DE 2015 Report

pathways to deep decarbonization in Germany

Summary

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SUSTAINABLE DEVELOPMENT SOLUTIONS NETWORK
A GLOBAL INITIATIVE FOR THE UNITED NATIONS

Wuppertal Institute for Climate, Environment and Energy

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1. Introduction

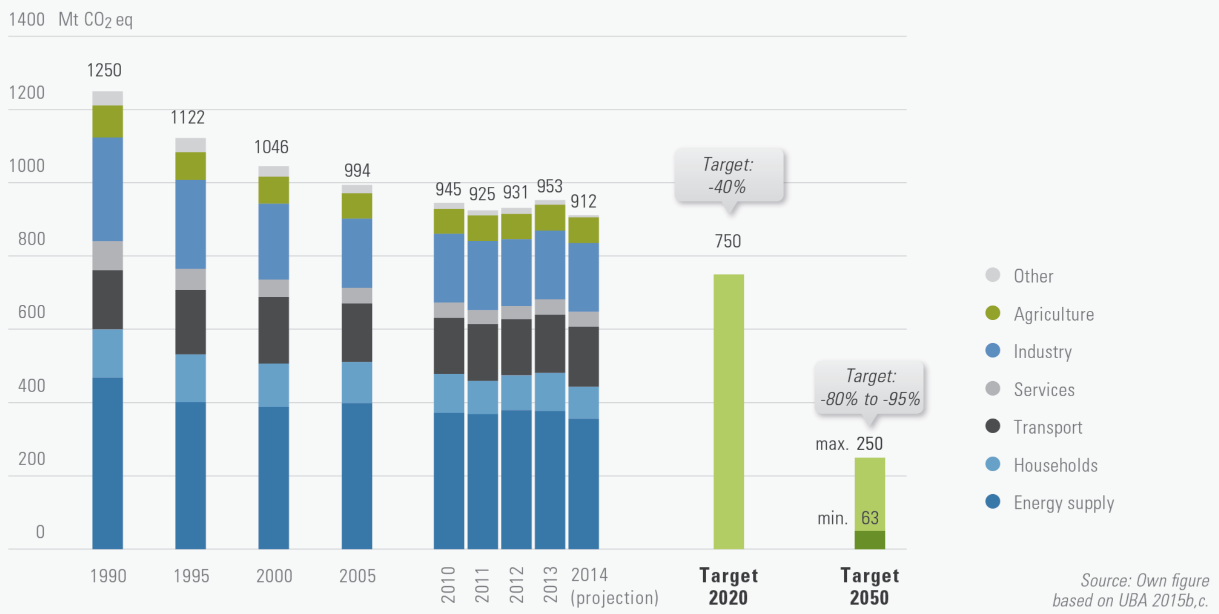
In order for the global community to succeed in climate change mitigation, the issue needs to be addressed at many different political levels, both internationally and nationally. Recognizing the existence of both individual national challenges and common global challenges in climate change mitigation, the Deep Decarbonization Pathways Project (DDPP) was co-founded in 2013 by the United Nations' Sustainable Development Solutions Network (SDSN) and the Institute for Sustainable Development and International Relations (IDDRI). The DDPP is a collaborative global initiative that aims to demonstrate how individual countries can transition to a low-carbon economy consistent with the internationally agreed target of limiting the anthropogenic increase in global mean surface temperature to less than 2 degrees Celsius (°C) compared with pre-industrial times. In order to achieve this target, global net greenhouse gas (GHG) emissions need to approach zero by the second half of the century, according to climate science. This will require, more than any other factor, a profound transformation of energy systems by mid-century, through steep declines in carbon intensity in all sectors, a transition we call "deep decarbonization".

In accordance with the proceedings of the other fifteen other countries' teams, this report explores what is required to achieve deep decarbonization in Germany. This is done by discussing how the German government's target of reducing domestic GHG emissions by 80% to 95% by 2050 (versus 1990) can be reached and how this pathway can build a suitable bridge to a GHG-free future in the following decades.

2. Past GHG emission reductions and the German government's target for 2050

In past years, Germany achieved significant progress in GHG emission mitigation and as one major step fulfilled its Kyoto target. Overall, GHG emissions have been reduced by 27% between 1990 and 2014 (see Figure 1).

Figure 1: Development of GHG emissions in Germany by sector



Source: Own figure based on UBA 2015b,c.

In most sectors of the economy, significant GHG emission reductions could be achieved in this timeframe (services 53%, industry 34%, residential 33%, energy supply 24%, agriculture 21%). Only in the transport sector, the amount of GHG emissions remained virtually at the same level (164 Mio t CO_2 equivalent in 2014 vs. 163 Mio t CO_2 in 1990).

It should, however, be noted that a certain amount of emission reductions can be attributed to the German reunification in 1990 and not to climate policy. Eichhammer et al. (2001) estimate that as a result of the economic breakdown in Eastern Germany following the reunification, about 9% of GHG emissions (105 m tons of CO_2 emissions) – so-called Wallfall profits – had been avoided by 2000 (compared with a hypothetical reference value for that year).

Considering the sources of GHG emissions, it can be seen that the huge majority of emissions in Germany (about 85%) currently originates from energy-related sources (energy supply sector, manufacturing industry, transport, small-scale furnaces and others). The major part of residual emissions is directly related to industrial processes and agriculture. Since energy-related sources are responsible for most emissions, mitigation efforts focus on this area.

However, progress on GHG emission reductions has slowed down over time. In order to reach an 80% to 95% GHG emission reduction by 2050 (as well as several sub targets contributing to this reduction), the average annual emission abatement must amount to at least 3.5% from 2014 on. Fulfilling this task requires annual reduction rates in the same range as historically reached maximum values in Germany. The challenge is significant since in contrast to the successful start of Germany's energy system transformation, future progress requires deeper structural changes in the energy system including behavioral changes and broad and constant public support and acceptance.

3. Deep decarbonization pathways for Germany – A comparison of three illustrative scenarios

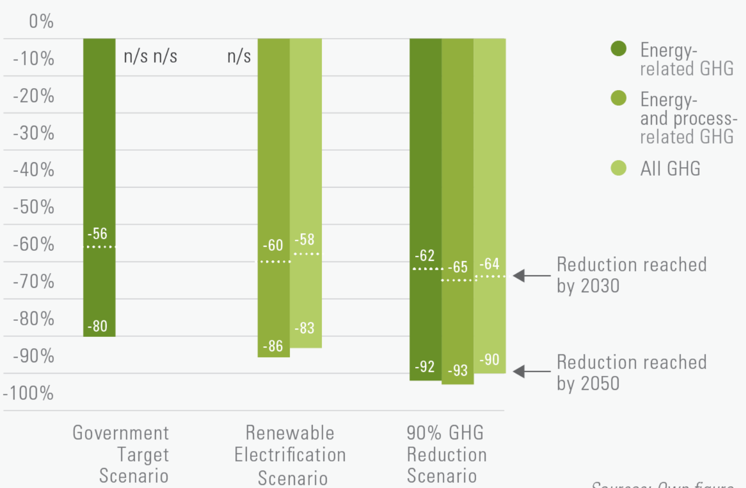
Potential decarbonization pathways for Germany are comparatively analyzed by a discussion of three mitigation scenarios that have been selected as illustrative from a whole bunch of recently published scenarios:

- Scenario "Target" from the study "Development of Energy Markets – Energy Reference Forecast" (Schlesinger et al. 2014), here referred to as **"Government Target Scenario"**
- Scenario "100-II" from the study "GROKO II – German Energy Supply Scenarios Based on the EEG Draft Bill" (Nitsch 2014), here called **"Renewable Electrification Scenario"**
- Scenario "KS 90" from the study "Climate Protection Scenario 2050" (Repenning et al. 2014), here referred to as **"90% GHG Reduction Scenario"**

The detailed analysis of the scenarios' underlying assumptions shows that all three scenarios do not assume any drastic or sudden changes in social and economic developments. For example, they do not assume dramatic technological breakthroughs, drastic lifestyle changes, a deindustrialization or substantial economic crises.

The three scenarios project greenhouse gas emission reductions of 80% to 90% by 2050 (see Figure 2). Thus, the German government's targeted emission reduction is achieved within the scenarios. It should, however, be noted that the types of GHG emissions included vary: While the "Government Target Scenario" looks only at energy-related GHG emissions and describes how these can be reduced by 80% by 2050, the "Renewable Electrification Scenario" expects an 86% decrease in energy- and process-related GHG emissions by the middle of the century. The third illustrative scenario, the "90% GHG Reduction Scenario", looks at all GHG emissions and describes a pathway that reaches – as the name suggests – an emission reduction of 90% by 2050.

Figure 2: Relative change in GHG emissions compared to 1990



Sources: Own figure based on Schlesinger et al. 2014, Repenning et al. 2014, Nitsch 2014.

Some of the strategies used to achieve emission reductions vary between the scenarios. Nevertheless, three strategies that strongly contribute to GHG emission reduction are used to a significant extent in all three analyzed scenarios:

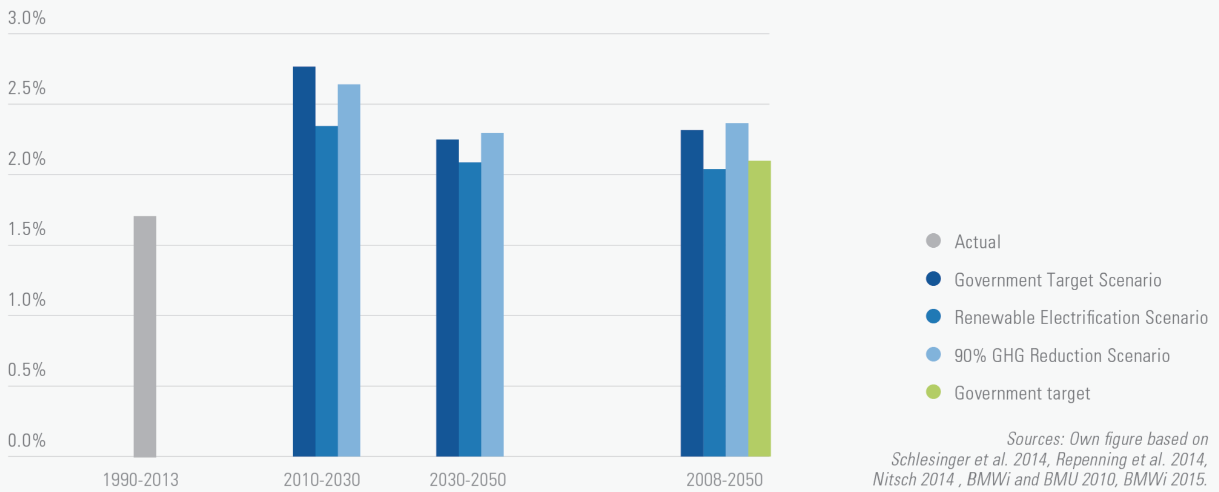
- Energy efficiency improvements (in all sectors but especially in buildings)
- Increased use of domestic renewables (with a focus on electricity generation)
- Electrification and (in two of the scenarios also) use of renewable electricity-based synthetic gases/fuels (power to gas/fuels), especially in the transport and industry sector

Energy efficiency improvements

The German government set an official target of improving final energy productivity (i.e. the ratio GDP/final energy consumption) between 2008 and 2050 by 2.1% annually. Achieving this goal is expected to lead to a decrease in primary energy consumption of about 50% between 2008 and 2050 (BMWi and BMU 2010). Figure 3 shows that the three analyzed scenarios realize average annual improvements in final energy productivity of between 2.0% and 2.4%. Thus, they are roughly in line with the government target and support the defined milestones.

The figure also shows that between 1990 and 2013, final energy productivity in Germany rose by 1.7%/year (using temperature-adjusted data), mainly due to more efficient power plants and the tapping of energy-efficiency potential in the industry and residential sectors (BMUB 2014).[1] However, productivity improvements will need to accelerate in the coming years and decades for Germany to reach its energy and climate targets. Recent studies suggest that this is feasible not only from a technological point of view but that a great majority of efficiency measures are cost-effective even under today's economic (e.g. low energy prices) and regulatory conditions (Schlomann et al. 2014).

Figure 3: Average annual change in final energy productivity over various periods



Sources: Own figure based on Schlesinger et al. 2014, Repenning et al. 2014, Nitsch 2014 , BMWi and BMU 2010, BMWi 2015.

Mainly due to energy efficiency improvements, the three scenarios expect final energy demand in 2050 to be between 40% and 47% lower than in 2010 (see Figure 4). Decreasing energy service demand is not considered an important driver for final energy demand reductions although limiting rebound effects plays at least implicitly an important role in the scenarios to secure the energy efficiency goals . While the change in total final energy demand is similar in all three scenarios, there are more pronounced differences between the individual sectors, as Figure 4 shows.

In contrast to total final energy demand, electricity demand varies considerably in 2050 in the three selected scenarios. In the "Government Target Scenario," electricity demand in 2050 is about 120 TWh or 20% lower than it was in 2014, while it is some 225 TWh or almost 40% higher than in 2014 in the "Renewable Electrification Scenario" (mainly due to the assumed electrification of processes and extensive hydrogen generation). In the "90% GHG Reduction Scenario," electricity demand is similar to 2014.

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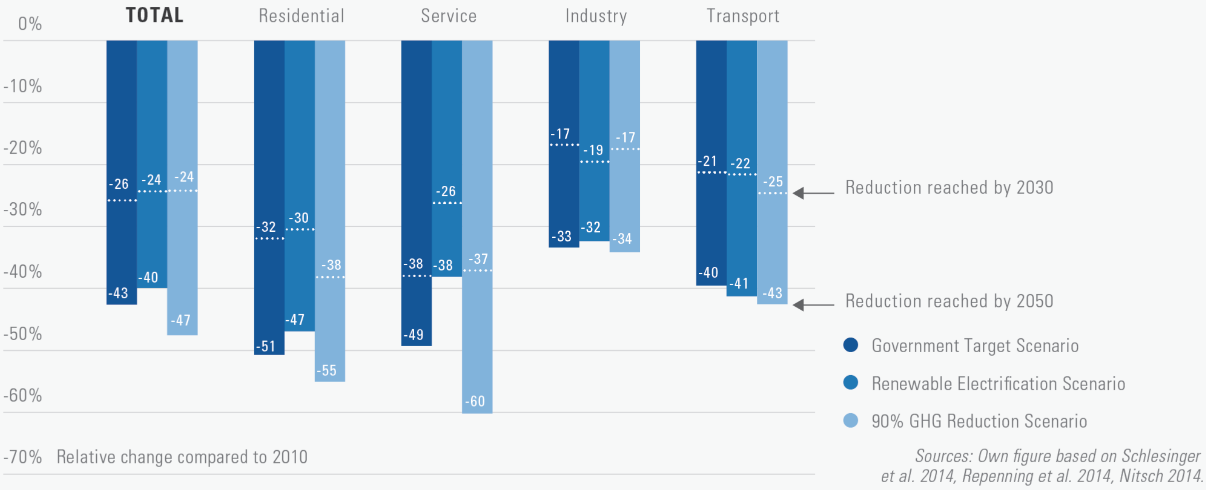
[1] It should be noted that in general energy efficiency improvements are difficult to measure on a macroeconomic scale since even temperature-adjusted indicators are influenced by factors such as structural change (e.g. change in industry production towards less energy-intensive products).

Figure 4: Change in final energy demand compared to 2010



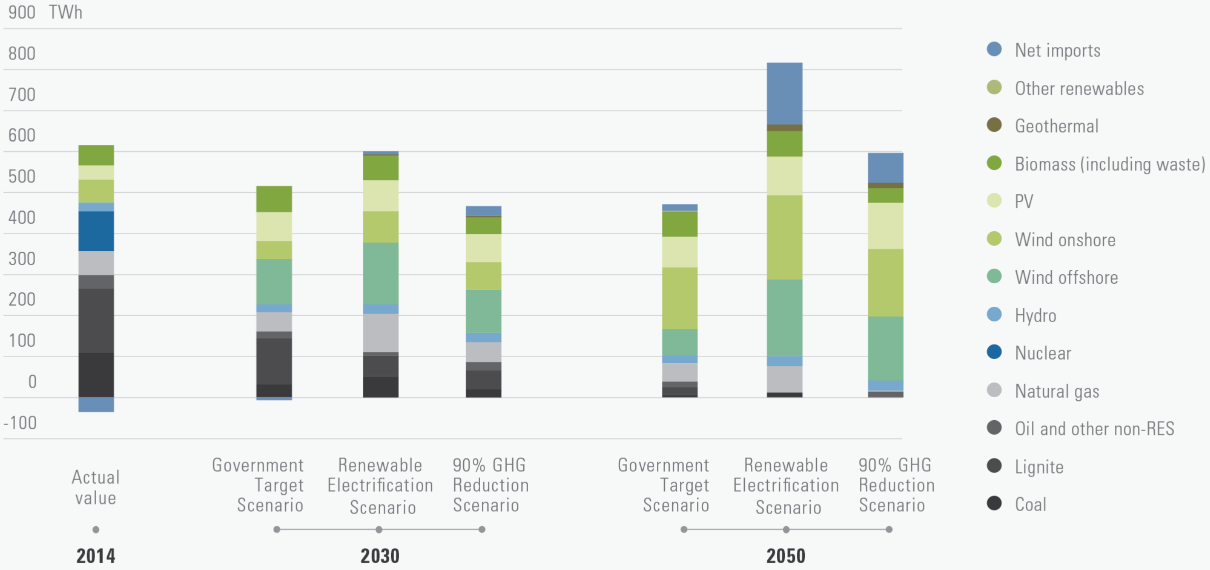
Sources: Own figure based on Schlesinger et al. 2014, Repenning et al. 2014, Nitsch 2014.

Increased use of domestic renewables (with a focus on electricity generation)

Besides energy efficiency, the integration of renewable energy sources in the German electricity system is one main strategy to reach a decarbonization of the energy system. According to the current political targets, renewable energy sources shall cover at least 80% of gross electricity consumption in 2050 to help achieve a reduction of greenhouse gases of 80% to 95% by 2050 compared with 1990.

In the past 15 years, electricity production from renewable energy sources has increased considerably in Germany. This was mainly due to the German Renewable Energy Sources Act ("Erneuerbare-Energien-Gesetz", EEG) which was introduced in 2000 and promotes the installation of renewable power plants by providing a fixed and technology-specific feed-in tariff. Since then the electricity production from renewables has risen from 3% to 5% in the 1990s to about 28% of gross electricity consumption in 2014. The main renewable energy sources used in electricity generation in Germany today are onshore wind (9% in 2014), biomass (8%, including biogenic part of waste) and solar PV (6%) (AGEB 2015c).

Figure 5: Electricity generation by source (including net imports)



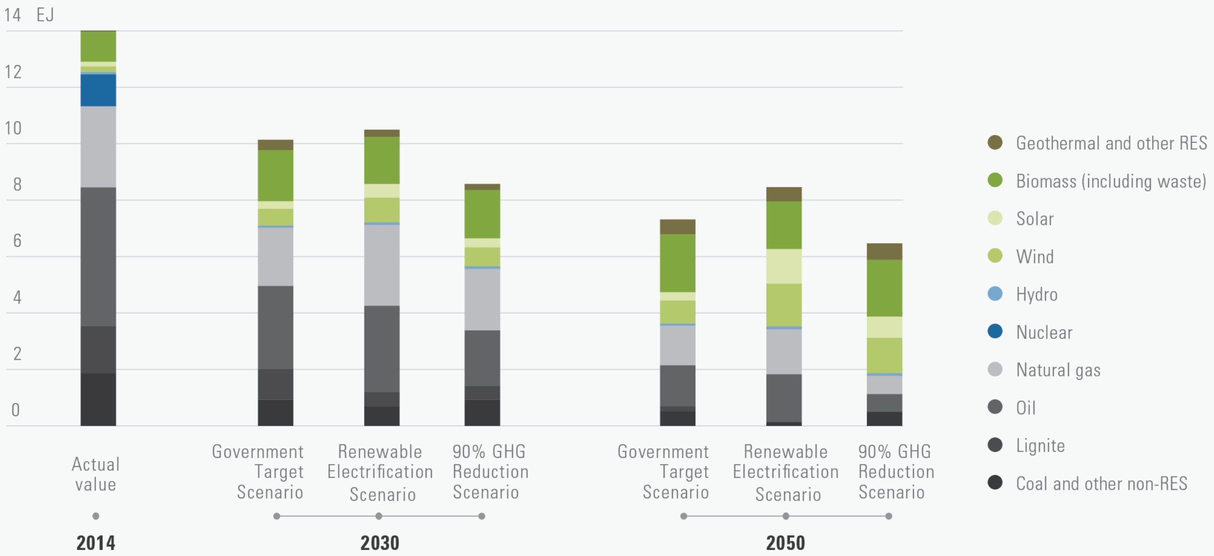
The figure refers to gross electricity generation except in the case of the 90% GHG Reduction Scenario, for which net electricity generation is shown as data for gross generation is not available.

Sources: Own figure based on Schlesinger et al. 2014, Repenning et al. 2014, Nitsch 2014, Nitsch 2015 (personal communication, April 30, 2015), Harthan 2015 (personal communication, May 11, 2015), AGEB 2015c.

As Figure 5 shows, the three analyzed scenarios expect domestic renewable electricity generation to more than double between 2014 and 2050, with even stronger growth in the two more ambitious scenarios. The figure also shows that renewable electricity generation is expected to increase its share in the total renewable energy supply from 40% today to between 41% and 56% in 2050.

Regarding the future primary energy mix, the three scenarios expect that renewable energy sources make up between 51% and 73% in 2050 (from 11% in 2014, see Figure 6, AGEB 2015a, b). Biomass continues to be the most important renewable energy source, but is followed closely in all three scenarios in 2050 by wind energy. With respect to fossil fuels, the combined share of coal and lignite (today 25%) decreases significantly to between 2% and 9%, while oil (today 35%) remains relevant with a 2050 share of between 9% and 20%, being used mainly in the transport sector. Natural gas with shares in primary energy supply of 10% ("90% GHG Reduction Scenario") to about 20% (the other two scenarios) continues to play a relevant role in 2050, acting as a sort of "bridge fuel" for the transformation towards an energy supply dominated by renewable energy sources.

Figure 6: Primary energy mix



Underlying primary energy data for the 90% GHG Reduction Scenario includes only energetic primary energy, while the data for the other two scenarios refer to total primary energy.

Sources: Own figure based on Schlesinger et al. 2014, Repenning et al. 2014, Nitsch 2014 , AG Energiebilanzen 2015a.

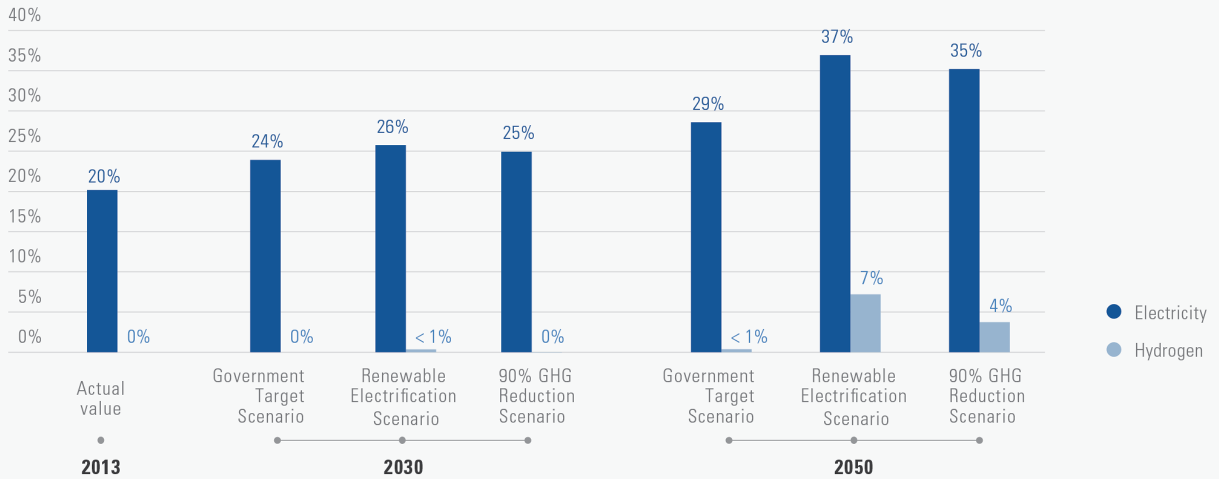
Electrification and use of renewable electricity-based synthetic gases/fuels (power to gas/fuels)

Electrification of processes and power-to-x ("x" standing in for heat, hydrogen/methane or synthetic fuels in general) are considered important in most available deep decarbonization scenarios, especially as means to reduce GHG emissions in transport and industry in the long-term. Both, electrification of processes and power-to-x will gain importance as the share of renewable energy sources in electricity production increases. Considering the efficiency losses along the process chain, choosing the correct starting point for implementing this strategy is decisive. If electricity was not produced sustainably, true decarbonization by means of this strategy would hardly be possible because it results in relatively high amounts of electricity demand and involves large conversion losses. For Germany, a power-to-x (particularly power-to-gas) strategy seems to be very promising as the existing gas infrastructure (gas grid, storage facilities) can by fully (methane) or at least partly (hydrogen) used.

Figure 7 shows that electricity as a final energy source is expected to play a much larger role in decarbonization scenarios than it plays today. Its share grows from 20% in 2014 to between 29% and 37% in 2050. Hydrogen will also become a relevant final energy source according to two of the three scenarios, mainly in the transport sector. The "Government Target Scenario" does not foresee a relevant role for hydrogen. The authors of that scenario point to the high costs and the energy losses of generating hydrogen from electricity and water.[2]

[2] It should be pointed out that it is easier for the "Government Target Scenario" to relinquish the option of replacing fossil fuels with hydrogen as this scenario is the least ambitious one in regard to GHG emission reductions.

Figure 7: Shares of electricity and hydrogen in total final energy demand



Sources: Own figure based on Schlesinger et al. 2014, Repenning et al. 2014, Nitsch 2014 , Nitsch 2015 (personal communication, April 30, 2015), AGEB 2015d.

Today, the electrification of processes and power-to-x is still not used prevalently. By the end of 2014, about 24,000 electric vehicles (i.e. battery electric vehicles and plug-in hybrid electric vehicles) were registered in Germany (NPE 2014). Electricity demand for the production of hydrogen is currently negligible (Schlesinger et al. 2014). However, the use of power-to-heat technology has been on the rise in recent years as a simple, but effective flexibility option to manage the rising volatility of electricity supplied by renewable energies (e.g. wind power and solar power). In general, flexibility options become more and more important to secure stability of the electricity grid. Besides power-to-x technologies, flexible power plants, demand-side management and storage systems (e.g. pumped hydropower storage facilities, batteries) will play an important role.

Additional strategies to achieve deep decarbonization

The aforementioned three decarbonization strategies are also used extensively in other GHG mitigation scenarios for Germany. It can be argued that they need to be implemented successfully to be able to reach substantial GHG emission reductions by 2050.

The scenario analysis shows that besides the three key strategies, there are other strategies used only in one or two of the three analyzed scenarios that can be regarded as more controversial:

- Final energy demand reductions through behavioral changes (modal shift in transport, changes in eating and heating habits etc.)
- Net imports of electricity from renewable sources or import of bioenergy
- Use of carbon capture and storage (CCS) technology to reduce industry sector GHG emissions

Due to their comparatively low current relevance, strategies to reduce non-energy related (often non-CO_2) emissions – especially in agriculture and industry – are not always discussed in mitigation scenarios. However, these strategies will gain importance in the future, as deep decarbonization requires these emissions to also decrease considerably compared with today. Efforts to put these GHG emissions on the public and political agenda will need to be strengthened.

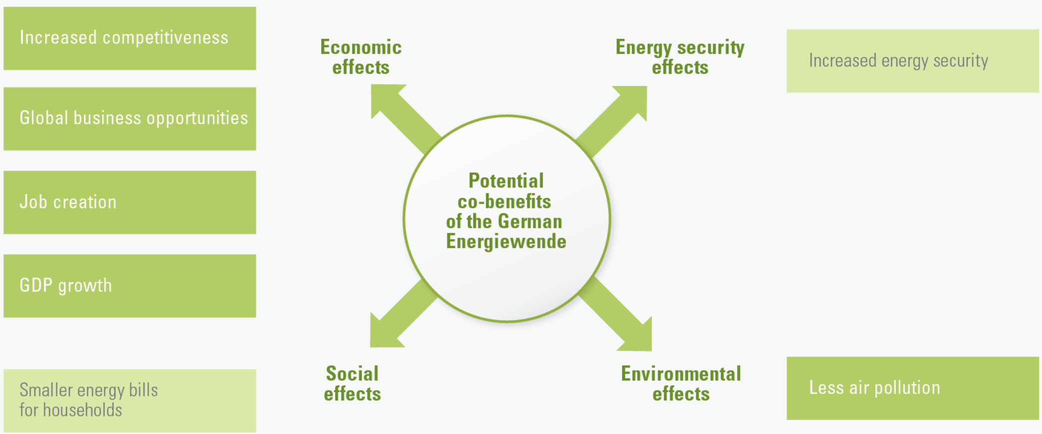
As a result of the decision to phase out nuclear energy in Germany, the deployment of nuclear power plants is not envisioned by any of the current energy scenarios for the years after 2022. There is widespread agreement in Germany that the disadvantages of nuclear power outweigh its benefits. CCS for use in power supply is also not considered in the analyzed scenarios as there is little acceptance for this technology within the German society and as a consequence little support from the political arena.

Overall, the analysis of the three illustrative scenarios shows that to reach very strong GHG emission reductions of 90% or more by 2050 (compared wiht 1990) it is necessary to implement most or all mitigation strategies mentioned above, as is done in the most ambitious of the three scenarios analyzed here, the “90% GHG Reduction Scenario.”

4. Co-benefits from a German perspective

Besides GHG emission mitigation, the implementation of decarbonization strategies can positively or negatively influence the attainment of other societal objectives. Beneficial non-climate impacts of mitigation measures have been named “co-benefits” by climate change researchers. Potential co-benefits for Germany include amongst others increased energy security, higher competitiveness of and global business opportunities for companies, job creation, impulses for GDP growth and less air pollution (see Figure 8). If different strategies are combined with care, this can result in smaller energy bills for households. Obviously, there are also risks, uncertainties and adverse side effects linked to the implementation of “Energiewende” measures that need to be addressed adequately and in time (for example challenges regarding grid stability and landscape consumption).

Figure 8: Potential co-benefits of the German ‘Energiewende’



Source: Own Figure

5. Resulting policy challenges

In order to achieve deep decarbonization and related co-benefits in Germany, the real challenge consists not so much of developing but of actually implementing decarbonization strategies. There is no lack of technologies but a lack of a concept to bring them into the market (i.e. an answer to the question of how to shape the right institutional, cultural and social environment for a successful deployment path). Therefore, authorities at different political levels need to introduce appropriate policies supporting the implementation of measures linked to the long-term mitigation strategies.

As transformation processes are subject to constraints, uncertainties and path dependencies, these implementation barriers need to be identified and addressed at an early stage. Concrete policy challenges linked to deep decarbonization in Germany exist for all decarbonization strategies, such as for the three key strategies mentioned above. For energy efficiency improvements, they include obtaining a considerable increase in the rate of building refurbishments and the development and dissemination of low-carbon technologies for transport vehicles. With regard to an increased use of renewable energy sources for electricity generation, it is, for example, necessary to foster the development of flexibility options that help keep the electricity grid stable and to introduce and shape a new electricity market design to guarantee sufficient investment in those options. In general, it seems to be particularly important to keep investment conditions stable and to ensure public acceptance for required infrastructure projects. In the currently less advanced field of electrification of processes and power-to-x, a consistent and stable policy framework needs to be established and research and development of innovative technologies should be supported.

6. Next steps

The report aims to show that although there are challenges to be overcome on the way to a fundamental transformation, deep decarbonization can be achieved in Germany by 2050. If very strong GHG emission reductions of 90% or more should be realized by 2050 (compared with 1990), most or all mitigation strategies mentioned above need to be implemented. As a result of about 30 years of critical engagement with climate and energy policies in Germany, a huge amount of theoretical and practical knowledge on transformation processes has been gathered. This knowledge should be used and also expanded in order to properly deal with the challenges associated with the complex process of achieving deep decarbonization. Germany should also be open to learn from transformation processes in other countries, just as other countries should learn from Germany’s experiences.

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