewable heat sector.

  Taking into consideration high energy intensity in construction and construction material industries, it needs to be assured that additional energy demand of these industries will be met with renewable electricity.

Figure 7-4
Additional investment in scenario Energiewende compared to Current Policy Scenario (in million EUR)

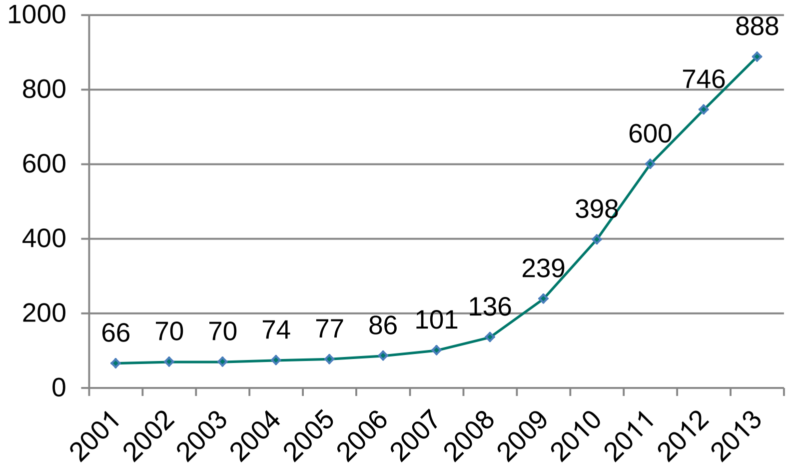


Source: Lehr et al. (2013, 21).

- **Municipalities and generators of renewable electricity** clearly benefit from the booming renewable electricity generation.

  A growing number of energy cooperatives generating renewable energies has been observed during the last ten years (Figure 7-5).

Figure 7-5
Number of energy cooperatives in Germany



Source: Agentur für Erneuerbare Energien (2014).

Municipal value added is the main driver for such development as well as for other initiatives of municipalities to attract renewable energy investment into their location. Value added at the municipal level created by decentralized renewable energy consists of taxes paid to the municipality (trade tax – Gewerbesteuer - almost entirely paid to the municipality and municipal share of income tax) after-tax profits of the participating enterprises (cooperatives) and net income of the employees involved (Heinbach et al. 2014, 4). Results of a model developed to quantify the value added and gross employment effects generated by renewable energies on a local scale and implemented for a model municipality of about 75,000 inhabitants show that a total of 9.3 million EUR of municipal value added was generated in 2011 (Heinbach et al., 2014, 6). In practice, the impact varies in different municipalities depending on the renewable technologies used, their absolute installed capacity and the work in fact carried out by employees and companies of the municipality. For Germany the total municipal value added generated by renewable energy in 2009 amounted to 6.8 billion EUR. More than 66% were generated by PV installations and about 30% by wind turbines (Weitblick, 2011, 3).

Municipalities also benefit from refurbishment of buildings which involves local companies, creates jobs and income on-site. According to results of model- and scenario-based assessment, out of the 14 billion EUR total value added by energy efficient refurbishment of buildings in Germany in 2011, 6.5 billion EUR have been generated directly by planers and trade contractors (Handwerksunternehmen) and 152,000 full-time jobs have been created (IÖW/ECOFYS, 2014,1-2). The bulk of the effects resulted from energetic refurbishment of single-family houses. To what extent these value-added and employment effects remain at the municipal level depends on the extent to which local companies, planers and trade contractors are involved.

8 Outlook - Tasks and possible solutions ahead

The *Energiewende* implies a long-term perspective and triggers learning processes on a broad societal basis. However, learning results need to be considered in an appropriate sequence and timing. Among the next steps to be developed the following are seen as particularly important:

- The transition of the heat market (Wärmewende)

  The heat market including also cooling, hot water supply and process heat consumes roughly half of the final energy demand. Most of it (about 60%) is sourced by fossil fuels. According to the Second Monitoring Report, the continuation of current energy efficiency policy will miss the 2020 overall GHG emissions reduction targets (Löschel et al, 2014a, 23). Scenario results indicate that the currently under-performing efficiency improvement cannot be compensated by additional renewable electricity generation as that would mean doubling of the level of renewable electricity reached by 2013 within the next six years (Nitsch, 2014, 4). Renewable heat is considered as an important contribution to solve the problem.

  Therefore, a transition of the huge and multifaceted heating sector is one of the most important tasks for the near future. Central for such transition would be adjustment and further elaboration of an integrated concept for a carbon neutral building sector until 2050, which combines efficiency improvement (heat demand reduction) with renewable heat including renewable CHP in a coherent manner. Heat demand reduction and renewables can be treated as substitutes related to the goal of carbon neutral buildings and, thus, to the overarching GHG emission reduction goal

  The government is planning to elaborate the respective policy approach. The National Action Plan for Energy Efficiency (NAPE) envisaged to be released by the government end of 2014 is expected to outline the respective strategic directions.

- With regard to the electricity market, the German Ministry for Economics and Energy commissioned a green book on options for electricity market reform to implement the *Energiewende* (BMWi 2014e).

- Particular challenges are linked with the integrated optimization of electricity generation and grid development. Currently, the grid planning is carried out so as to facilitate the integration of all potential supply, i.e. the conceivable maximum supply of all projected electricity generators. This practice can hardly be considered economically sound. Therefore, the green book proposes to plan the grid not for all contingencies of renewable energy supply, but rather for only 97% of possible peak supply. In the same vein, the EEG 2014 will incentivize the curtailment of renewable energy supply under enduring negative prices. These policy novelties have the potential to economize the grid planning and to reduce the difference costs of renewables, since negative electricity prices would not automatically lead to negative revenues for all renewable energy units.
- A further important issue is the contribution of the electricity sector to the climate targets for 2020. As the renewable energy rollout does not automatically lead to proportional reductions in emission intensive conventional generation, the target of 40% reduction of GHG emissions compared to 1990 is called into question by the latest developments in the electricity sector. Therefore, the government currently proposes to introduce measures that will reduce the overall allowed emissions of the sector by additional 22 million tons. For the international reputation and perception of the *Energiewende* as an outstanding project of national climate change mitigation, it seems particularly important to adhere to the established targets concerning emissions.

The *Energiewende* is to be seen as work in progress backed by the framework setting of the ruling government and by the consensus of the public. In the long run, until 2050, new challenges will emerge which have to be solved in order to keep on track. The most relevant of them which will have an impact on the political backing are linked to expected raising overall costs of the *Energiewende* spurred by:

- A substantially larger share of renewable electricity – up to 80% of gross electricity consumption. In case the current approach on extension of renewable electricity generation will be continued, the portion of the costs resulting from increased curtailment[16], from further grid extension and from additional storage capacity is likely to increase more than proportionally.

- Increasing costs of nuclear waste disposal (long-term storage of fuel elements and decommissioning of nuclear plants). No long-term waste disposal has been identified so far. However, the corresponding planning requirements and long-term waste disposal itself are anticipated to induce huge costs. Close time horizons and mounting costs due to almost parallel phasing-out of a significant number of nuclear power plants might increasingly appear as a bottleneck for the decommissioning of further nuclear power plant facilities. Consequently, policy makers might get under pressure from various interest groups to delay the realization of the nuclear phaseout and to pass on the huge and unknown disposal costs to the future. However, questioning the phaseout schedule could seriously impair the whole package of political commitments linked to the *Energiewende* as a whole.
- Changes in the supporting scheme for renewable electricity supply: The existing fixed feed-in tariff based supporting scheme for renewable electricity will be replaced step by step by a tendering scheme for the determination of the support level. Contingent on the specific tendering, the procedure may increase the revenue risk for investors, whereas the quantity risk for society as a whole can be controlled. At the same time, higher investor risks raise average margins and favor large companies with their lower hedging costs. Consequently, this policy may lose the support of small-scale investors and open citizen cooperatives and risks to obstruct a main pillar of the *Energiewende*. In addition, a tendering scheme bears the risk that targets for renewable electricity extension will not be met if a significant number of winning bids is not realized due to *ex ante* underrating of costs. However, penalties for failing realization of winning bids would in turn raise the investors' risk.

[16] Curtailment refers to regulating down power provision by renewable energies due to e.g. grid congestion or negative market prices. Under the EEG the renewable energy suppliers are granted the fixed tariff even for curtailed renewable energy and therefore create particularly high difference costs to the consumer.

In addition, the international framework and particularly the political and institutional framework of the future EU energy marked shaped by the European authorities will play a crucial role. For example, currently discussed approaches of public funding of new nuclear power plants by the EU Commission may support lobbying groups that are calling for a re-scheduling of the nuclear phase-out in Germany.

Literature

ACER (2014): Agency for the Cooperation of Energy Regulators, Annual Report on the Results of Monitoring the Internal Electricity and Natural Gas Market in 2013

Acworth, William (2014): Can the Market Stability Reserve Stabilise the EU ETS: Commentators Hedge Their Bets, http://www.diw.de/de/diw_01.c.465890.de/presse/diw_roundup/can_the_market_stability_reserve_stabilise_the_eu_ets_commentators_hedge_their_bets.html

AGEB (2014): AG Energiebilanzen e.V., Energieverbrauch in Deutschland im Jahr 2013, Stand März 2014, http://www.ag-energiebilanzen.de/index.php?article_id=29&fileName=ageb_jahresbericht2013_20140317.pdf

Agentur für Erneuerbare Energien (2014): Wachstumstrend der Energiegenossenschaften ungebrochen, http://www.unendlich-viel-energie.de/wachstumstrend-der-energiegenossenschaften-ungebroche

Agora (2014): Agora Energiewende. Das deutsche Energiewende-Paradox: Ursachen und Herausforderungen. Eine Analyse des Stromsystems von 2010 bis 2030 in Bezug auf Erneuerbare Energien, Kohle, Gas, Kernkraft und CO2-Emissionen. http://www.agora-energiewende.de/fileadmin/downloads/publikationen/Analysen/Trends_im_deutschen_Stromsektor/Analyse_Energiewende_Paradox_web.pdf

Agora (2015): Agora Energiewende. The Energiewende in the Power Sector: State of Affairs 2014. http://www.agora-energiewende.de/fileadmin/downloads/publikationen/Analysen/Jahresauswertung_2014/Agora_Energiewende_Review_2014_EN.pdf

*Albrech*t, Tanja / *Zundel*, Stefan (2010): Gefühlte Wirtschaftlichkeit – Wie Eigenheimbesitzer energetische Sanierungsmaßnahmen ökonomisch beurteilen. http://www.enef-haus.de/fileadmin/ENEFH/redaktion/PDF/Enef-Haus_Gefuehlte_Wirtschaftlichkeit.pdf

Baden-Württemberg (2007): Gesetz zur Nutzung erneuerbarer Wärmeenergie in Baden-Württemberg (Erneuerbare-Wärme-Gesetz – EWärmeG), Landtag von Baden-Württemberg, Drucksache 14/1969

BAFA (2012): Solar - Basis-, Bonus- und Innovationsförderung, Stand: ab dem 15.08.2012, http://www.bafa.de/bafa/de/energie/erneuerbare_energien/publikationen/energie_ee_so_uebersicht.pdf

BEM (2014a): Bundesverband eMobilität. NAPE: Bund plant Steuervorteile für eFahrzeuge, http://www.bem-ev.de/nape-bund-plant-steuervorteile-fur-efahrzeuge/

BEM (2014b): Bundesverband eMobilität. BEM-Stellungnahme zum Elektromobilitätsgesetz, Press release 19.08.2014, http://www.bem-ev.de/pm-bem-stellungnahme-zum-elektromobilitatsgesetz/

BFW (2010): Bundesverband Freier Immobilien- und Wohnungsunternehmen e.V., Press release 10.06.2010, http://www.bfw-bund.de/nc/pressecenter/pressemitteilungen/detailansicht/bfw-streichkonzert-bei-co2-gebaeudesanierungsprogramm.html?filename=Pressemitteilungen.pdf.

BMBF (2011): Bekanntmachung einer gemeinsamen Initiative des BMWi, des BMU und des BMBF zur Förderung von Forschung und Entwicklung auf dem Gebiet von Energiespeichertechnologien (Förderinitiative Energiespeicher), 21.04.2011, http://www.bmbf.de/en/furtherance/16431.php

BMU (2012a): Richtlinien zur Förderung von Maßnahmen zur Nutzung erneuerbarer Energien im Wärmemarkt vom 20. 07.2012

BMU (2012b): Erfahrungsbericht zum Erneuerbare-Energien-Wärmegesetz (EEWärmeG-Erfahrungsbericht), in Deutscher Bundestag, Drucksache 17/11957

BMU (2012c): Förderung im Marktanreizprogramm 2012 des Bundesumweltministeriums. Teil BAFA. Investitionskostenzuschüsse, http://www.energie-experten.org/uploads/media/Marktanreizprogramm_2012_BAFA.pdf

BMU (2013): Marktanreizprogramm – Bilanz Förderjahr 2012

BMU (2014a): Entwurf eines Gesetzes zur Bevorrechtigung der Verwendung elektrisch betriebener Fahrzeuge (Elektromobilitätsgesetz - EmoG). 24.09.2014

BMU (2014b): Aktionsprogramm Klimaschutz 2020

BMVBS (2013a): Maßnahmen zur Umsetzung der Ziele des Energiekonzepts im Gebäudebereich – Zielerreichungsszenario, in: BMVBS-Online-Publikation No. 03/2013 http://www.bbsr.bund.de/BBSR/DE/Veroeffentlichungen/BMVBS/Online/2013/DL_ON032013.pdf?__blob=publicationFile&v=5.

BMVBS (2013b): The Mobility and Fuels Strategy of the German Government, http://www.bmvi.de/SharedDocs/EN/Anlagen/UI-MKS/mfs-strategy-final-en.pdf?__blob=publicationFile

BMWi (2011): Research for an environmentally sound, reliable and affordable energy supply. 6th Energy Research Programme of the Federal Government

BMWi (2012): Vereinbarung zwischen der Regierung der Bundesrepublik Deutschland und der deutschen Wirtschaft zur Steigerung der Energieeffizienz vom 28. September 2012.

BMWi (2013): Gesamtausgabe der Energiedaten – Datensammlung des BMWi. Last update 20.08.2013

BMWi (2014a): Zweiter Monitoring-Bericht „Energie der Zukunft“

BMWi (2014b): Bilanz 2013, http://www.erneuerbare-energien.de/EE/Redaktion/DE/Standardartikel/marktanreizprogramm_bilanz_zum_foerderjahr_2013.html

BMWi (2014c): Gesamtausgabe der Energiedaten. Datensammlung des BMWi. Last update 21.10.2014

BMWi (2014d): Erneuerbare Energien im Jahr 2013. Erste vorläufige Daten zur Entwicklung der erneuerbaren Energien in Deutschland auf der Grundlage der Angaben der Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat)

BMWi (2014e): Ein Strommarkt für die Energiewende. Diskussionspapier des Bundesministeriums für Wirtschaft und Energie (Grünbuch). October 2014

BMWi (2014f): Nationaler Aktionsplan Energieeffizienz

BMWi (2014g): Die Energie der Zukunft. Erster Fortschrittsbericht zur Energiewende. December 2014

BMWi (2014h): Zeitreihen zur Entwicklung der erneuerbaren Energien in Deutschland unter Verwendung von Daten der Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat). February 2014

*BMWi (*2014i): Bruttobeschäftigung durch erneuerbare Energien in Deutschland im Jahr 2013

BMWi (2014j): Bundesbericht Energieforschung. Forschungsförderung für die Energiewende

BMWi / BMU (2012): Erster Monitoring-Bericht „Energie der Zukunft“

Bonhoff, Klaus (2009): Electrification of Future Mobility - National Programs and Activities in Germany, National Organization Hydrogen and Fuel Cell Technology, May 2009, http://www.hpath.org/resources/additional%20material/6_bonhoff_2009_amr.pdf

BPIE (2014): Buildings Performance Institute Europe. Renovation strategies of selected countries. A status report on compliance with article 4 of the Energy Efficiency Directive. http://bpie.eu/uploads/lib/document/attachment/86/Renovation_Strategies_EU_BPIE_2014.pdf

BReg (2010): Energiekonzept der Bundesregierung für eine umweltschonende, zuverlässige und bezahlbare Energieversorgung, 28.10.2010

BReg (2011): Regierungsprogramm Elektromobilität, May 2011

BReg (2014): CO2-Gebäudesanierung – enrgieeffizient Bauen und Sanieren. http://www.bundesregierung.de/Webs/Breg/DE/Themen/Energiewende/Energiesparen/CO2-Gebaeudesanierung/_node.html

DIW (2007): Comprehensive package of climate protection measures could substantially decrease cost of emission reductions in Germany, in: DIW Weekly Report No. 3/2007, Berlin, 15-20

DIW (2012): Erneuerbare Energien. Quotenmodell keine Alternative zum EEG. DIW Weekly Report No. 45, Berlin,15-23

DIW (2013): Netzsituation in Deutschland bleibt stabil. DIW Weekly Report No. 20, Berlin, 3-12

DUH (2014): Deutsche Umwelthilfe. Netze für den Klimaschutz, http://www.duh.de/uploads/tx_duhdownloads/FactSheet_Klimaschutz_und_Netzausbau_DUH.pdf

Ecofys / *Fraunhofer* ISI */ TU Vienna EEG / Ernst & Young* (2011): Financing Renewable Energy in the European Energy Market. By order of: European Commission - DG Energy, http://www.ecofys.com/en/project/financing-renewable-energy-in-european-markets/

Energiewirtschaftsgesetz (EnWG) (2005): Gesetz über die Elektrizitäts- und Gasversorgung. Ausfertigungsdatum: 07.07.2005

EnEV (2014): Energieeinsparverordnung, 21.11. 2013, http://www.enev-online.com/enev_2014_volltext/index.htm

EPO (2014): European Patent Office. Worldwide Patent Statistical Database (PATSTAT), http://www.epo.org/searching/subscription/raw/product-14-24_de.html

Erneuerbare-Energien-Gesetz (EEG) (2014): Gesetz für den Ausbau erneuerbarer Energien. Arbeitsausgabe der Clearingstelle EEG. Gesetzesfassung vom 22. Juli 2014. In Kraft ab 1. August 2014. RELAW – Gesellschaft für angewandtes Recht der Erneuerbaren Energien mbH. Berlin.

European Commission (2011): Renewable energy. Progressing towards the 2020 target, COM(2011) 31 final, Brussels.

European Environment Agency (2013): Annual European greenhouse gas inventory 1990-2011, EEA Technical report No 8/2013, Copenhagen

European Photovoltaic Industry Association (EPIA) (2014): Global Market Outlook for Photovoltaics 2014-2018, http://www.epia.org/fileadmin/user_upload/Publications/EPIA_Global_Market_Outlook_for_Photovoltaics_2014-2018_-_Medium_Res.pdf

EWI / Prognos/ GWS (2014): Entwicklung der Energiemärkte – Energiereferenzprognose. Endbericht. Studie im Auftrag des Bundesministeriums für Wirtschaft und Energie, http://www.bmwi.de/BMWi/Redaktion/PDF/Publikationen/entwicklung-der-energiemaerkte-energiereferenzprognose-endbericht,property%3Dpdf,bereich%3Dbmwi2012,sprache%3Dde,rwb%3Dtrue.pdf

Fraunhofer IWES (2013): Wind Energy Report Germany 2013, http://windmonitor.iwes.fraunhofer.de/windmonitor_de/5_Veroeffentlichungen/1_windenergiereport/

Fraunhofer ISI / Fraunhofer IFAM/ Prognos/ Ifeu (2014): Ausarbeitung von Instrumenten zur Realisierung von Endenergieeinsparungen in Deutschland auf Grundlage einer Kosten-/Nutzen-Analyse. Wissenschaftliche Unterstützung bei der Erarbeitung des Nationalen Aktionsplans Energieeffizienz (NAPE). Zusammenfassung. http://www.bmwi.de/DE/Mediathek/publikationen,did=677320.html

Fraunhofer ISI / RISO / VUT (2007): Assessment and optimisation of renewable energy support schemes in the European electricity market. OPTRES Report (D7 report), http://www.optres.fhg.de/results/OPTRES_D7_interactions.pdf

Global Wind Energy Council (GWEC) (2014): Top 10 Cumulative Capacity Dec 2013, http://www.gwec.net/wp-content/uploads/2014/04/9_Top-ten-cumulative.jpg

Heinbach, Katharina et al. (2014): Renewable energies and their impact on local value added and employment, in: Energy, Sustainability and Society 4 (1), 1-10

Herold, Johannes/ Christian von Hirschhausen (2010): Hohe Unsicherheiten bei der CO2-Abscheidung. Eine Energiebrücke ins Nichts?, in: DIW Weekly Report No. 36/2010, Berlin, 2-7

Ifeu / GWS (2012): Volkswirtschaftliche Effekte der Energiewende: Erneuerbare Energien und Energieeffizienz, http://www.ifeu.de/energie/pdf/volkswirtschaftl_%20effekte_%20energiewende_broschuere_pehnt_RZ.pdf

IÖW / ECOFYS (2014): Kommunale Wertschöpfungskette durch energetische Gebäudesanierung. Endbericht. Im Auftrag des BMUB, https://www.klimaschutz.de/sites/default/files/article/141028%20Endbericht_KoWeG_final_0.pdf

Jarass, Lorenz (2013): Stromnetzausbau für erneuerbare Energien erforderlich oder für unnötige Kohlestromeinspeisung, in: Zeitschrift des Instituts für Energie- und Wettbewerbsrecht in der Kommunalen Wirtschaft e. V. 2013 (6), Berlin, 320-326

KfW (2013): Erneuerbare Energien – Speicher, https://www.kfw.de/inlandsfoerderung/ Unternehmen/Energie-Umwelt/F%C3%B6rderprodukte/Erneuerbare-Energien-%E2%80%93-Speicher-%28275%29/

Klessmann, Corinna (2014): Experience with renewable electricity (RES-E) support schemes in Europe. Current status and recent trends, http://www.leonardo-energy.org/sites/leonardo-energy/files/documents-and-links/ecofys-support_policies_2014_04.pdf

Lehr, Ulrike / Christian Lutz / Philip Ulrich (2013): Gesamtwirtschaftliche Wirkungen von Klimaschutzmaßnahmen und –instrumenten. Ökonomische Analysen der Politikszenarien für den Klimaschutz VI. Im Auftrag des Umweltbundesamtes, https://www.umweltbundesamt.de/publikationen/gesamtwirtschaftliche-wirkungen-von-0

Löschel, Andreas et al. (2014a): Expertenkommission zum Monitoring-Prozess „Energie der Zukunft“. Stellungnahme zum zweiten Monitoring-Bericht der Bundesregierung für das Berichtsjahr 2012, http://www.bmwi.de/DE/Themen/Energie/Energiewende/monitoring-prozess.html

Löschel, Andreas et al. (2014b): Expertenkommission zum Monitoring-Prozess „Energie der Zukunft“. Stellungnahme zum ersten Fortschrittsbericht der Bundesregierung für das Bereichtsjahr 2013, http://www.bmwi.de/DE/Themen/Energie/Energiewende/monitoring-prozess.html

*McKinsey (*2007): A Cost Curve for Greenhouse Gas Reduction. McKinsey Quarterly 2007 (1)

NBW News (2011): Gesetzgebung: Bundesrat stoppt Steuervereinfachung und Förderung der Wohngebäudesanierung. News from 11.07. 2011, http://www2.nwb.de/portal/content/ir/service/news/news_1228188.aspx

Netzentwicklungsplan (NEP) (2014): Netzentwicklungsplan Strom. 1. Entwurf, http://www.netzentwicklungsplan.de/netzentwicklungsplan-2014-erster-entwurf

Nitsch, Joachim (2014): GROKO-II Szenarien der deutschen Energieversorgung auf der Basis des EEG-Gesetzentwurfs – insbesondere Auswirkungen auf den Wärmesektor. Kurzexpertise für den Bundesverband Erneuerbare Energien e.V., http://www.bee-ev.de/Publikationen/20140827_SzenarienderdeutschenEnergieversorgung_Waermesektor.pdf

Öko-Institut / Fraunhofer ISI (2014): Klimaschutzszenario 2050. 1. Modellierungsrunde. Studie im Auftrag des Bundesministeriums für Umwelt, Naturschutz, Bau und Reaktorsicherheit. Kurzfassung, http://www.oeko.de/oekodoc/2065/2014-638-de.pdf

Pegels, Anna/ *Lütkenhorst*, Wilfried (2014): Is Germany's energy transition a case of successful green industrial policy? Contrasting wind and solar PV, in: Energy Policy 74, 522-534.

PTJ (2010): Projektträger Jülich, www.ptj.de/energy-storage

REN21 (2014): Renaewables 2013. Global Statur Report, http://www.ren21.net/ren21activities/globalstatusreport.aspx

Renews Kompakt (2014): Großteil der erneuerbaren Energien kommt aus Bürgerhand. http://www.unendlich-viel-energie.de/media/file/284.AEE_RenewsKompakt_Buergerenergie.pdf

Schlomann, Barbara et al. (2014): Monitoring of the "Energiewende" – Energy Efficiency Indicators for Germany, in: Fraunhofer ISI Working Paper Sustainability and Innovation No. S10/2014

Schröder, Andreas et al. (2013): Current and Prospective Costs of Electricity Generation until 2050, in: DIW Data Documentation No. 68, Berlin

The Guardian (2013): Interview with Manfred Fischedick, 10.05.2013, http://www.theguardian.com/sustainable-business/nuclear-power-germany-renewable-energy

VdZ (2014): Vereinigung der deutschen Zentralheizungswirtschaft e.V., Gebäudesanierungsfahrplan, http://www.gebaeudesanierungsfahrplan.de/sanierungsfahrplan/ausgangssituation.html

von Hirschhausen, Christian et al. (2012): CO2-Abscheidung europaweit vor dem Aus, in: DIW Weekly Report No. 6/2012, Berlin, 3-9

Weitblick (2010): Regionale Wertschöpfung – neue Energie für Kommunen, in: Weitblick No. 02/2011, https://germanwatch.org/3728

Wirth, Harry (2014): Aktuelle Fakten zur Photovoltaik in Deutschland. Fraunhofer-Institut für Solare Energiesysteme ISE, Freiburg

Ziesing, Hans-Joachim (2014): Weltweite CO2-Emissionen 2013: Trendwende lässt trotz einiger Hoffnungsschimmer auf sich warten, in: Energiewirtschaftliche Tagesfragen 64 (9), 84-98