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The German energy transition and impulses for China to achieve carbon peaking and carbon neutrality – targets, status and prospects

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Imprint

The report "The German energy transition and impulses for China to achieve carbon peaking and carbon neutrality – targets, status and prospects" is a comprehensive introduction to experiences, achievements and lessons learned during energy transition in Germany and how it contribute to the achievement of climate target of Germany. Furthermore, the report introduces the inspiration of German experiences to the energy transition in China. Also, the policy recommendation is suggested in the report as well.

The report is published in the framework of the Sino-German Energy Partnership between the German Federal Ministry for Economic Affairs and Climate Action (BMWK) and the National Development and Reform Commission of the People's Republic of China (NDRC). As the central dialogue platform on energy between two countries, the main objective of the partnership is to foster and advance the far-reaching and profound energy transitions ongoing in both countries by exchanging views, best practices and knowledge on the development of a sustainable energy system, primarily centered on improving energy efficiency and expanding the use of renewable energy. The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH implements the project under commission of BMWK. As a German federal enterprise, GIZ supports the German government in the achievement of its goals in international cooperation for sustainable development.

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List of abbreviations

BaFa	Federal Office for Economic Affairs and Export Control
BMUV	Federal Ministry for Environment, Nature Conservation, Nuclear Safety and Consumer Protection
BMDV	Federal Ministry for Digital and Transport
BMWK	Federal Ministry for Economic Affairs and Climate Action
BMWSB	Federal Ministry for Housing, Urban Development and Building
BNetzA	Federal Network Agency
EE	Energy efficiency
EEG	Renewable Energy Sources Act
EMS	Energy management system
ETS	Emission trading system
EU	European Union
GDP	Gross domestic product
GEG	Buildings Energy Act
GHG	Greenhouse gases
GIZ	German Corporation for International Cooperation GmbH
GW	Gigawatt
IPCC	Intergovernmental Panel on Climate Change
kW	Kilowatt
kWh	Kilowatt-hour
NAPE	National Action Plan for Energy Efficiency
RE	Renewable energy/ies
SME	Small and medium-sized enterprises
TWh	Terawatt-hour
UBA	Federal Environment Agency

Executive summary

Objectives of the energy transition

The overarching policy objectives of the German energy transition are threefold: keep the security of energy supply at a high level, ensure the affordability of energy, and create a sustainable energy supply system that is in line with environmental and climate targets.

The most impressive achievements of Germany's energy transition until 2022 are reaching 46.2% of RE in gross electricity consumption, almost 20.4% of RE in gross final energy consumption and the reduction of the country's greenhouse gas (GHG) emissions by 40.4% compared to 1990.

Russia's war of aggression in Ukraine has given rise to global energy security concerns. Germany has decided to phase-out Russian fossil fuel imports as soon as possible while accelerating its energy transition. The provision of energy by renewable energy (RE) domestically will make Germany less dependent on fossil fuels from international markets, reduce import costs and increase national energy security. Through market-based measures, strengthening of the domestic grid and the interconnection within the European electricity and gas networks, the security of energy supply is at a very high level.

The early support of RE increased electricity prices for consumers. Now, the cost of electricity generation from RE is competitive with coal, gas and nuclear power plants. The energy transition industry that has developed in Germany has a positive impact on the German economy in various ways: a rise in export income, annual private investments of more than 50 billion EUR and the creation of close to one million new jobs.

The three pillars of the energy transition

The energy transition is a long-term and comprehensive strategy to transform Germany's energy supply and demand system. The dependence on nuclear power and finite fossil fuels – mainly imported – will give way to domestic RE, predominantly wind and solar. Achieving the energy transition and a carbon-neutral economy by 2045 requires efforts by all economic sectors through a focus on energy efficiency (EE), RE and sector coupling. These three pillars are interconnected and co-evolve during the implementation of the energy transition.

The expansion of RE sources in the electricity sector has been supported by the introduction of a feed-in tariff system since 2000. RE – especially wind, solar and electricity from biomass – now provide 45 to 50% of Germany's electricity supply. With more than 17% in the heating and approximately 7% in the transport sector, the share of RE in these sectors is comparably lower.

With the Energy Concept of 2010, EE was brought into greater focus. By lowering final energy consumption, the supply of energy to the different sectors can be accommodated more easily and reduces the costs for energy consumers. A wide variety of support programmes in the form of direct financial support or grants strengthens the adoption of energy-efficient appliances, housing and industrial processes.

Energy consumption can be drastically reduced when electrifying a large part of the energy demand, be it in the heating sector through heat pumps or in the transport sector through electric vehicles. Coupling other sectors of the economy with the electricity sector through direct electrification or the production of hydrogen and synthetic fuels with renewable electricity is the third pillar on which the success of the energy transition depends. Gaining traction from 2015 onwards, sector coupling presents a systemic approach to the implementation of the energy transition. The adoption of heat pumps, e-mobility and the development of a green hydrogen infrastructure is accelerated by support programmes and policies on the national level.

The energy transition: the global and European perspective

Facilitating ambitious international action has been a cornerstone of Germany's climate and energy policy. The Paris Climate Agreement testifies to the increased drive on the global level to tackle climate change as one of the greatest challenges of the 21st century. Since Germany embarked on its energy transition - "Energiewende" in German – early on, the climate- and energy-related developments in the largest European economy have been closely observed nationally and internationally. The adoption of the European Green Deal for a climate neutral European Union (EU) by 2050 and increasingly ambitious climate and energy targets in other countries lend credibility to Germany's energy transition.

With its influential "Fit for 55 package", the EU Commission presented a detailed proposal for the EU's energy and climate targets until 2030. The objectives are to reach a share of RE in final energy consumption of 40%, an efficiency improvement of 36 to39% and a reduction of GHG emissions by 55% compared to 1990.

Increased ambition for the German energy transition

Germany's climate and energy policy framework is tightly connected with political action and targets on the EU level. Germany's new Federal Government has proclaimed to further strengthen and accelerate national action on climate protection and the transformation of the energy system, with specific details currently being worked out. The implementation of the new policies will overhaul the country's energy system and ensure that until 2030 RE will cover 80% of electricity consumption and provide at least 50% of heating demand. GHG emissions will drop by 65% compared to 1990.

Sector coupling will speed up dramatically during this decade. Until 2030, the stock of all-electric passenger vehicles is expected to increase from less than 1 to 15 million cars, 4 to 6 million heat pumps need to be installed, and 10 GW of electrolysers producing 28 TWh of green hydrogen will be added to the energy system. Until the end of this decade, solar PV capacity will quadruple. At the same time, wind energy capacity will more than double. Five high-voltage transmission lines from the north to the south of Germany will be installed, and an even better integration with the European electricity grid will be ensured.

Germany's energy transition is now entering a new phase with stronger interconnections between the different energy-consuming sectors. The successful implementation of the energy transition not only offers Germany a credible path to climate neutrality by 2045, but also ensures a secure and affordable supply of energy to its citizens, businesses and industries.

Insights and policy recommendations for China

While the ultimate goals regarding energy transition and carbon neutrality in Germany and China are comparable, the starting conditions, institutional and policy frameworks are different. The main insights for China regarding the German energy transition are to strengthen the top-level policy design, prioritise and support energy efficiency and enhance market-based systems. Energy conservation and efficiency should be priority areas where better coordination and support of relevant actors can lead to significant economic and climate protection benefits. Similarly, market reforms and the utilisation of supporting measures are necessary for creating policy synergies across all relevant energy transition topics.

Introduction

The report "The German energy transition and impulses for China's carbon peaking and carbon neutrality action plans – targets, status and prospects" provides a comprehensive overview of the energy transition in Germany and valuable insights for China's own energy transformation.

Chapter 1 sets the background of this report and illustrates the necessity of the energy transition in Germany. It describes the overarching framework and objectives of the energy transition. By comparing the most relevant energy metrics of Germany and China, similarities and differences of both energy systems are presented.

Chapter 2 gives an overview of the policy framework and the overarching governance of the German energy transition. The governance system, the relevant stakeholders and their interactions are introduced, including a case study on the coal phase-out. As Germany is embedded into the EU, both the German national and EU policy dimensions of the energy transition are explained.

Chapter 3 goes into the details of the three distinct but interconnected pillars upon which the implementation of the energy transition in Germany rests: EE, RE and sector coupling. The most relevant policies, targets and achievements of each pillar are presented.

Chapter 4 provides a detailed description of the three objectives of the German energy transition: ensuring a high level of security of supply, providing an affordable energy supply and creating an energy system in line with sustainability and environmental targets. Based on suitable metrics, each of the objective's development is tracked.

Chapter 5 focuses on the future developments of the German energy system. The transformation towards a decarbonised economy is expected to speed up during the coming years. Scenarios for the medium-term until 2030 as well as for longer-term developments up to 2045 are provided.

Chapter 6 outlines the main insights and recommendations for China based on the experiences and lessons learnt from the German energy transition. Relevant examples for policy design as well as concrete measures are presented.

Figures and tables

1 Background on the energy transition

1.1 Why we need an energy transition

Climate change caused by anthropogenic GHG emissions poses systemic risks to human civilisation. In its sixth assessment report published in three parts during 2021 and 2022, the Intergovernmental Panel on Climate Change (IPCC) established a firm consensus on the science underpinning climate action.

Among the key findings of the IPCC are that climate change is already bringing changes to every region in the world, and that its impacts are already more widespread and severe than expected. Climate change and extreme weather events will put pressure on food production and access, especially for vulnerable countries and already cause substantial damage and irreversible losses to global ecosystems. Risks will escalate with higher temperatures and restricting global warming to 1.5°C demands radical action to reduce global GHG emissions by 40% as early as 2030. Current and planned fossil fuel infrastructure will make a 1.5°C future almost impossible, according to the IPCC. Mitigation efforts necessitate a swift transition to low-carbon energy systems, leaving fossil fuels in the ground and related infrastructure potentially stranded[1]. Fossil fuel resources are non-renewable on human timescales and thus subject to depletion. Coal, oil and gas are also unevenly distributed across the globe. These two facts need to be reflected in strategies for long-term energy security.

Based on scientific understanding of climate change and finite fossil fuels, the EU and Germany are on the way to largely decarbonise their economies by 2050. RE will become the mainstay of energy supply systems. For Germany specifically, the energy transition is a strategic and decade-long strategy towards a secure, environmentally friendly and economically successful future. The benefits are threefold. Firstly, by using energy more efficiently and phasing-out the utilisation of fossil fuels, Germany wants to make a significant contribution to mitigate climate change and rising global temperatures. Secondly, Germany views the transition towards a decarbonised economy and society as a unique business opportunity. The energy transition can be a key driver of modernising industrial society by developing new business areas, stimulating innovation and creating economic growth and employment. As a third benefit – especially relevant in the face of Russia's war of aggression against Ukraine – the energy transition will enable Germany to be less reliant on importing coal, oil and natural gas. Increasing domestic RE generation will reduce expenditures for fossil fuel purchases and increase security of supply[2].

The energy transition as a long-term strategy can thus provide economic, environmental and societal benefits for Germany, the EU as well as globally.

1.2 The German energy transition in a nutshell

The energy transition – "Energiewende" in German – describes the transformation of energy systems based on fossil fuels such as coal, natural gas and oil as well as nuclear power to sustainable and renewable sources of energy. Wind, solar radiation, hydro power, geothermal energy and renewable raw materials such as biomass are used as energy sources to supply electricity, heating and cooling as well as fuel for transportation to a much more energy-efficient economy and society. The energy transition in Germany is best understood as a long-term strategy which transforms not only the energy system, but the entire way the economy and society function.

Energy transition policy architecture

The energy transition in Germany is integrated into the EU energy and climate strategy as well as global developments. The EU has set itself the target to become the first climate

1 IPCC, 2022, IPCC Reports

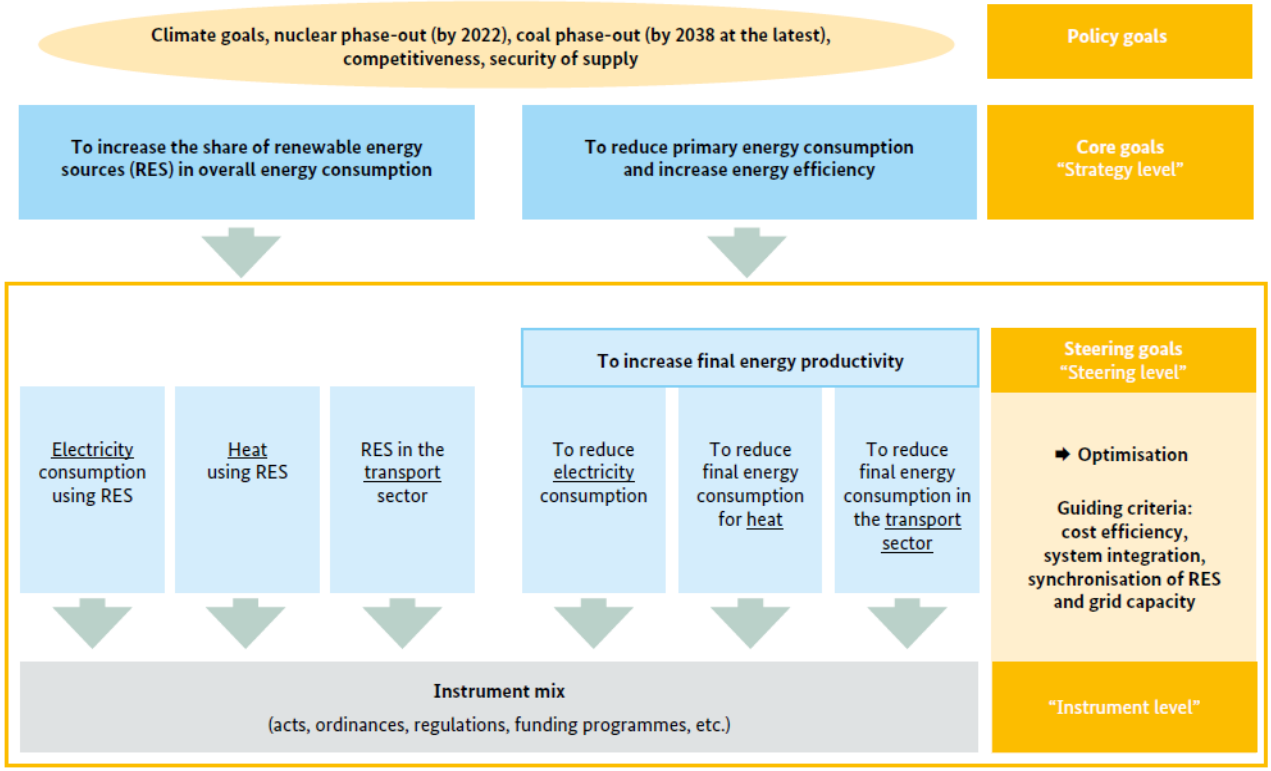
2 BMWi, 2015, Making a success of the energy transition

neutral group of countries by 2050. In line with the Paris Climate Agreement, the European Commission has put forward a series of strategies, targets and policy proposals in the 2030 Climate and Energy Framework. These have been updated by the European Green Deal and aim to achieve a reduction of GHG emissions of at least 55% by 2030 compared to 1990. Important policy areas at the EU level are the EU climate legislation, the integration of energy markets, the EU Emission Trading System as well as laws on EE, transport and land use.

As a Member State of the EU, Germany is bound to the targets and related laws of the EU and contributes significantly to the energy transition on the European level. Germany is currently pursuing national energy and climate targets that go beyond those of the EU. The transition follows a target architecture that sets out a framework for action at the political, strategic, control and measure levels. The target architecture is based on the Federal Government's Energy Concept from 2010, laws passed by the German Bundestag and requirements of the EU (Figure 1).

The energy transition in Germany combines three main objectives: ensuring a high level of security of supply, cost-effectiveness and environmental protection. Restructuring of the energy supply away from fossil fuels towards RE sources must take into account security of supply and a reliable provision of energy services. The affordability of energy for citizens and businesses as well as the overall competitiveness of the economy is paramount for the energy transition's success. At the same time, the implementation of the energy transition has to be conducted in an environmentally sound way and allow Germany to reach its climate and sustainability targets.

The pillars of the German energy transition are energy efficiency, renewable energy and sector coupling. On the strategic level, the energy transition comprises the core goals of the reduction of primary energy consumption, the increase of EE, the growth of RE in energy consumption and advancing sector coupling technologies and applications. The targets are further defined and laid out in detailed strategies, laws, regulations or support programmes to achieve the core goals.



Source: In-house data from the BMWi

Figure 1: Target architecture of the German Energy Concep[3]

3 BMWi, 2021a, The Energy of the Future: 8th Monitoring Report on the Energy Transition - Reporting Years 2018 and 2019

The most important areas of action are the electricity, the heating and the transport sectors. To increase EE and productivity, the reduction of primary energy consumption, energy use for heat generation and energy use in transport are important metrics. The progress of RE is measured by their share in the electricity, heating and transport sectors. In the area of sector coupling, specific targets for the expansion and use of sector-coupling technologies are in place.

Energy transition targets and monitoring

Since the beginning of the energy transition in the early 2000s, Germany has put forward a variety of energy-related indicators as well as qualitative and quantitative targets. With the adoption of the Energy Concept in 2010, the energy transition is subject to a coherent and continuous monitoring process to provide timely updates about the progress and achievability of targets as well as the implementation of instruments and measures.

At the heart of the monitoring process is the annual monitoring report, which provides an overview and evaluation of the progress made. Furthermore, it gives an outlook on the foreseeable development of important energy transition indicators. The Federal Ministry for Economic Affairs and Climate Action (BMWK) – known as Federal Ministry for Economic Affairs and Energy (BMWi) until October 2021 – is responsible for its preparation. The report's writing process is accompanied by a commission of four independent and distinguished energy experts. The final report is submitted to the Bundestag (Germany's national parliament) and the Bundesrat (Germany's federal council). The independent commission of energy experts prepares an additional statement report assessing the overall progress and the state of the energy transition in Germany.

More than 70 indicators reflect progress on quantitative and qualitative targets and the implementation of the energy transition in general (Annex 1). The evaluation of the indicators is based on official and publicly accessible data. A point system is used to evaluate the gap between target and actual values. Qualitative targets are assessed based on a variety of indicators. The latest monitoring report was released in summer 2021 and contains a summary of the targets[4]. In their latest report from 2021, the independent experts evaluated 21 indicators: eight of the indicators were on track, six were partially on track, and seven indicators were not on track[5]. Table 1 shows the overarching qualitative targets and policy areas of the energy transition.

Table 1: Targets and policies affecting the energy transition

Security of supply	To cover the energy demand in Germany efficiently at all times.
Nuclear energy phase-out	To shut down the last nuclear power plants at the end of 2022.
Coal phase-out	To phase out coal-fired electricity generation in Germany by 2038 at the latest in a socially balanced, predictable and economically viable manner.
Affordability and competitiveness	To maintain the affordability of energy and to ensure Germany's competitiveness.
Environmental compatibility	To make the energy supply compatible with the environment, the climate and the nature throughout the entire life cycle.
Grid expansion	To expand and modernise grids to meet demand.
Sector coupling and digitalisation	To unlock the potential of efficient sector coupling and digitalisation for a successful energy transition.
Research and innovation	To foster forward-looking innovations for the transformation of the energy supply.
Investment, growth and employment	To foster forward-looking innovations for the transformation of the energy supply.

The most important high-level quantitative targets for 2020 as well as for 2030 and beyond are depicted in Figure 2, along with the achievements until 2021. In addition to the targets below, the parties of the new Federal Government updated some targets for the year 2030 in their Coalition Agreement[6][7],

4 BMWi, 2021a, The Energy of the Future: 8th Monitoring Report on the Energy Transition - Reporting Years 2018 and 2019

5 Löschel, Grimm, Lenz, & Staiss, 2021, Stellungnahme zum achten Monitoring-Bericht der Bundesregierung für die Berichtsjahre 2018 und 2019. Expertenkommission zum Monitoring-Prozess "Energie der Zukunft"

6 The parties forming a government coalition in Germany usually publish a coalition contract that includes objectives and goals they have agreed on for their future government work. A coalition contract is a political Memorandum of Understanding and provides the public with an outline of vision and plan of a new government.

7 BMWK, 2022a, Germany's current climate action status

such as increasing the share of climate-neutral heat supply to 50%, achieving a registration of 15 million fully electric passenger cars and installing an electrolyser capacity of 10 GW to produce green hydrogen. A detailed overview of the most important energy transition targets can be found in Annex 2.

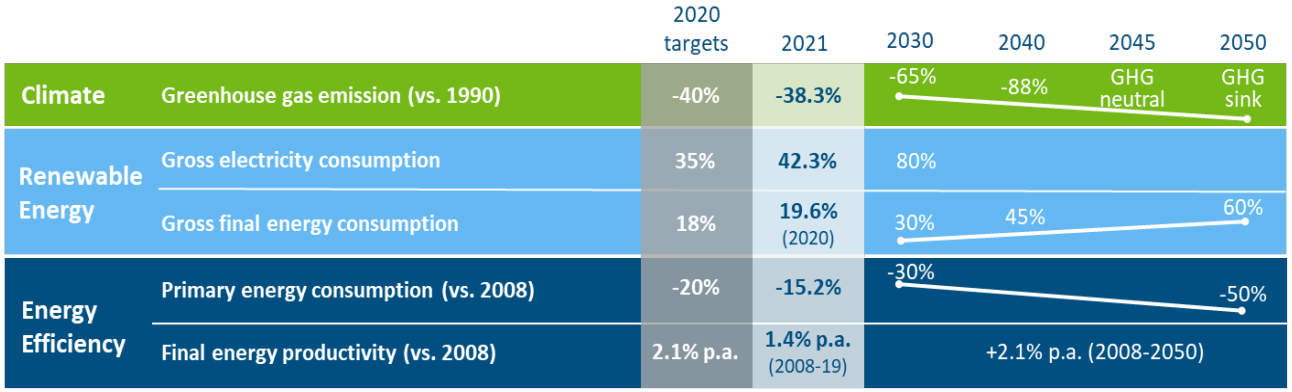


Figure 2: High-level quantitative energy transition targets and achievements of Germany , adapted by author

1.3 Comparison of German and Chinese energy statistics

A comparison of the most relevant energy system and consumption metrics of Germany and China sheds light on similarities and differences between the two countries (Table 2, Table 3, Table 4 and Figure 3). Data for consumption and generation is from Our World in Data[9] while generation capacity is from AGEB[10] and the Chinese Electricity Council[11]. As data comes from different sources as indicated, it could partially deviate from other data sets.

Primary energy and electricity consumption

In 1990, China's primary energy consumption was twice as large as Germany's. Due to economic development, primary energy consumption underwent further rapid growth in China. In contrast, primary energy consumption has steadily declined in Germany since the 1990s. While the absolute numbers show a big difference due to the much larger population of China, primary energy consumption per capita of both countries is slowly converging. China's electricity consumption and generation have been rising dramatically during the past decades. The generation of electricity in Germany has remained stable. German per capita electricity generation has been relatively constant for the past 30 years, whereas China's has increased rapidly and approaches Germany's.

The main drivers for the observed trends in Germany are increasing EE, the declining share of coal power in the electricity mix and a larger focus on the service sector instead of heavy industry. In China, the dominant use of coal for electricity generation as well as strong economic growth have led to the increases, especially since 2000.

Energy and carbon intensity

Two other important energy and climate metrics are energy intensity and carbon intensity per unit of energy. Energy intensity is measured as primary energy consumption per unit of gross domestic product (GDP). The lower the indicator, the more economic value one unit of energy provides to the economy of a country. Carbon intensity of energy production relates to the quantity of CO2 being emitted per unit of energy production. The lower the metric, the more climate-friendly and less CO2-intensive the energy system of a country. For both Germany and China, carbon intensity per unit of energy has been on a long-term downward trend due to an increase in renewable electricity in the generation mix, greater EE and a structural change of the economy.

8 BMWK, 2022b, International communication of the German energy transition

9 Our World in Data, 2022, Energy

10 AGEB, 2022, AG Energiebilanzen

11 CEC, 2022, China Electricity Council

Table 2: Energy consumption and intensity metrics of Germany and China

		1990	2005	2020
Primary energy consumption (TWh)	Germany	4180	3940	3360
	China	7970	21000	40400
Primary energy consumption per capita (kWh)	Germany	52870	48220	40150
	China	6770	15780	28070
Electricity generation (TWh)	Germany	547	613	565
	China	621	2500	7727
Electricity generation per capita (kWh)	Germany	6920	7520	6740
	China	530	1880	5379
Energy intensity of primary energy consumption per unit GDP (kWh/ 2011$ PPP)	Germany	2.07	1.32	0.96*
	China	2.35	2.44	2.10*
Carbon intensity of energy production (kgCO2/kWh)	Germany	0.25	0.22	0.19
	China	0.31	0.28	0.26
* Numbers for the year 2018				

Share of energy sources

The main difference between the Chinese and the German energy systems lies in the relative shares of key energy sources in the two countries. Primary energy consumption in Germany has a higher share of oil and gas than in China, which is still dominated by coal.

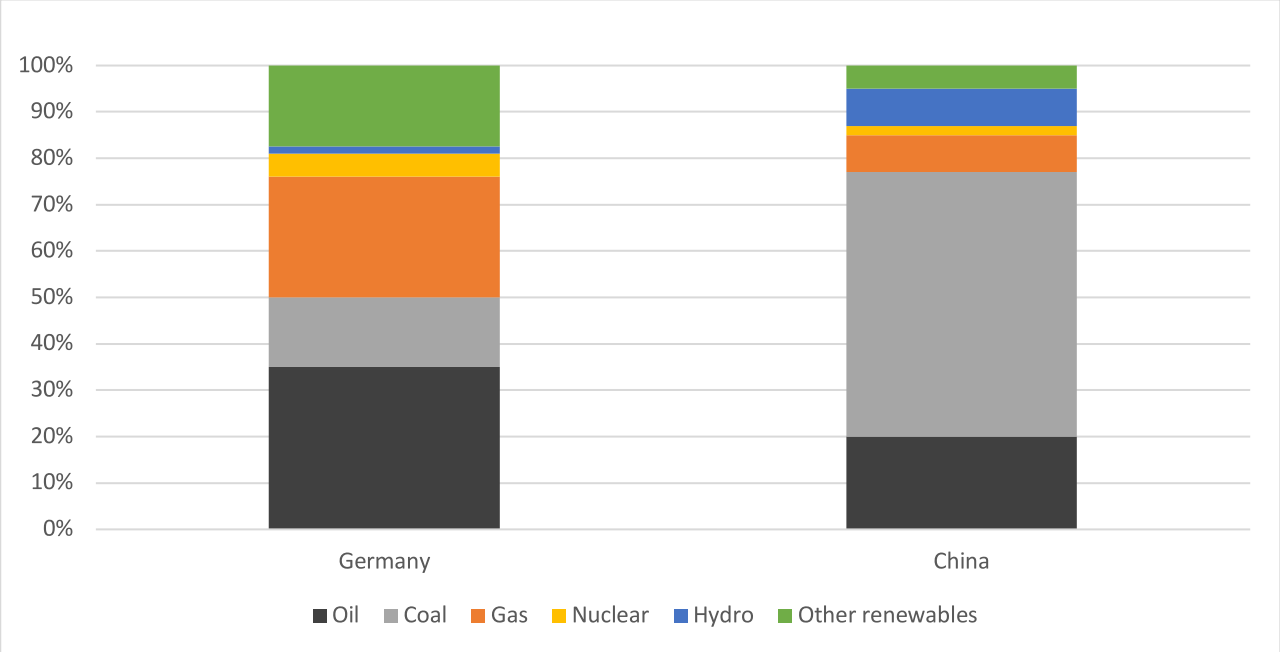


Figure 3: Share of energy sources in primary energy consumption in Germany and China in 2020

In the electricity sector, the difference between the two countries becomes evident as well. In China's electricity mix, coal still has a share of about 65%, with hydropower being the next largest source. Electricity production from other RE such as wind and solar in China is growing but has a lower share in the electricity mix compared to Germany.

Table 3: Share of energy sources in primary energy consumption and in electricity generation in Germany and China

	Share in primary energy consumption in %				Share in electricity generation in %			
	Germany		China		Germany		China	
	2000	2020	2000	2020	2000	2020	2000	2020
Oil	40	35	23	20	3	3,5	3,5	0
Coal	25	15	70	57	52	23.5	78	60.7
Gas	21	26	2	8	9	17	0,5	3
Nuclear	12	5	0	2	30	11.5	1.5	5
Hydro	1.5	1.5	5	8	4	3.5	16.5	17.7
Other RE	0.5	17.5	0	5	2	41	0	13.6

The electricity generation capacity in Germany grew from 120 GW to more than 230 GW during the past two decades, while China's has increased sevenfold at the same time: from less than 300 GW to more than 2000 GW. RE made up more than half of the German installed capacity in 2020, while coal-fired power plants are the dominant generation technology in China.

Table 4: Electricity generation capacity in Germany and China (data from BMWK and China Electricity Council)

	Generating capacity in GW					
	Germany			China		
	2000	2010	2020	2000	2010	2020
Oil	8	6	5	10	5	1
Coal	54	53	45	200	652	1080
Gas	23	24	32	2	9	100
Nuclear	24	22	8	2	11	50
Hydro	9	10	14	61	216	370
Other RE	7	50	127	0	31	536
Total (incl. others)	125	165	232	275	924	2202

With a lower share of coal in both primary energy consumption and electricity production as well as a lower reliance on heavy industry, Germany's energy system is less energy- and carbon-intensive compared to China's. A declining share of fossil fuels in primary energy and electricity consumption can be observed in both countries. The Chinese energy system is roughly ten times the size of the German system, however per-capita emissions of both countries are converging. The numbers for Germany show that lowering the share of coal can be achieved by the expansion of RE. Consequently, energy and carbon intensity as well as primary energy consumption can be reduced.

2 Guiding the energy transition: policy framework and governance

2.1 The EU dimension

Policy framework on energy transition and climate in the EU

A European-wide policy framework is necessary for a successful energy transition and decarbonisation of the EU. Since the late 1990s and the adoption of the Kyoto Protocol, EU energy policy has shifted towards decarbonisation and climate protection. Figure 4 presents a timeline of the major EU programmes and frameworks along with their respective targets from 1997 to 2018[12]. It demonstrates how ambitions to decarbonise the EU economy and to progress on the transition towards RE have grown during the years.

Starting from 2007, the EU took a comprehensive and integrated approach towards achieving its climate and energy goals. The Climate and Energy Package introduced major energy and climate-related regulations at the EU level and placed the EU Emission Trading System (EU ETS) at the core of the EU's climate policy. The EU ETS covers approximately 40% of total EU emissions and includes large-scale facilities from the energy and industrial sectors.

The Effort Sharing Decision[14] formulated national emission reduction targets for the sectors not covered by the EU ETS. These non-ETS sectors are small industry and businesses, housing, agriculture, waste and transport. Those targets varied according to national wealth, where the richest countries had to cut emissions, while the least wealthy ones were even allowed to increase their emissions. The progress of the national emission reduction under those effort-sharing sectors is monitored annually by the EU commission.

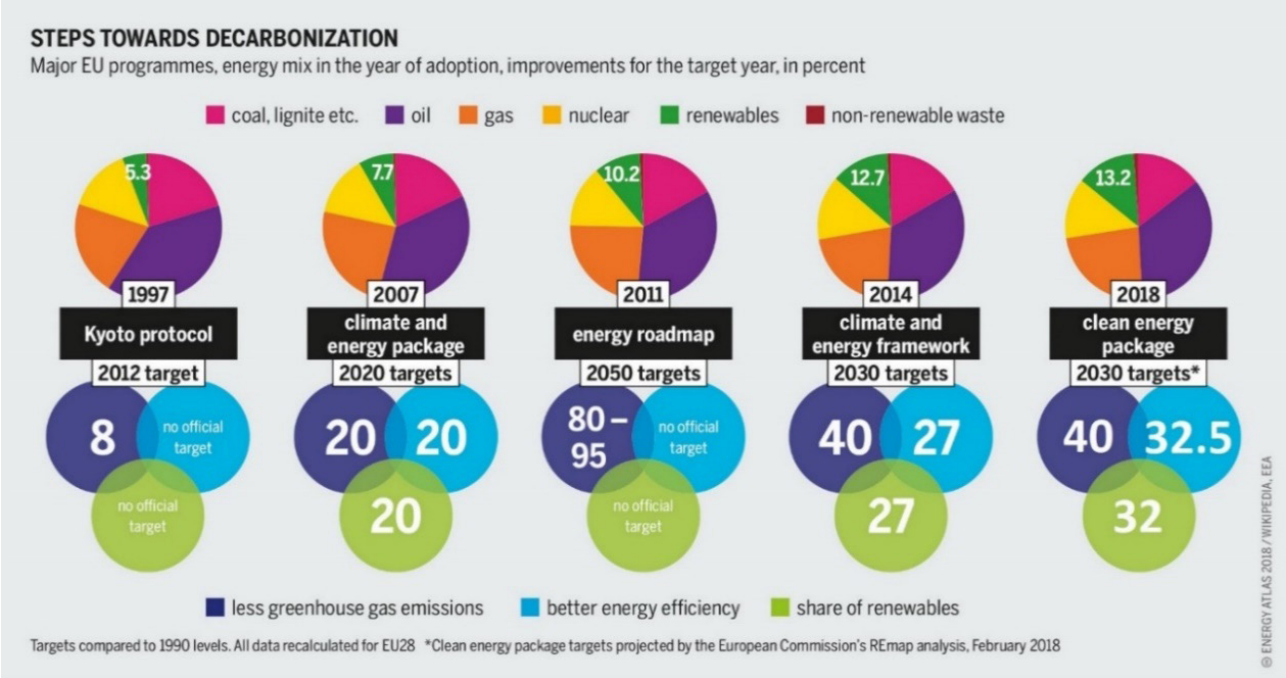


Figure 4: Major energy and climate programmes, frameworks and targets until 2018 at EU level[13], adapted by author

12 Heinrich Böll Foundation, 2018, Energy Transition

13 Heinrich Böll Foundation, 2018, Energy Transition

14 The Effort Sharing Decision is an EU law that set national emission targets for 2020 expressed as percentage changes from 2005 levels. The Effort Sharing Regulation updated the Effort Sharing Decision and sets binding yearly emission reductions for the Member States from 2021 to 2030.

National targets for RE have also been part of the Climate and Energy Package through its legislative execution in the Renewable Energy Directive. The Member States' targets varied to account for different starting points for RE generation and the ability to increase it (RE targets ranged from 10% for Malta to 49% for Sweden). Taken together, the individual national RE targets amount to a 20% RE share for the entire EU –doubling the share of 2010 – and a 10% share in the transport sector until 2020.

A follow-up on the EE targets of the Climate and Energy Package came with the Energy Efficiency Directive in 2012. It covers a set of binding measures for the Member States to reach the 2020 EU target of reducing primary energy consumption by 20% compared to the reference scenario projections for 2020. Member States had to establish National Energy Efficiency Action Plans (compare Chapter 3.1) in which they report estimated energy consumption, planned EE measures, long-term renovation strategies and the improvements that they expect to achieve. The plans must be updated every three years, and progress must be reported annually to the EU commission.

The European Green Deal and the "Fit for 55 package" – increased ambitions

After the targets of the Paris Climate Agreement had been set on the international level, the EU Council and the EU Commission published and adopted the European Green Deal as the core EU energy and climate strategy in December 2019. It sets the EU on the path to a more ambitious green transition and consists of several policy initiatives. The European Green Deal supports the transformation of the EU towards climate neutrality by 2050 and covers topics ranging from climate, the environment, energy, transport, industry, agriculture to sustainable finance. The energy and climate targets have been revised upwards to reflect increased ambitions at the EU level (Table 5).

Table 5: Current energy and climate targets of the EU according to the European Green Deal

Reduce the GHG emissions by at least 55% by 2030 compared to 1990.
Increase the share of RE to at least 40% in energy consumption by 2030.
Improve the EE by 36 to 39% (with a possible upwards revision by 2023).
Carbon neutrality (net-zero GHG emissions) for the entire EU by 2050.

To implement the European Green Deal and to achieve the new targets, the EU Commission proposed a variety of updates to energy and climate regulations in July 2021. The "Fit for 55 package" revises climate, energy and transport-related regulations to align them with the new ambitions for 2030 and 2050. It is a comprehensive and interconnected set of new and updates to existing regulations. Its details are currently being negotiated at the EU level.

Amongst others, the EU ETS, the Effort Sharing Regulation, the Renewable Energy Directive, the Energy Efficiency Directive and the Energy Taxation Directive are updated and strengthened. New policies such as the Carbon Border Adjustment Mechanism are being implemented as well. Within the "Fit for 55 package", the targets of the European Green Deal are integrated into legislative texts. The EU Commission increased the nationally binding annual GHG emission reduction targets for non-ETS sectors from 29% to 40% compared to 2005. It set a target of 100% emission reduction for new cars and vans for 2035 while also introducing a Climate Social Fund to address the social and distributional impact of CO2-prices in the planned EU ETS for road transport and buildings (European Council, 2022).

Compliance mechanism for National Energy and Climate Plans at EU level

To meet the EU's energy and climate targets for 2030, EU countries had to establish a ten-year integrated National Energy and Climate Plan (NECP) for the period from 2021 to 2030. The NECPs outline how each Member State addresses EE, RE, GHG emission reduction, electricity and gas grid interconnections, research and innovation. The NECPs allow for cross-country comparison due to their consistent reporting structure. To better develop and implement the plans, the EU countries were required to consult citizens, businesses and local authorities in drafting and finalising the NECPs. Member States were also required to submit national long-term strategies for 2050 by the start of 2020.

Under the Governance Regulation of the EU, each Member State had to submit their draft NECP for the period 2021 to 2030 by the end of 2018. The EU Commission analysed the NECPs and published an overall assessment as well as country-specific recommendations in 2019. The final NECPs, which should take the recommendations into account, had to be submitted by the end of 2019. In September 2020, the EU Commission published a detailed EU-wide assessment of the final NECPs as well as assessments of the individual

national plans. The EU Commission will monitor progress of the entire EU towards achieving its targets in annual reports. Member States must submit progress reports every two years.

In case NECPs lacked ambition or if Member States do not make sufficient progress towards the EU's energy and climate objectives, the EU Commission issues recommendations to the respective Member States. Member States concerned shall take the recommendation into account in the following progress report. As the recommendations are made public, all other Member States are informed about the shortcomings of the individual Member State's NECPs with respect to the EU-wide climate and energy targets and full transparency is achieved.

Reality check of the EU energy and climate targets

The Climate and Energy Package from 2007 formulated key targets for 2020 (compare Figure 4). The European Environment Agency published its assessment of those targets in October 2021 (compare Annex 3). The EU-27 GHG emissions in 2020 were 31% below 1990 levels – overachieving the target of 20%. The target of a 20% reduction in energy consumption compared to the reference scenario projections seemed unattainable for many years. However, the COVID-19 pandemic has reduced the EU's 2020 energy consumption below target levels – to 17% less primary and 10% less final energy consumption compared to 2005. The share of RE in gross final energy consumption rose above 21%, slightly overachieving the targeted 20%. With the end of COVID-19 restrictions, an increase in energy consumption took place in 2021. While all three 2020 targets have been achieved, additional measures are required to get on track for most of the 2030 targets (European Environment Agency, 2021).

2.2 German energy and climate policy

German energy transition milestones and strategies

The aim of the energy transition – as Germany's most important economic and environmental policy undertaking – is to restructure the energy supply from being based on fossil and nuclear sources towards RE. High-level objectives of the energy transition (compare Table 1) are the GHG reduction targets and to phase-out nuclear and coal-fired electricity generation while ensuring energy security and maintaining the international competitiveness of the economy.

The energy transition in Germany is embedded in the international consensus on climate change mitigation. As a Member State of the EU, Germany must comply with the EU's regulations and targets on energy and climate described above. Germany's national emissions reduction and renewable targets have been more progressive than the overall targets of the EU. Important milestones of Germany's energy transition as well as their integration into global developments are depicted in Figure 5.

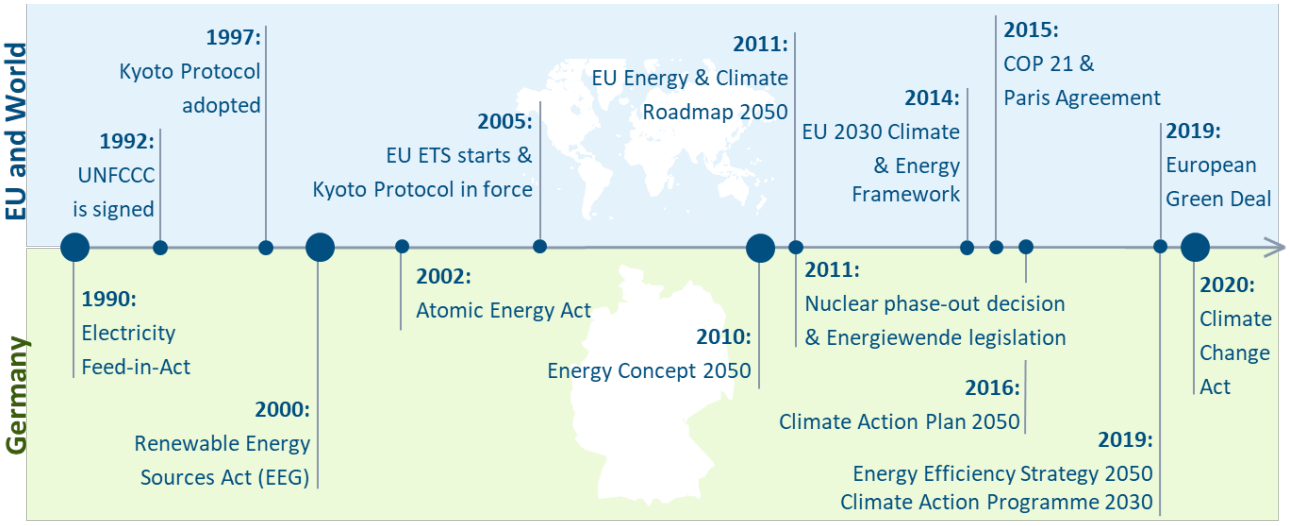


Figure 5: Milestones of the global and the German energy transition[15], adapted by author

15 BMWK, 2022b, International communication of the German energy transition

While RE were supported by the Renewable Energy Sources Act (EEG) already from the year 2000, the Energy Concept from 2010 provided the first comprehensive architectural structure for the German energy transition. It set medium- and long-term goals and paved the way for more specific strategies and plans for EE, RE, climate protection and sector coupling. The Energy Efficiency Strategy 2050 published in 2019 updated the guidelines on EE of the Energy Concept (BMWi, 2019a). Strategies and policies on climate protection complement the energy transition policy framework (see below).

Many laws and ordinances with detailed regulations exist, ranging from electric mobility and grid expansion over labelling requirements for energy consumption of products to emission trading systems and are depicted in the legislative overview in Annex 4.

Making sure emissions go down: Germany's compliance mechanisms for climate targets

The Climate Action Plan 2050 represents the overarching sectoral strategy for reducing GHG emissions and ushered in a focus on sector coupling. It defines Germany's climate targets in detail, including the 2030 targets [16] for individual sectors (energy, industry, buildings, transport, agriculture and land use and forestry). The plan also describes the necessary development pathways, lists initial measures for implementation and establishes a process for monitoring and updating measures at the national level. For each sector, areas of action, targets and measures are proposed.

The Climate Action Plan 2050 will be reviewed and updated every five years, serving the Paris Agreement's objective of progressively raising the ambition of national climate policies. The first update did not start yet, but the Federal Government published its Climate Protection Programme 2023 including measures to reach the German and the new EU climate targets proposed by the European Commission.

To operationalise the Climate Action Plan 2050, legally binding climate targets and emission allocations for the different sectors had to be adopted. Therefore, the German Government defined measures in the Climate Action Programme 2030. The Climate Change Act anchored the target of GHG neutrality in German law for the first time. It set legally binding annual reduction targets and emission budgets for all sectors from 2020 to 2030. An annual monitoring and compliance mechanism ensures that targets are met (Table 6). Every two years, the independent Council of Experts on Climate Change presents a report in which it proposes measures and trends.

Table 6: Monitoring and compliance mechanisms of the Climate Change Act

1. The Federal Environment Agency publishes the emissions data of the previous year by mid-March of each year.
2. The Council of Experts on Climate Change assesses the emissions data within one month.
3. In case emission budgets are exceeded in one or several sectors, the respective ministries are required to initiate an immediate action programme within 3 months, including targeted measures to ensure that annual emission budgets in the following years are met.
4. The Council of Experts on Climate Change reviews the individual measures of the immediate action programme.
5. The Federal Government deliberates and decides on the measures to be taken under the immediate action programme.
6. The Federal Government informs the German parliament about the measures, which discusses or adopts any resulting laws or amendments to laws.

In 2021, the German Government had to amend the Climate Change Act due to a ruling of the Federal Constitutional Court. The ruling obliged the Federal Government to take more immediate action and to raise its climate protection ambitions in line with EU plans and regulations. The amendment brought the timeline for climate neutrality forward to 2045. Figure 6 clarifies the updated GHG emission reduction targets of Germany.

16 It is called Climate Action Plan 2050, because it is the plan/strategy for achieving Germany's climate targets until 2050. But it formulates also targets for 2030, because it doesn't make sense to just make targets for 2050 without intermediary targets.

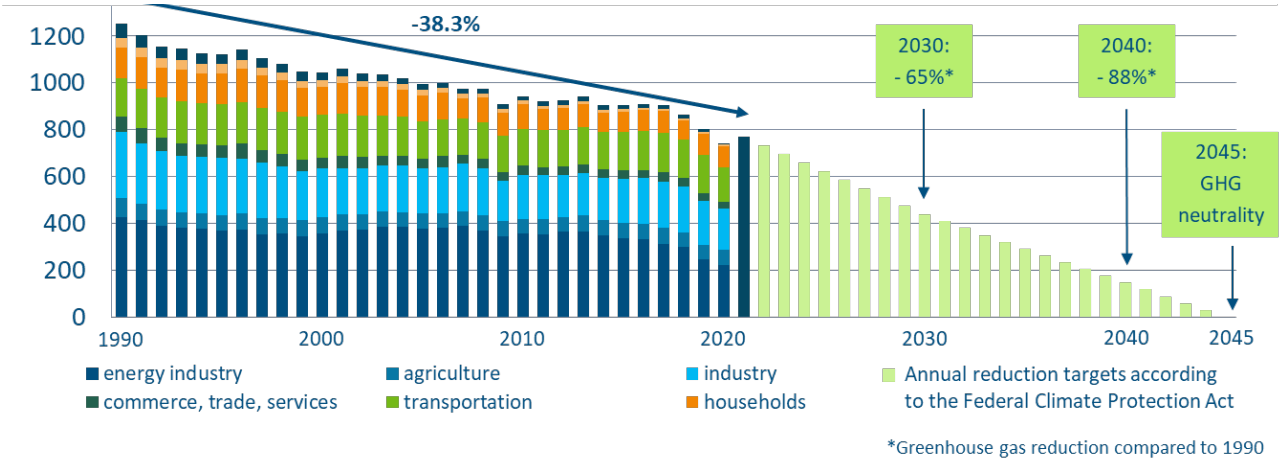


Figure 6: German GHG emission development and target[17]

2.3 Governance and stakeholders of the German energy transition

Politically and strategically, the energy transition is a nationwide project. Its development and implementation are not only driven by political decisions at the federal level but by society as a whole. Various stakeholders are therefore involved: starting from the EU and the German federal states to the private sector, including energy companies and business associations, over research institutes to civil society groups, NGOs and the citizens.

The governance of the energy transition

EU regulations play a decisive role in shaping Germany's overall energy and climate policy. On the national level, the Federal Government is responsible for most of the energy and climate legislation. The Federal Government also has a coordinating function, considering both EU regulations and the demands and suggestions of the federal states, as shown in the high-level governance structure of the energy transition in Figure 7. Drafting the respective laws as well as coordinating the dialogue between relevant stakeholders is primarily the task of the Federal Ministry for Economic Affairs and Climate Action (BMWK)[18].

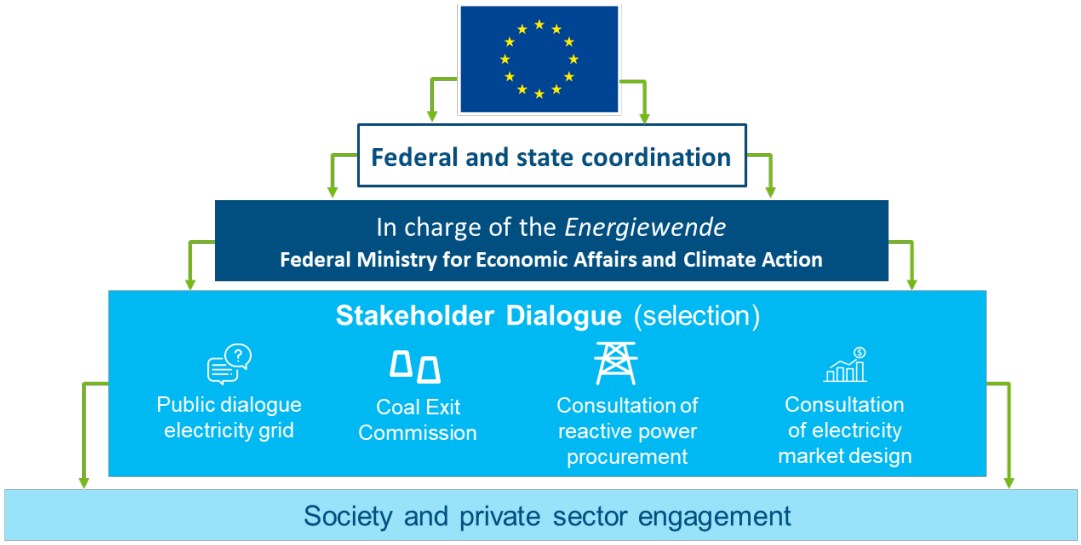


Figure 7: Governance structure of the energy transition in Germany[19], adapted by author

17 BMWK, 2022b, International communication of the German energy transition

18 The BMWK was known as Federal Ministry for Economic Affairs and Energy (BMWi) until October 2021.

19 BMWK, 2022b, International communication of the German energy transition

The BWMK is in constant exchange with the German federal states, businesses, industry and research institutes through high-level dialogue platforms and stakeholder processes (Table 7). Such stakeholder dialogues not only help to find a common consensus on certain topics, but also ensure ownership and transparency of the energy transition for all stakeholders. They play an important role in the governance of the German energy transition. Regular consultations allow citizens and the private sector to comment on governmental strategies and to actively participate in the decision-making process. The consultations are commonly conducted via pre-formulated guiding questions on which the public is invited to comment.

Table 7: Selected stakeholder processes

Stakeholder process	Main task and achievements
Public dialogue on electricity grids	This initiative provides a platform for dialogue on general issues related to the planned grid expansion in Germany, to inform the public and to increase acceptance for grid expansion. It has ten citizen offices in Germany and a mobile office, organises various local information and dialogue formats; provides an online information and participation portal; organises regional networks with local stakeholders and does press relations work.
Coal Exit Commission	Germany's Commission on Growth, Structural Change and Employment ("Coal Exit Commission") was established by the Federal Government in 2018. It included a wide range of stakeholders and who were tasked to find consensus on the coal phase-out and to promote a just transition (see detailed case study below).
Consultation of reactive power procurement	In October 2019, the European Commission presented its final report on the procurement of reactive power. Previously, the BMWi conducted a consultation process to allow the expert audience, associations, companies, organisations and institutions formulate their remarks. The comments received have been evaluated and incorporated into the decision-making processes.
Consultation of electricity market design	The BMWi has conducted a broad consultation on the electricity market of the future in 2014 and 2015. Focus was on the question of which electricity market design can guarantee a secure, cost-effective and environmentally compatible supply of electricity, even with a high share of RE.

The role of other ministries and governmental agencies

Other ministries involved in energy transition legislation are the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), the Federal Ministry for Digital and Transport (BMDV) and the Federal Ministry for Housing, Urban Development and Building (BMWSB). The BMUV is responsible for nature and for climate protection and adaptation policies in some sectors, the BMDV for the energy transition in transport and for digital infrastructures and the BMWSB drafts energy and climate legislation for city development and housing. Consultations between all federal ministries affected by new or updated laws take place regularly and sometimes result in revisions of proposed legislation.

A wide range of governmental agencies are involved in supporting the energy transition. Each agency works for a specific ministry by conducting research, providing quantitative and qualitative data, giving policy advice and making sure laws and support programmes are being implemented and adhered to. For the energy transition and climate protection, the most important of those authorities are the Federal Network Agency (BNetzA), the Federal Office for Economic Affairs and Export Control (BaFa) and the Federal Environment Agency (UBA).

The BNetzA is an independent federal agency subordinated to the BMWK. Its prime task is to foster competition in the fields of network infrastructures by regulating these sectors and by ensuring that access to the networks is granted in a non-discriminatory way. The BNetzA is granted a high level of independence with tasks regarding the removal of obstacles that impede access to the energy supply networks for suppliers and consumers, the standardisation of the relevant processes for switching energy suppliers and the improvement of conditions under which new power plants are connected to the grid. It is also responsible for executing RE and coal phase-out auctions and oversees national high-

voltage and gas grid development and expansion plans. The BNetzA also approves network fees for the transmission of electricity and gas under the guidance of policies set by the government. With a ruling of the European Court of Justice at the end of 2021, the German Government must provide the BNetzA with greater independence, especially in relation to setting network fees without political guidance or interference. The process to implement a higher level of independence for BNetzA concerning network fees is currently ongoing.

The BaFa is a federal agency subordinated to the BMWK and responsible for a variety of tasks aimed at promoting the efficient and economical use of energy and the further expansion of RE, specifically in the building and heating sector. The BaFa processes a wide range of support programmes on EE and gives out grants for the purchase of electric vehicles or heat pumps.

The UBA is subordinated to the BMUV. It calculates and provides emission data to support the government's energy and climate plans and targets. In addition, it executes a wide range of research on energy, nature protection and climate. The German Emission Trading Authority (DEHSt) is part of the UBA. It is responsible for organising and monitoring the EU ETS as well as the national emission trading scheme.

The Coal Exit Commission: A case study of successful energy transition governance

The necessity to phase out coal power as part of Germany's energy transition and climate goals was a controversial topic, especially in federal states that would be directly impacted by this measure. Therefore, the Federal Government established the Commission on Growth, Structural Change and Employment (Coal Exit Commission) in June 2018. A wide range of different stakeholders including representatives from the Federal Government and the German parliament, the impacted federal states, local authorities of coal-mining regions, trade unions, environmental NGOs and research institutes was assembled to find an overarching consensus on the phase-out (Clean Energy Wire, 2018). The Coal Exit Commission consisted of up to 31 individuals tasked with developing detailed plans for managing the coal phase-out's technical, legal, economic and social impacts (Table 8).

Table 8: Tasks of the Coal Exit Commission

Development of transition plans and concrete prospects for the economic future of the lignite-mining regions in Germany.
Identification of strategies to reconcile climate action with economic stability.
Agreement on a roadmap and a deadline for the end of coal-fired electricity generation in line with the Climate Action Plan and Germany's international commitments under the Paris Climate Agreement.
Proposing measures to ensure that Germany meets its 2030 climate targets by reducing emissions from the energy sector by 61 to 62% compared to 1990 levels.
Recommendations on how to meet Germany's 2020 climate targets.

After six months, the Coal Exit Commission adopted a report in early 2019. Many studies on the effects of the coal phase-out on the energy system, the climate targets and social compatibility – written by independent research institutes, consultancies and NGOs – aided during the decision-making process. The most important results of the Coal Exit Commission were the following:

- formulation of an end for coal-fired electricity generation in Germany by 2038 latest, with intermediary phase-out steps defined for 2022 and 2030;
- support for federal states with coal regions worth 40 billion EUR provided by the Federal Government, targeted at supporting the structural transition for investments into science and education, diversification of the local economy, transport infrastructure and the local energy transition;
- compensation measures to keep electricity prices low and to ensure that the costs of the phase-out are not passed on to consumers;
- compensation payments to coal power plant operators.

Many of the results of the Coal Exit Commission have been transferred into laws at the federal level in 2019 and 2020. More detailed programmes on financing the economic restructuring in the respective coal regions as well as an auctioning process to determine the compensation payments to coal power plant operators have since been implemented.

With its clear mandate, objectives and independence, the Coal Exit Commission was able to arrive at balanced and societally accepted results. It simultaneously aligned national and international climate targets with concrete actions. The multi-stakeholder negotiation helped to gather diverging and polarised interests surrounding coal power under one process and achieved acceptable compromises for all relevant parties[20].

20 WRI, 2021, Germany's "Coal Commission": Guiding an Inclusive Coal Phase-Out

3 Implementing the energy transition: the three pillars

The energy transition in Germany is built upon three pillars: energy efficiency, renewable energy and sector coupling. While each pillar has a different focus, they are closely intertwined in their efforts to reach energy and climate targets. Progress in one pillar facilitates the realisation of targets addressed in the other pillars as well.

EE and RE are both important for Germany to achieve its emission reduction goals. EE contributes directly to emission reduction by decreasing the amount of fossil fuels required in heating, transport or electricity generation. Additional benefits of increased EE in an energy system dominated by RE arise through less need for limited fossil and material resources, required land area for RE installations and hydrogen or other synthetic fuels. EE thus also helps to minimise the cost of energy supply[21].

Sector coupling entails the coupling of different sectors such as heating, transport or industry with the energy sector. Through electrification, large gains in efficiency can be leveraged across the sectors, especially regarding lowering primary and final energy demand. When RE form the backbone of the energy and electricity sector, carbon-free energy carriers can be utilised in other sectors as well, enabling a climate-neutral economy.

3.1 Making more with less: energy efficiency as key for the energy transition

Policy framework for energy efficiency

An in-depth report on the German EE policy commissioned by GIZ China is the basis for this chapter[22]. Within the European energy transition and climate policy framework, EE plays an important role. The national framework on EE in Germany complements and implements the EU-level strategies and policies (Figure 8). While changes in the electricity generation system from conventional thermal power plants to RE are estimated to contribute nearly half of the energy reduction target for primary energy consumption, demand also must decrease substantially to reach long-term targets.

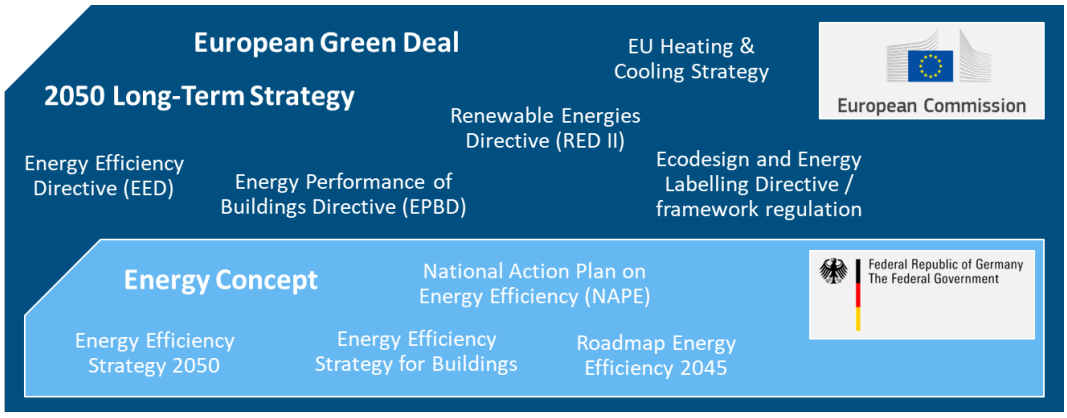


Figure 8: EU and German energy efficiency framework policies[23], adapted by author

21 BMWi, 2019a, Energieeffizienzstrategie 2050

22 Fraunhofer ISI and IREES GmbH, 2021, Energy Efficiency Policy in Germany

23 BMWK, 2022b, International communication of the German energy transition

The Federal Government aims at making Germany the "most energy-efficient economy in the world". Through a "continuous increase in EE, the energy transformation and climate protection can be reached effectively and cost efficiently"[24]. The Energy Concept and the Energy Efficiency Strategy 2050 contain the national targets and the long-term strategy on EE[25]. The overarching strategy and its targets are complemented by the Second National Action Plan for Energy Efficiency (NAPE 2.0), the Roadmap Energy Efficiency 2045, as well as sector-specific strategies such as the Energy Efficiency Strategy for Buildings. Monitoring and evaluating implemented policies and targets are crucial in all programmes..

As part of the Energy Efficiency Strategy 2050, the NAPE 2.0 was published in 2019[26]. he plan focuses on the demand side of the energy system and addresses all relevant sectors: buildings, industry and commercial users, transport and agriculture. Measures in the NAPE 2.0 are fourfold: providing information and advice to customers on how to save energy; promoting efficiency investments through tax incentives; obliging large-scale enterprises to conduct energy audits and setting standards for new installations and buildings. NAPE 2.0 aims at reducing primary energy demand across the economy by 300 TWh until 2030.

The Roadmap Energy Efficiency 2045[27] is the central dialogue platform of the Federal Government to advance EE in Germany. It is set up as a stakeholder process involving industry, businesses, civil society, scientists and representatives of the federal states in Germany. The goal of the process is to develop pathways for a substantial reduction of primary energy demand by 2045 and to develop concrete measures in a dialogue-oriented setting with all stakeholders. The roadmap process is structured in plenary sessions, working groups and workshops that partially have a sectoral focus and partially address cross-cutting issues. A second dialogue process, Climate Neutral Heat 2045, was initiated by BMWi at the beginning of 2021 and complements the Roadmap Energy Efficiency 2045.

The German EE framework is currently under review to conform to the updated requirements of EU policies – specifically the European Green Deal and the "Fit for 55 package" – as well as to the new German energy and climate targets. With more RE in the energy system, more suitable EE indicators need to be developed and the reduction of final instead of primary energy demand comes into focus. The dialogue platform Roadmap Energy Efficiency 2045 will discuss whether targets should be converted from primary energy demand to final energy demand as the headline indicator[28].

Support programmes, policies and instruments

Germany has several programmes under which financial support for EE measures is available for private households, enterprises and municipalities. These programmes typically provide investment grants or access to loans at reduced interest rates and can be differentiated into four categories: support for consultation, entry-level support, systemic support and specialised funding.

The Federal Funding Programme for Energy and Resource Efficiency in the Economy[29] rovides grants and loans with favourable conditions to the industrial sector and businesses. At its core, the programme aims at helping companies to increase their energy and resource efficiency as well as to support applications using process heat from RE. It consists of five different modules: (1) support for cross-sectional technologies such as pumps or motors; (2) renewable process heat; (3) measurement and control technology, sensors and energy management software; (4) energy and resource-related optimisation of plants and processes; (5) transformation and decarbonisation concepts.

Since 2000, the government supported renovations of heating systems through the Market Incentive Programme with an annual budget of more than 300 million EUR per year. Financial support has been provided primarily for existing buildings to promote the use of RE technologies. With the new Buildings Energy Act (GEG) – effective from 2020 – the Market Incentive Programme was replaced by the Federal Funding for Efficient Buildings Programme[30]. It provides financial support for EE and RE in buildings. The programme addresses residential and non-residential buildings as well as new buildings and the renovation of existing buildings. It supports measures such as the

24 BMWi, 2019a, Energieeffizienzstrategie 2050

25 BMWi, 2019a, Energieeffizienzstrategie 2050

26 BMWi, 2019a, Energieeffizienzstrategie 2050

27 BMWK, 2022c, Roadmap Energieeffizienz 2045

28 BMWi, 2021b, Energieeffizienz für eine klimaneutrale Zukunft 2045 - Zwischenbericht

29 BaFa, 2022a, Bundesförderung für Energie- und Ressourceneffizienz in der Wirtschaft

30 BaFa, 2022b, Bundesförderung für effiziente Gebäude

insulation of the building envelope as well as renewable heating systems. The programme and its predecessors have been very successful not only in terms of implemented EE measures but also in establishing market standards regarding quality and minimum efficiency standards of technologies as well as holistic construction standards for highly efficient buildings.

The Federal Funding for Energy Advice in Residential Buildings programme supports owners, homeowners' associations and tenants of residential buildings in the implementation of EE measures. The objective of the funding is to offer owners of residential buildings advice about options for energy-efficient building refurbishment. Energy advice services provide comprehensive information and can be the basis for investment decisions. Funding is provided in the form of subsidies for advisory services for residential buildings by energy consultants approved by the granting authority[31].

In 1992, the EU Labelling Directive made it mandatory to provide comparative energy labels for the sale of certain household appliances. Consumers would thus be informed about usage costs to deter them from buying products with low purchasing costs but high total (energy) expenditures. The current EU Energy Labelling scheme is based on an EE index calculated in relation to standard values for every product. The available range of labelling classes is limited by the mandatory standards defined in the Eco-Design Directive. Certain poor efficiency classes are basically banned, and minimum energy performance standards are determined individually for every product category based on a technical, economic and ecological analysis.

Energy audits are an important and effective instrument for raising awareness for efficiency measures in enterprises. According to DIN EN 16247, an energy audit is "a systematic inspection and analysis of the energy input and energy consumption of an installation, a building, a system or an organisation with the aim to identify energy flows and potential EE improvements and report on them"[32]. The energy auditor evaluates EE measures and allows companies to identify where they can potentially and profitably save energy. Companies that are not small or medium sized are obliged to conduct energy audits unless they already have an energy or environmental management system in place. The audit must be repeated every four years. A separate report on energy audits in Germany is available from GIZ China.

Energy management systems (EMS) are an instrument towards more EE by identifying EE measures and overcoming implementation barriers. An energy management system establishes a systematic structure and responsibilities to improve EE within an enterprise. It further establishes targets for energy consumption and efficiency. The foundation of an EMS is the measurement and analysis of energy carriers and energy flows on a regular basis. The auditor identifies the potentials for EE improvements based on available data. There are incentives for enterprises to introduce EMS. These include tax peak compensation schemes that allow for a substantial refund on energy and electricity taxes and a special compensation mechanism within the Renewable Energy Sources Act, under which qualified energy-intensive enterprises are eligible to reduced electricity surcharges.

Ecologically motivated taxes are a tool to internalise externalities. In the case of energy consumption, the externalities refer to negative environmental consequences of burning fossil fuels and the associated emission of GHG. The taxation of energy use increases the price of energy and thereby sets economic incentives for energy conservation and rational use of energy. In Germany, the laws for energy taxation and electricity taxation stipulate differentiated tax rates by energy carrier and by utilisation. Several exemptions that reduce the effective tax rate exist with the aim of avoiding undue burdens on industry and consumers or fostering the use of environmentally favourable energy carriers or transport modes. RE and certain energy-intensive processes are exempt from some taxes.

Energy efficiency achievements: further efforts required

Since 1990, final energy demand in Germany dropped by 12% while GDP rose by almost 46%. Final energy productivity thus increased by 66% over the past 30 years, as depicted in the long-term development of energy demand and energy productivity in Figure 9. The increase was due to a change in the economic structure of the country towards a higher share of services. Energy saving and efficiency measures in all economic sectors and private households contributed as well. Germany managed to decouple economic growth from energy use: GDP increased while energy use declined.

31 Fraunhofer ISI and IREES GmbH, 2021, Energy Efficiency Policy in Germany

32 BaFa, 2020, Leitfaden zur Erstellung von Energieauditberichten

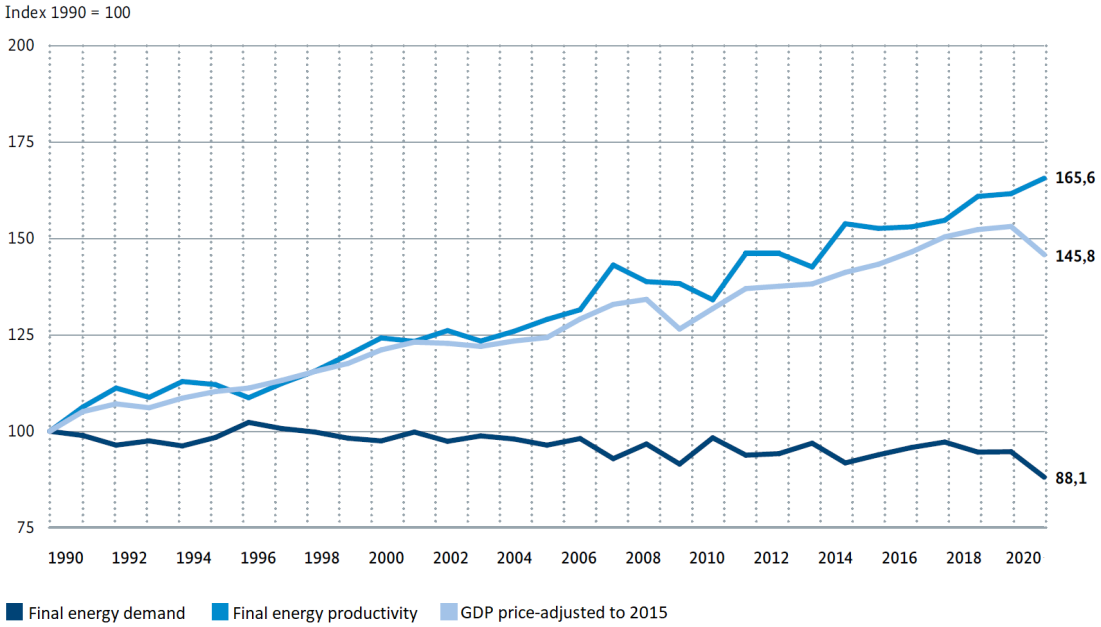


Figure 9: Final energy demand and productivity in Germany[33]

However, many of the actual EE targets could not be reached (compare Figure 2 and Annex 2). Despite the drop in energy consumption during the COVID-19 pandemic in 2020, primary energy consumption only declined by 17.3% compared to 2008. The target of reducing primary energy consumption by 20% could thus not be achieved. During 2021, primary energy consumption rose again to about 5 percentage points above the 2020 target. Final energy productivity in Germany increased by only 1.4% per year during the past decade and could not match the target value of 2.1%. While structural changes from energy-intensive industries to services allowed for steady improvements, energy savings through EE measures were lower than expected across the economy.

Given the challenges of reaching the 2020 EE targets, more efforts are required to achieve the ambitious medium- and long-term targets of 2030 and 2050. The updated emission reductions formulated in the new Climate Change Act require an update of the German EE targets as well[34].

3.2 Transforming energy supply: renewables for all sectors

Renewable energy framework and policies

RE should provide most of the German energy supply by the middle of this century. The expansion of RE has been the focus during the early years of the energy transition and RE have become especially prevalent in the electricity sector. In addition to EU-level strategies, Germany's RE policy framework is determined by its long-term energy and climate targets (Figure 10).

33 BMWK, 2021, Energieeffizienz in Zahlen

34 BMWi, 2021b, Energieeffizienz für eine klimaneutrale Zukunft 2045 - Zwischenbericht

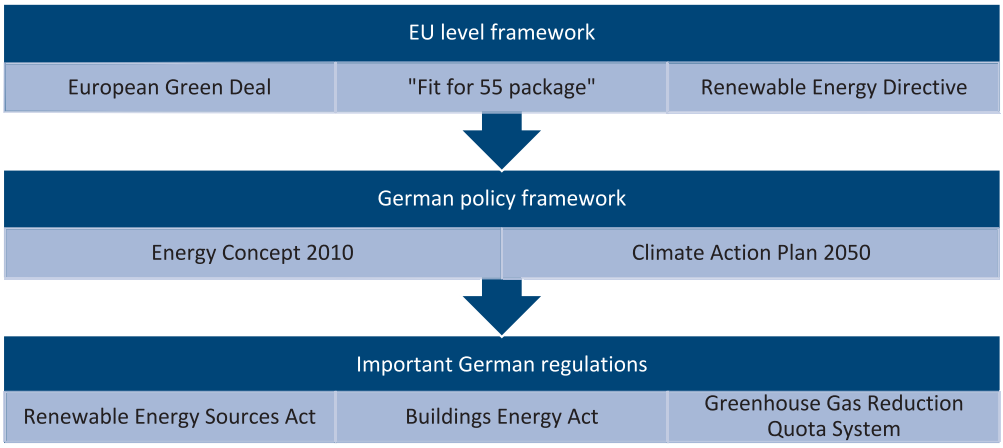


Figure 10: German renewable energy policy framework

The important regulations for RE across all sectors are the Renewable Energy Sources Act (EEG) for the electricity sector, the Buildings Energy Act (GEG) with a focus on the building sector and the Greenhouse Gas Reduction Quota System in the transport sector.

The Renewable Energy Sources Act (EEG) entered into force in 2000. It is one of the key drivers for the expansion of RE in Germany. The EEG has been revised various times, especially to adjust the level of support to changing price and market conditions and to integrate the generation of renewable electricity into the electricity market. The Renewable Energy Sources Act enabled the expansion of RE – especially wind, solar and biomass – through a guaranteed and generous feed-in tariff. The EEG surcharge levied on end customers financed the expansion. In addition to the gradually decreasing feed-in tariff for later renewable installations, grid priority and a purchase guarantee of the generated electricity are instrumental in growing the share of renewable electricity.

A major overhaul of the EEG occurred in 2014, when larger new solar and wind power plants had to market their electricity on the electricity markets and pilot auctions for determining the financial support for RE started. A further update was introduced with the amendment in 2017 and the launch of regular public auctions for large PV plants and wind turbines. New small-scale renewable power plants below 750 kW still receive a feed-in tariff and do not need to participate in public auctions. The competition in those auctions helped to bring down costs and financial support rates for new RE plants. Against the backdrop of more ambitious targets of the new Federal Government and the need to reduce the dependence on fossil fuel imports, the EEG has been amended in 2022.

Since 2017, rules and regulations about offshore wind energy are not part of the EEG anymore but are formulated in the Offshore Wind Energy Act. The law regulates the expansion of offshore wind energy in a cost-efficient manner by auctions while taking into account the necessary grid capacities to transmit and distribute the electricity generated. The build-out of offshore wind installations and offshore power line connections must take place in a coordinated manner. Planning, construction and start-up of both the generation and the transmission infrastructure are aligned.

Heating and cooling accounts for about half of Germany's energy demand. The Buildings Energy Act covers obligations and requirements on EE and RE in the housing sector. It obliges owners of new buildings to produce a certain share of their heating demand from renewable sources. The owners can choose how to meet the obligations of the law at their discretion with different technological solutions, such as solar thermal collectors, heat pumps or wood-fired boilers. Instead of using RE, greater levels of insulation or heat from district heating networks or cogeneration units are options as well. Owners of old buildings are eligible for financial support for renovations. The Buildings Energy Act also sets requirements for the energy performance of buildings and for the issuance and use of energy performance certificates[35]. The Coalition Agreement of the new Federal Government stipulates that from 2025, every newly installed heating system must be powered by at least 65% RE.

35 BMI, 2020, Buildings Energy Act

Most targets and regulations concerning RE in the German transport sector come from the EU's Renewable Energy Directive. To achieve the target of 10% RE in transport by 2020, the German Government implemented the Greenhouse Gas Reduction Quota system in 2015. This annual percentage reduction obligation is a market-based instrument with the aim to increase the share of RE in the transport sector and to reduce the GHG intensity of fuels. Under the quota system, companies that supply fuels to the transport sector are obliged to reduce the GHG emissions of their products. Respective companies can fulfil their obligations in various ways, such as bringing to market (advanced) biofuels, synthetic fuels and green hydrogen or by buying quotas from e-mobility users.

Renewable energy targets and achievements until 2020

In its Energy Concept from 2010, the German Government formulated several RE targets. Some of these targets have been updated over the years through EU or national policy changes. The new Federal Government once again raised the ambition for the expansion of RE in its coalition agreement and the amendment of the EEG. The new official targets for the share RE in the electricity mix are 80% in 2030 and GHG neutral electricity after the coal-phase out. The new government also set a clear and ambitious goal for RE in the heating sector in line with the EU's Renewable Energy Directive: 50% of the heat supply in 2030 should be provided in a climate-neutral way[36].

For the transport sector, a RE target in Germany has existed through the Renewable Energy Directive of the EU since 2012. For 2020, the share of RE sources in final energy consumption in the transport sector in each EU Member State was targeted to be 10% while for 2030 the minimum share should be 14%. By strengthening the GHG reduction quota system, the share of RE in the German transport sector is supposed to grow to 14% by 2026 and to 32% by 2030[37]. Table 9 summarises the German RE targets and the achievements towards them for the year 2022. Three out of four RE targets for 2020 have been overachieved.

Table 9: Overview of German renewable energy targets and achievements

	2020	Target 2020	Target 2030	Target 2040	Target 2050
Share of RE in gross final energy consumption	19.7%	18%	30%	45%	60%
Share of RE in gross electricity consumption	45.2%	35%	80%*	Climate-neutral*	Climate-neutral*
Share of RE in final energy consumption for heating and cooling	15.3%	14%	50%*		
Share of RE in final energy consumption in the transport sector	7.6%	10%	32%**		

* targets in the new amendment of the Renewable Energy Sources Act from July 2022 and the coalition contract

** electricity in transport and other means of fulfilling the GHG quota partly count towards the 32% target

Despite increasing energy consumption after the COVID-19 pandemic most targets were also met in 2022 as Figure 11 shows. During the past decades, the use of RE has expanded unevenly in the different sectors. The main driver is the electricity sector with an increase from 6% in 2000 to over 46% in 2022. Wind power contributes about half of the renewable electricity, while solar and generation from biomass each have a share of about 20%. Hydro power provides the remainder. The share of RE in the heating sector rose from around 4% in 2000 to over 17% in 2022 with bioenergy – mainly wood for heating purposes – providing more than 80%.

The biggest challenge in terms of RE for Germany lies in the transport sector. The share of RE in transport has remained below 7% for many years due to the slow uptake of electric vehicles. In addition, scaling the utilisation of biofuels in a sustainable manner without compromising food production and land-use domestically and abroad has proved difficult. Considerable efforts, such as increasing shares of electric mobility powered by renewable electricity and more ambitious targets for the GHG reduction quota, are required to increase the share.

36 BMWK, 2022a, Germany's current climate action status

37 Bundesregierung, 2021, CO2-Ausstoß von Kraftstoffen senken

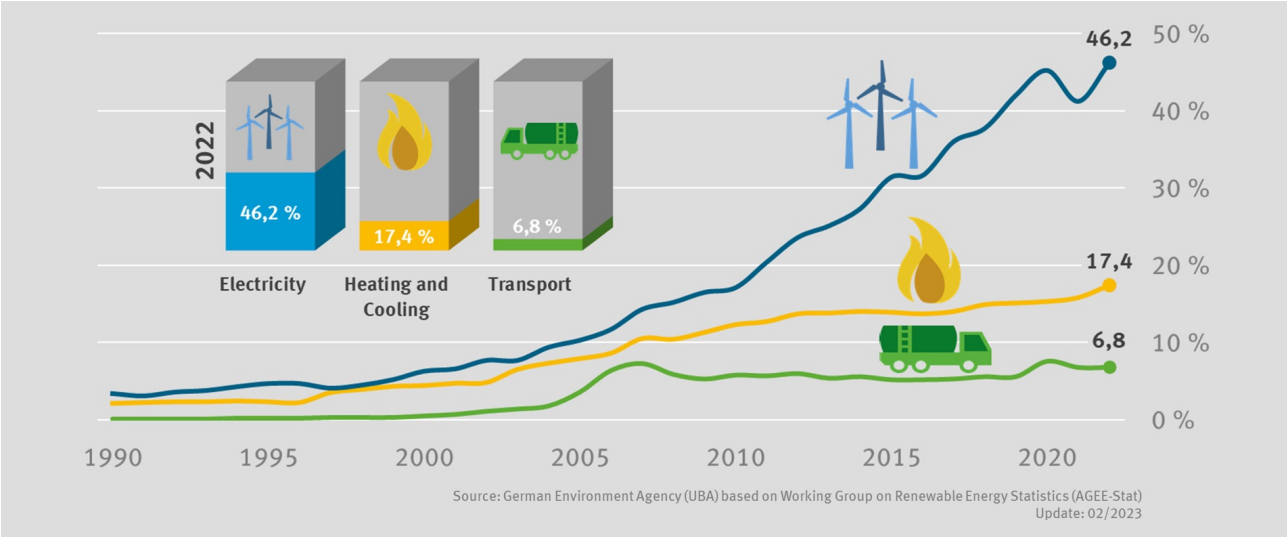


Figure 11: Share of renewable energy in different sectors until 2022[38] (UBA, 2023a)

While the share of RE is highest in the electricity sector, the main RE source in Germany is neither wind nor solar, but biomass. Biomass is still being used extensively, especially in the heating sector, thus making up more than 50% of total RE supply in Germany in 2022. RE supplied a total of 485 TWh of energy in 2022 (Figure 12). More than half of the RE in Germany is provided in the electricity sector, 41% in the heating sector and only 7% in the transport secto[39].

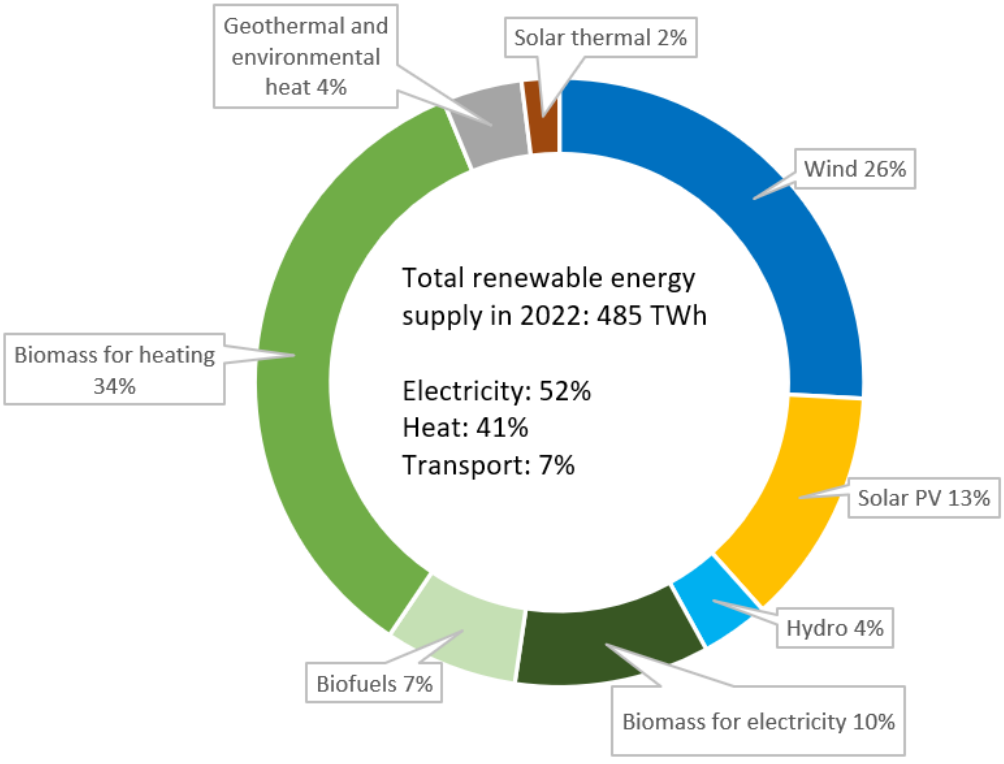


Figure 12: Total renewable energy supply in Germany in 2021

38 UBA, 2022a, Renewable energies in figures

39 BMWK, 2022d, Development of Renewable Energy Sources in Germany in the year 2021

3.3 Flexibility and connections: sector coupling for unlocking decarbonisation

Sector coupling and the energy transition

The demand for energy that remains after unlocking existing EE potentials and utilising RE directly in some sectors has to be covered with renewable electricity. This requires an integrated and more flexible energy system where much of the energy need is electrified and where the different sectors, such as heating and transport are connected in a sustainable, economic and intelligent way[40]. This process is referred to as sector coupling. It requires both the utilisation of new and existing technologies for providing energy services as well as increased systemic connections between the different sectors through energy infrastructures, policies and market-based mechanisms. Figure 13 depicts technologies and interconnections of a sector-coupled energy system.

In the building and heating sector, heat pumps will play a more important role in covering the energy needs of space heating. Heat pumps can also provide low and medium temperature process heat for industrial purposes. Through the electrification of drive trains, the transport sector will be more efficient and less carbon-intensive as it is linked to an increasingly renewable electricity system. Sector coupling also allows for the use of electricity at times of surplus renewable generation. Power-to-heat applications can store energy and make it available for heating buildings later. Batteries in electric vehicles can serve as short-term storage systems and can also be used for load shifting through intelligent charging algorithms.

The production of hydrogen or other synthetic fuels through power-to-gas or power-to-X technologies can store surplus electricity in chemically stable form. These green fuels can be transformed back into electricity to keep the electricity system in balance or be used to decarbonise industrial processes and to power vehicles. However, liquid or gaseous

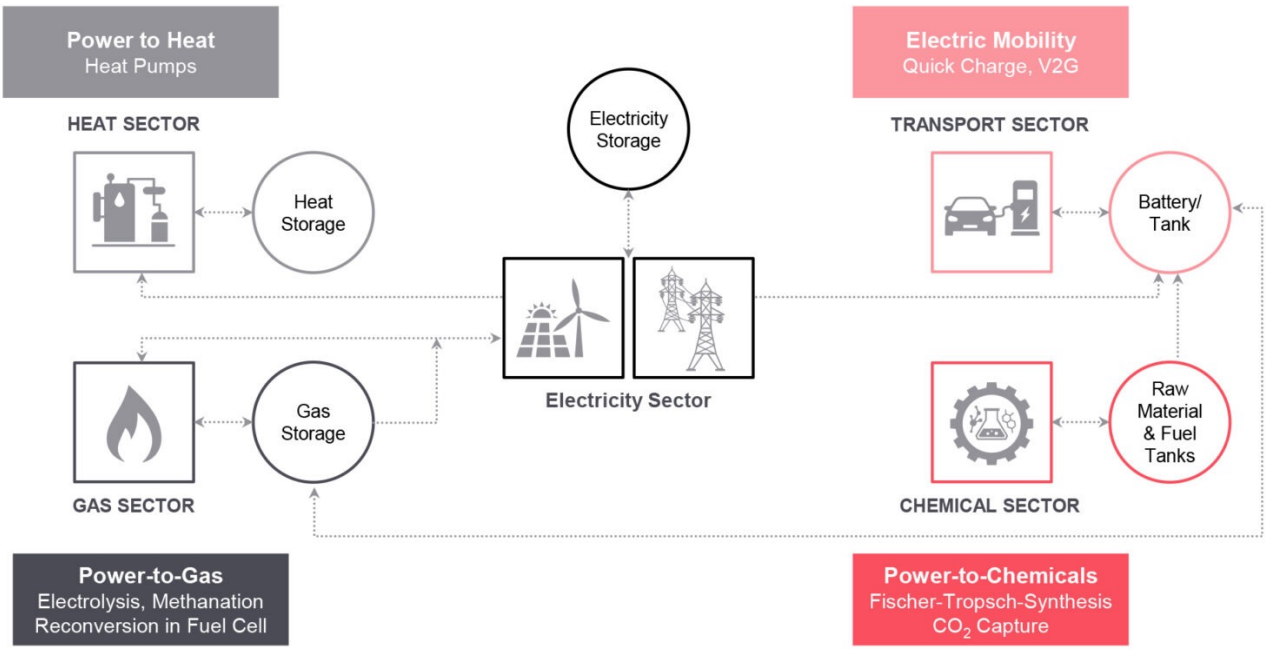


Figure 13: Sector coupling between the electricity and other energy consuming sectors[41]

40 BMWi, 2021a, the Energy of the Future: 8th Monitoring Report on the Energy Transition - Reporting Years 2018 and 2019

41 ENTSO-E, 2020, Vision on Market Design and System Operation towards 2030

fuels produced by RE will be expensive and in short supply. Their usage would be restricted to hard-to-abate sectors where direct electrification is not economically feasible or technically difficult to achieve. Sectors such as aviation, maritime and heavy-duty transport or industries producing basic materials such as steel, cement or chemicals rely on high temperature heat, fuels with high energy density or on feedstock materials. Synthetic fuels and hydrogen from RE are too valuable to be used in other sectors and will be required to decarbonise these hard-to-abate applications.

The biggest advantage of using electricity in the different sectors is the higher efficiency of electrified solutions compared to traditional boilers or engines that run on either fossil or synthetic gas and oil products. Electrification thus reduces primary and final energy consumption. However, electricity demand will rise with extensive sector coupling and electrification despite efficiency gains in the underlying processes. The German Government estimates that electricity consumption will increase from about 550 TWh in 2021 to between 680 and 750 TWh by 2030[42].

The development and implementation of solutions and technologies that electrify industries and sectors has accelerated since 2015 and couple the electricity sector with heating, transport and the industry. As sector coupling is an overarching strategy for the energy transition, relevant targets and regulations are spread throughout various policy documents. Table 10 summarises the current state and the most important targets and expectations for a range of sector-coupling solutions.

Table 10: Overview of selected German sector coupling targets and achievements

	2020	Target 2020	Target 2030
Electric vehicles registered in Germany in mil.*	0.59**	1	15
Publicly accessible charging points	36,500	50,000	1 million
Installed heat pumps in mil.	1.3	no target	4-6 million***
Installed capacity of electrolysers running green electricity	60 MW****	no target	10 GW*****
Generation of green hydrogen***	3 GWh****	no target	28 TWh*****

* the 2020 target included all electric vehicles including hybrid electric vehicles, the new target for 2030 only includes fully electric vehicles
** the numbers for 2020 in detail: 309k battery electric vehicles, 280k plug-in hybrid electric vehicles and 0.1k fuel cell electric vehicles
*** not an official target but an estimate by the current government
**** data from the monitoring report of the Federal Network Agency[43]
***** new targets of the Federal Government doubling the previous ambition for 2030

Sector coupling in the building sector

A large part of the framework for sector coupling in the building sector – specifically for heating and cooling – is part of the Energy Efficiency Strategy 2050, NAPE 2.0 and the Buildings Energy Act, as described in chapter 3. Regulations concerning the support for heat pumps as a sector coupling technology can be found in the Buildings Energy Act. The financial support for heat pumps is regulated in the Federal Funding for Efficient Buildings Programme[44] and new funding programmes are being currently developed.

The utilisation of heat pumps in Germany grew gradually from 2008 onwards. Governmental support programmes enabled the increasing uptake. The deployment of heat pumps grew by 30% in 2021. The 1.5 million heat pump systems installed in Germany by the end of 2021 had a combined thermal capacity of 13.8 GW and provided almost 18 TWh of final energy consumption for heating purposes[45]. Increasingly, heat-pumps are used instead of gas or other heating systems in new buildings (Figure 14). The technology made up more than 60% of all heating systems proposed in new residential buildings applying for a building permit in Germany in 2021[46].

42 BMWK, 2022a, Germany's current climate action status
43 BNetzA, 2022a, Monitoringbericht 2021
44 BaFa, 2022b, Bundesförderung für effiziente Gebäude
45 BMWK, 2022d, Development of Renewable Energy Sources in Germany in the year 2021
46 Bundesverband Wärmepumpe e.V., 2022, Zahlen und Daten

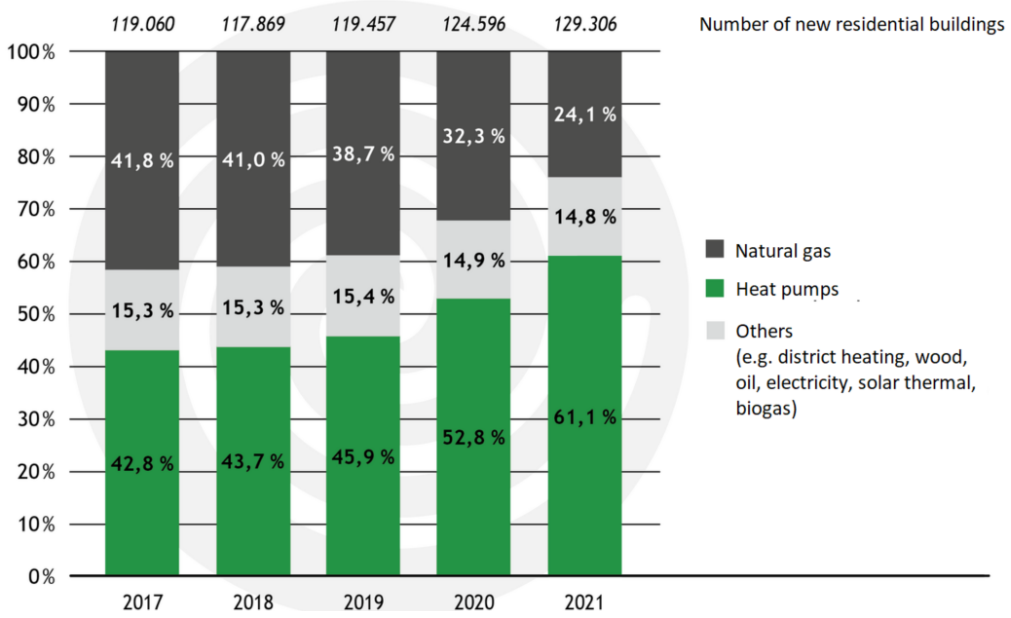


Figure 14: Market share of heating systems proposed in new residential buildings in Germany[47], adapted by author

Electrifying and decarbonising the transport sector

The National Development Plan for E-Mobility from 2009 along with the Governmental Programme E-Mobility from 2011 initiated a coherent policy framework to establish Germany as leading market for electric mobility by 2022. The National Platform "Future of Mobility" has been launched by the Federal Government in 2018. Its six working groups formulate recommendations for action in specific areas on mobility, such as climate protection in transport, rules for sustainable mobility, battery cell production, sector integration and standardisation, norms and certification[48].

To align the growing number of electric vehicles with the electricity grid infrastructure, the Charging Infrastructure Master Plan was adopted at the end of 2019. It contains measures for the rapid development of a nationwide and user-friendly charging infrastructure for up to ten million electric vehicles by 2030[49]. Specifically, it involves targeted funding, improved legal framework conditions and active coordination between the Federal Government, the federal states, local authorities and industry. The Federal Government has committed to providing public funding for charging points to accelerate the expansion of the charging infrastructure and thus increase the attractiveness and willingness to purchase electric vehicles. The plan is coordinated by BMDV and will be evaluated every three years from 2021 onwards.

To support e-mobility, the German Government changed the vehicle tax scheme in 2012. Fully electric vehicles are exempt from the vehicle tax for ten years when registered before the end of 2015. This tax exemption has now been extended to fully electric cars registered until the end of 2025. Further structural incentives for e-mobility have been achieved through the Electric Mobility Act from 2015. The law allows local governments to grant electrically powered vehicles special privileges in public traffic areas, such as their own parking spaces free of charge.

Especially important for the adoption of electric vehicles by private and business users is the so-called Environmental Bonus, which consists of a financial support when a private owner purchases an electric vehicle. It was implemented in 2016 and has since undergone changes in scope and amount of support. Since the outbreak of the COVID-19 pandemic, an additional support – the Innovation Premium – is paid on top. Depending on the specific electric car purchased, up to 20% of the price is covered by those two schemes.

The uptake of electric vehicles in Germany started slowly, but the governmental support along with a growing number of available models from car manufacturers have led to strong increases, especially from 2018 onwards (Figure 15).

47 Bundesverband Wärmepumpe e.V., 2022, Zahlen und Daten

48 NPM, 2022, National Platform Future of Mobility

49 Bundesregierung, 2019, Masterplan Ladeinfrastruktur

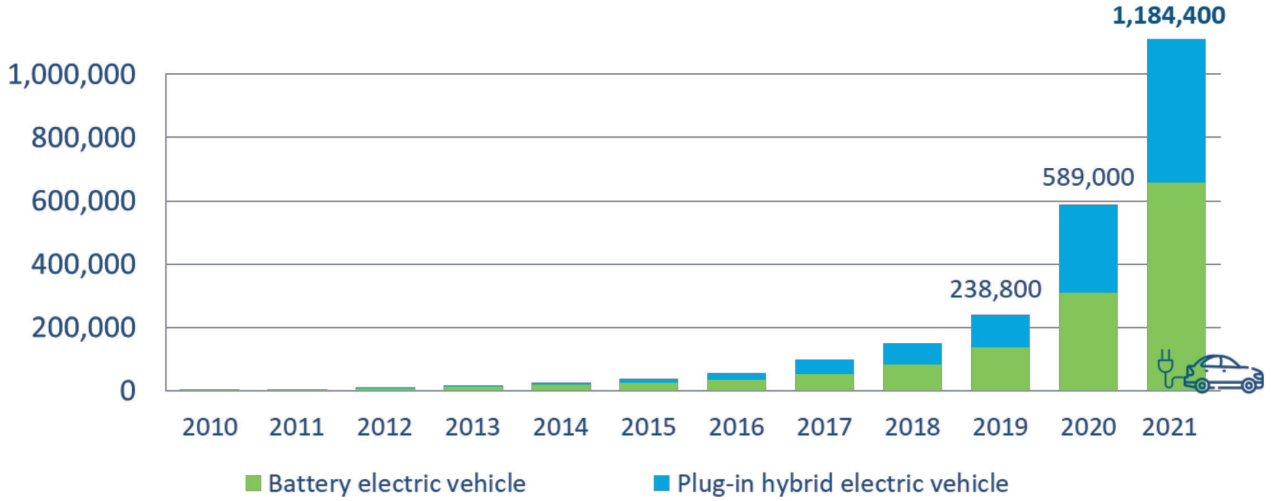


Figure 15: Registered electric passenger vehicles in Germany by end of year[50], adapted by author

The number of fully electric vehicles grew to almost 620 thousand by the end of 2021 while the share of electric vehicles (including plug-in hybrids) in the total German passenger vehicle fleet reached 2.6%. Plug-in hybrids and fully electric vehicles have made up about 25% of monthly vehicle registrations since the end of 2020[51]. The 2020 target of 1 million electric vehicles was achieved a few months later in July 2021. Until April 2022, almost 60,000 public charging points have been registered at the Federal Network Agency[52].

Industrial decarbonisation through sector coupling

Making up more than 20% of the entire German GHG emissions, industrial processes and value-chains are among the largest contributors to GHG emissions of the country. The transformation towards a climate-neutral industrial sector is challenging due to the inherent energy-intensity of many processes and process-related emissions. While roughly 75% of industrial GHG emissions in Germany can be traced back to the use of fossil fuels for energy-related purposes, process-related emissions account for the remaining quarter. Important aspects of decarbonising the industry through sector coupling are electrification, more efficient processes and replacing fossil feedstock. Energy-related emissions can be decarbonised through the utilisation of renewable electricity or synthetic fuels in low, medium and high-temperature applications. Process-related emissions in metallurgic, mineral or basic chemical processes are more difficult to address. Green hydrogen and its derivatives can replace fossil hydrogen or coking coal and alternative production processes, new technologies and carbon capture utilisation and storage solutions can lower or eliminate process-related emissions.

In addition to the EU ETS, which incentivises industrial actors to adopt less carbon-intensive production processes, support programmes for the industry exist on the EU and the national level. The programme “Decarbonisation in the industry” by the BMWK funds projects in energy-intensive industries that aim to largely and permanently reduce process-related GHG emissions which are unavoidable or difficult to avoid according to the current state of the art. Funding is provided for research and development, testing and demonstration as well as investments in innovative climate protection technologies. The programme is aimed at the steel, chemical, cement, lime and non-ferrous metal industries, but also at other energy-intensive sectors. Long technical lifetimes of production facilities in the basic raw material industry require the upcoming investments by industrial actors to already consider decarbonisation solutions. The Competence Centre on Climate Change Mitigation in Energy-Intensive Industries (KEI) provides the German industry with support for the mitigation of GHG emissions[53].

50 BMWK, 2022b, International communication of the German energy transition

51 electrive, 2022, Deutscher Elektroauto-Bestand hat sich 2021 verdoppelt

52 BNetzA, 2022b, Elektromobilität: Öffentliche Ladeinfrastruktur

53 KEI, 2022, Climate action in industry

Excursus: Pioneering green hydrogen markets and infrastructures

An important building block of sector coupling is the application of green hydrogen. A dedicated framework for hydrogen in Germany has been in place since 2020, when the National Hydrogen Strategy was approved (compare Table 11). The development of green hydrogen production and infrastructure is supported through various governmental programmes ranging from basic research grants up to the financial support of large-scale implementation in industrial sectors[54].

High up-front investments and difficulties to recover costs in this new market field are barriers for the uptake of green hydrogen. To accelerate the domestic hydrogen and power-to-X market to an industrial level, H2Global as an innovative support instrument was implemented in 2021. H2Global concludes long-term purchase contracts on the supply side and short-term sales on the demand side. The differences in prices between supply and demand are covered by a grant from the German Government. With this auction-based mechanism, a timely and efficient power-to-X market ramp-up should be achieved[55].

As of today, 35 green hydrogen and synthetic fuel production plants exist in Germany[56]. More than 60 projects with a total of 2 GW of electrolysis capacity are in the planning process[57]. Gas grid operators increasingly take hydrogen demand and supply into account when modelling the future gas infrastructure. They developed a plan for a nationwide hydrogen pipeline network of more than 1700 km in length. It would serve to connect the chemical and steel industry with hydrogen supply from imports and generation within Germany (Annex 5).

Table 11: The National Hydrogen Strategy in a nutshell

Hydrogen demand	Expected demand of 90 to 110 TWh in 2030. Expected demand of 110 to 380 TWh in 2050.
Green hydrogen generation	10 GW of installed electrolyser capacity in 2030. 28 TWh of green hydrogen generation in 2030.
Domestic generation vs. import	Until 2030 focus on kick-starting domestic generation and demand for green hydrogen to build up an industrial ecosystem. Long-term demand largely to be met by imports of green hydrogen and its derivatives from different countries.

54 Bundesregierung, 2020, The National Hydrogen Strategy

55 H2Global Stiftung, 2022, The H2 Global Mechanism

56 DVGW, 2022, Power-to-Gas

57 Chemie Technik, 2022, Die wichtigsten Wasserstoff-Projekte in Deutschland

4 Enabling a successful energy transition: security of supply, affordability and sustainability

The energy transition combines three overarching objectives. They guide Germany's pathway into a future energy system away from fossil fuels towards RE and increased EE. The threefold objectives are to provide a high level of security of energy supply for people and businesses, to ensure an economic and affordable energy supply for the country and to make energy supply compatible with environmental, sustainability and climate-related targets.

These objectives are all relevant to the success of the energy transition. They provide the basis for strategic plans and policies and are taken into account for all measures related to the energy transition.

4.1 Increasing security of supply through energy transition

A high level of security of supply means that Germany covers its energy demand efficiently and securely at all times while phasing out nuclear and coal-fired power plants. Measures are in place to increase energy security by becoming less dependent on fossil fuel imports, to integrate RE sources into the energy system and to extend the interconnected European electricity and gas supply system further.

Energy security and import dependencies

Security of energy supply is pivotal for any economy. It provides stability and confidence for industry, businesses and households and ties in with keeping prices of energy sources at a competitive level. Russia's war of aggression against Ukraine has highlighted the vulnerability of the energy sector to geopolitical events. The negative impact can come across all dimensions relevant to the energy transition: energy can be less affordable, sustainable and secure. Due to the globalised nature of the energy markets, the effects are also being felt globally.

The reliance on only a few suppliers can be detrimental to national (energy) security. In the wake of the war in Ukraine, one of the EU's and Germany's top priorities is to diversify their energy supply sources and phase-out energy imports from Russia. More than 10 LNG import terminal projects have been proposed in Europe since the onset of the war[58].

Energy security has large implications, especially for Germany, which imports much of its oil, gas and hard coal demand. From March 2022 to May 2022 Germany reduced its import dependency from Russia drastically (Table 12). To diversify natural gas imports as soon as possible, LNG import terminals – four floating storage and regasification units and three onshore terminals – are being commissioned. They are expected to come online from late 2022 to 2025 and have a total import capacity equivalent to Russian gas supplies[59].

Table 12: Share of fossil fuel import from Russia to Germany: past, present and future targets

	2020/2021	May 2022	Target for 2024
Hard coal	50 %	8 %	0 %
Oil	35 %	12 %	0 %
Natural gas	55 %	35 %	10 %

In addition to phasing out Russian fossil fuel imports as soon as possible, Germany has decided to accelerate the energy transition and associated targets (compare targets in Chapter 3 and Annex 2). Domestic RE and imports of green hydrogen from different suppliers will replace fossil fuel imports entirely in the long term. Importantly, the challenge to reduce fossil fuel import dependencies and to increase energy security will be alleviated through the successful execution of the energy transition towards a renewable based energy system within Germany and the EU.

Security of supply in the electricity system

A second aspect of security of supply is to keep the electricity system in balance while an increasing share of electricity is provided by RE. Wind and solar provide variable electricity

58 IGU, 2022, Global Gas Report 2022

59 BMWK, 2022e, Zweiter Fortschrittsbericht Energiesicherheit

generation. This generation can, however, be forecast and integrated into the electricity system if the institutional and policy framework of the electricity market allow for it. Renewable capacities installed over a larger area also reduce fluctuations in the electricity output and thus reduce challenges for the entire electricity system. The current level of more than 40% of variable RE in the German electricity system does not pose problems. A separate report on the security of supply in the German electricity system under high shares of variable RE is available from GIZ. The grid integration of variable RE in Germany is achieved due to a combination of market-based and regulatory approaches, such as:

- the balancing group mechanism in the liberalised electricity market;
- advanced and improved weather and RE generation forecast models;
- market integration through requirements for selling electricity from RE on the spot market;
- integration of RE in redispatch mechanisms for alleviating grid congestion;
- reserves for thermal power plants to be activated in certain situations.

A common indicator to determine the security of supply is the System Average Interruption Duration Index (SAIDI), which calculates the average supply interruption per connected end consumer within a calendar year. For many years and despite the ongoing expansion of fluctuating RE to more than 40% in the electricity sector, Germany's SAIDI is at an international top level (Figure 16). The average supply interruption of customers has fallen during the past ten years and even only half its 2006 value[60].

Excursus: How the German electricity system stays secure during the energy transition

Every two years, the BMWK must submit a report on the status and development of security of supply in the electricity supply sector according to the Energy Industry Act (EnWG). In this context, security of supply is understood as the adequate coverage of electricity demand: Security of supply is ensured when demand can be met with the available resources for the generation and distribution of electricity with a very high probability. Security of supply in the electricity system is thus largely determined by:

- the availability of generating (and storage) capacity, both variable and dispatchable;
- the status of the national electricity grid and its expansion;
- the interconnection of Germany in the wider European electricity grid.

Dispatchable capacity (fossil fuels and nuclear) only contracted marginally during the past years to about 100 GW by the end of 2021 while generation capacity of RE in the German electricity sector grew to roughly 140 GW. A further reduction in dispatchable capacity occurred due to the phase-out of nuclear electricity generation by mid April 2023. Generation from coal fired-power plants will also end within the coming 15 years in a socially balanced, predictable

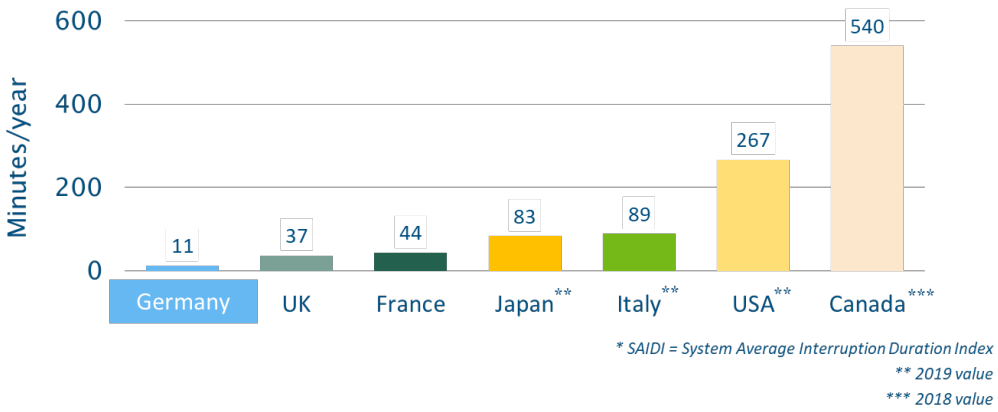


Figure 16: Duration of unplanned electricity outages per year (SAIDI) in 2020 in G7-countries[61], adapted by author

60 BNetzA, 2022a, Monitoringbericht 2021

61 BMWK, 2022b, International communication of the German energy transition

and economically viable way. With nuclear and coal capacity leaving the electricity market, building new gas-fired power plants to compensate for the loss of firm capacity is a priority. Those gas-fired power plants must be built in a hydrogen-ready manner to be able to play a key role in using renewable fuels as well. In addition, several instruments are in place to keep dispatchable power plants in special reserves. Those power plants have a capacity of about 8 to 10 GW and could come online and produce electricity in a time of capacity shortfall. The latest monitoring report showed that criteria for the security of supply in the electricity sector are currently met and will also be met in the future[62].

To accommodate increasing amounts of renewable electricity into the national grid, the domestic transmission and distribution grid in Germany is expanded (Figure 17).

A better connection between the consumption centres in the south and the RE generation bases in the north of the country will be achieved. In addition to upgrading and expanding the existing AC grid over several thousand kilometres in length, five high-voltage direct current (HVDC) power lines are currently being planned and constructed. They run from north to south and will integrate parts of the generation from the offshore wind farms in the North and Baltic Sea into the German transmission system. The HVDC-lines will become operational from 2027 to 2030, have a total transmission capacity of about 10 GW and are predominantly constructed as underground cables.

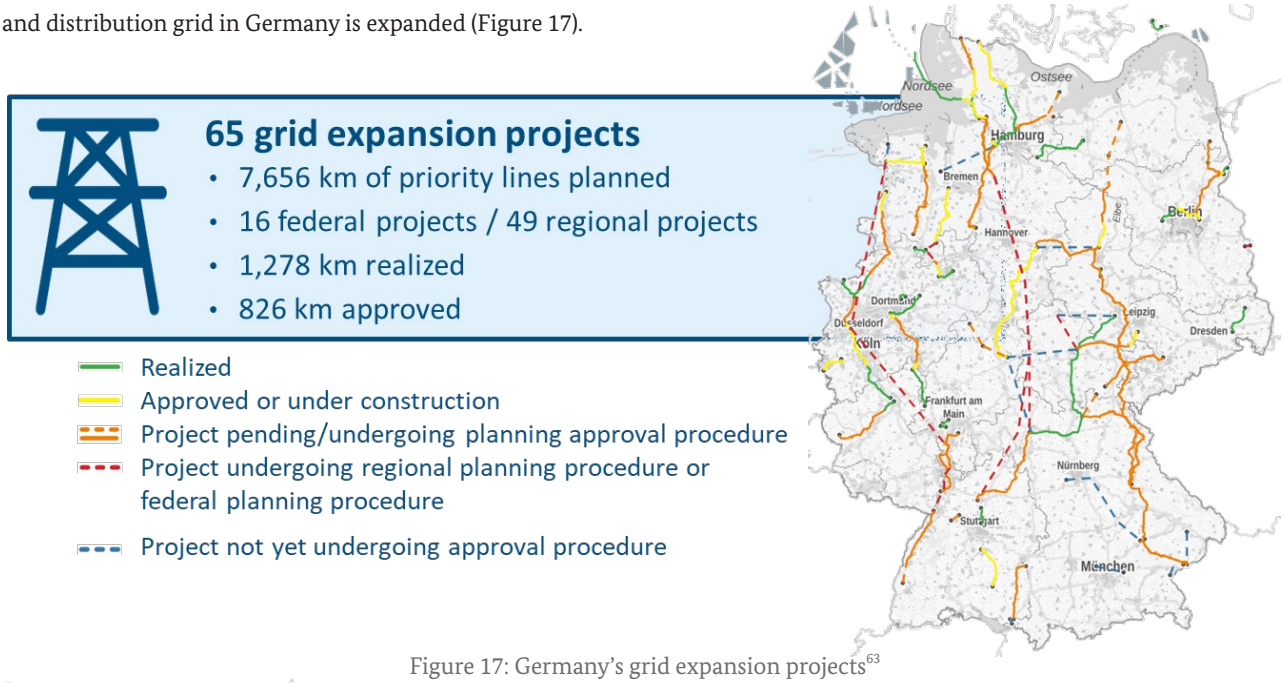
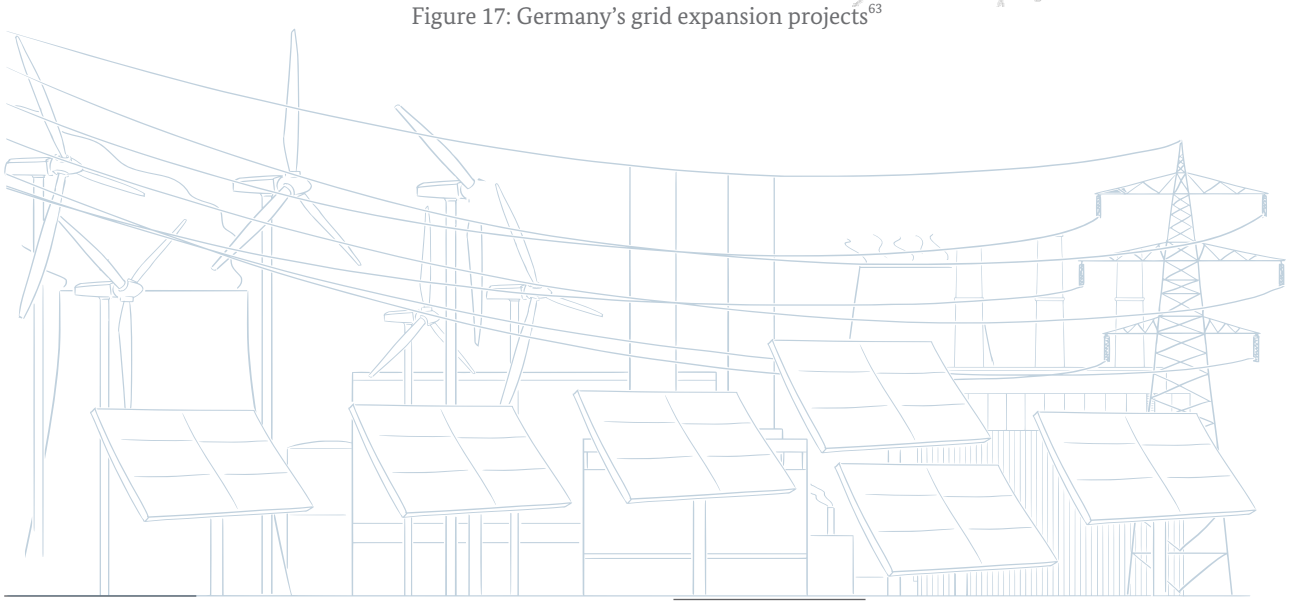


Figure 17: Germany's grid expansion projects[63]



62 BMWi, 2019b, Monitoringbericht zur Versorgungssicherheit im Bereich der leitungsgebundenen Versorgung mit Elektrizität

63 BMWK, 2022b, International communication of the German energy transition

Germany sits at the heart of the European interconnected electricity grid. Most countries in the EU are linked through both the physical transmission grid and the European electricity market. Cross-border trading of electricity leads to cost-effective use of the European power plant fleet and allows to make use of large-scale balancing effects between countries and regions. Thus, fluctuating generation from wind and solar can be integrated and electricity is exchanged between neighbouring countries constantly. The German cross-border interconnectors to other countries have a capacity of more than 20 GW. Germany exports electricity in times of high generation from RE and imports electricity in times of lower generation. Annual exports of electricity ranged between 5 and 10% of German electricity consumption in the past ten years. To give guidance to policymakers on the further integration of the European electricity market, the European System Operators for Electricity (ENTSO-E) prepares a Ten-Year Network Development Plan (TYNDP) every second year. In its latest plan, ENTSO-E identified the need for an additional 50 GW of cross-border capacity between European countries. With more than 10 GW of additional cross-border capacity to be constructed between Germany and other countries in Europe by 2030, increasing interconnections ensure a functioning and safe electricity supply system[64].

Security of electricity supply in Germany is at a high level and projected to remain so in the coming years, even if more dispatchable capacity in form of coal-fired power plants are shut down. Additional firm capacity in form of hydrogen-ready gas power plants will be necessary. Important prerequisites to ensure future security of electricity supply are the finalisation of the domestic grid expansion and the further integration of Germany into the European interconnected electricity grid.

4.2 The economics and affordability of the energy transition

To be successful, the energy transition must guarantee Germany's international competitiveness and maintain the affordability of energy for the end customer. Both aspects are relevant to ensure social cohesion and societal support for transforming the country's energy system. The cost of energy or electricity is important, but focussing on direct costs alone does not capture the entire picture. An approach neglecting other economic factors could give the impression, that if there were no energy transition, it would be possible to provide an energy supply system at no extra cost. Of course, the opposite is true. Serious cost-benefit analyses would have to include the investments needed to continue to operate the current fossil generation fleet along with the procurement costs of fossil fuels. Holistic economic analyses must consider further relevant macro-economic effects of the energy transition. Important aspects are increased economic activity and employment, reduced import costs of fossil fuels, phasing-out of high subsidies for fossil fuels or decreasing generation costs of RE.

Macro-economic benefits of the energy transition

Improving investment, growth and employment is a goal nested under the objective of an affordable energy transition as well. Moreover, energy transition technologies constitute an important category of German exports. A wide variety of German industries ranging from motor vehicles, mechanical engineering, electronics and chemicals meet international demand for RE and EE solutions. The share of the energy industry in German exports grew to almost 10% in 2018, corresponding to a value of 120 billion EUR.

Investments into the construction of RE plants stood at almost 20 billion EUR in 2022and have been growing after a slump during 2018 and 2020. Investments are lower now than they were during the years of 2008 to 2012 (Figure 18) due to falling costs of RE over time and lower renewable capacity additions from 2018 to 2020. In addition to the investment in RE plants, more than 10 billion EUR are invested annually in expanding and modernising the electricity grid[65]. Apart from the electricity sector, investments in other areas important to the energy transition such as in energy-efficient buildings, heating and the transport sector are increasing. Investments for energetic renovations in the existing building stock experienced an increase of more than 25% since 2010 and reached 46 billion EUR in 2019.

64 ENTSO-E, 2021, Completing the map: Power system needs in 2030 and 2040

65 BNetzA, 2022a, Monitoringbericht 2021

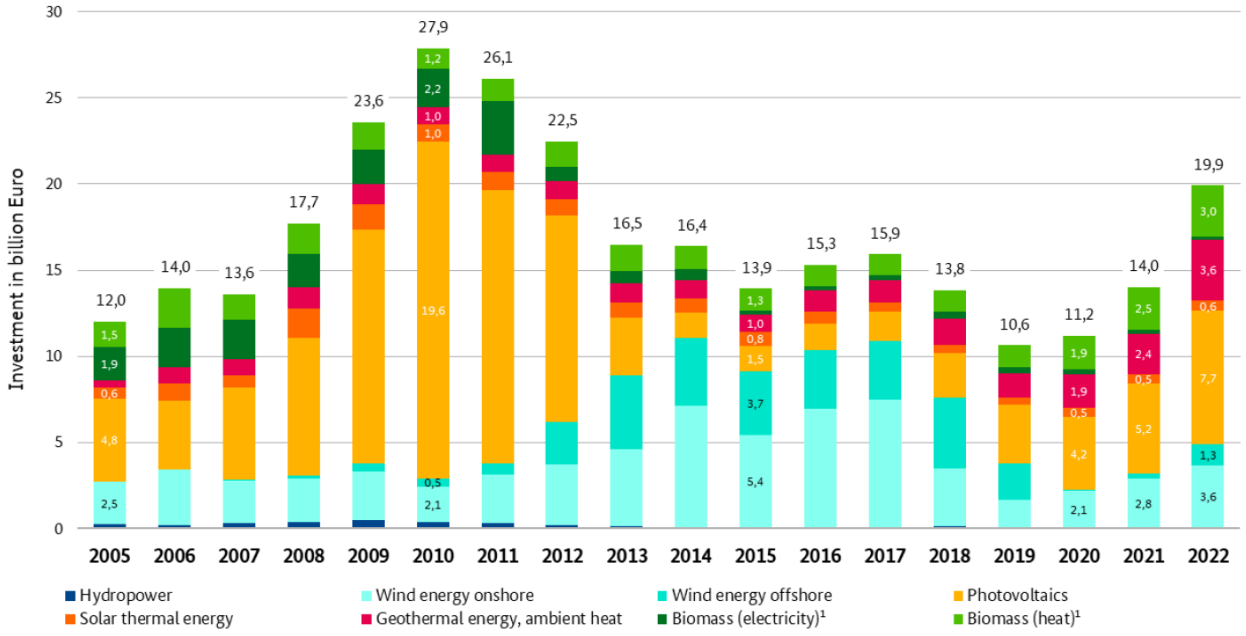


Figure 18: Development of investment in construction of RE plants in Germany[66]

A further macro-economic aspect of the energy transition is the provision of employment and new jobs to a large number of people. While in 2018 roughly 270 thousand people worked in the German conventional energy industry (generation, transmission, distribution, trading, mining or refining), about 300 thousand people are now employed in the RE sector in total and an additional 540 thousand are working in the energetic renovation sector[67].

For the year 2018 alone, RE and EE measures saved Germany 24.6 billion EUR due to a lower need for imported fossil fuels. This is approximately the same amount as is paid as financial support to RE generators through feed-in tariffs or the market premium under the Renewable Energy Sources Act. In times of high fossil fuel prices as currently experienced globally, savings are even higher.

Cost reduction of renewables

The rapid expansion of RE worldwide generated demand for renewable technologies and led to cost savings across the entire manufacturing and deployment cycle of wind and solar power. Feed-in tariffs paid to the generators gradually declined, and with the introduction of public auctions in the Renewable Energy Sources Act from 2014 and 2017, competition between project developers of renewable power plants reduced the costs even further.

For large ground-mounted PV systems, the average financial support dropped by almost 50% from more than 9 ct/kWh in 2015 to less than 5 ct/kWh within three years. During the first half of 2022, the average funding rate for ground-mounted PV systems rose slightly above 5 ct/kWh. For wind energy, the maximum funding rate also went down due to the introduction of public auctions. Average funding rates for onshore wind dropped below 6 ct/kWh in the latest auctions in 2021 and 2022. The offshore wind energy auctions produced average funding rates between 0 and 4.6 ct/kWh[68].

Energy and electricity price development

The average annual energy expenditure of German households has been relatively stable. The share of all energy expenditures in net consumption for households stayed below 10% during the past years[69]. The share of energy expenditures of German households is in the lower third when compared with other EU countries[70].

Electricity prices for households in Germany have increased from about 20 to 30 ct/kWh from 2007 to 2020. Main contributors to the price increase were the grid fee and the EEG surcharge. The EEG surcharge finances the feed-

66 BMWK, 2022d, Development of Renewable Energy Sources in Germany in the year 2021

67 BMWK, 2021, Energieeffizienz in Zahlen

68 BNetzA, 2022c, Roadmap Energieeffizienz 2045

69 BMWi, 2021a, The Energy of the Future: 8th Monitoring Report on the Energy Transition - Reporting Years 2018 and 2019

70 EU Commission, 2018, Commission Staff Working Document: Energy prices and costs in Europe

in tariff and the market premium for renewable electricity generators. With more RE being added to Germany's grid, this surcharge has increased during the past. As RE became cheaper and the older more expensive RE will not receive any funding after 20 years, the expenditures for the feed-in tariffs and the market premium will decrease in the coming years.

Certain energy-intensive industries and businesses are partially or fully exempted from some electricity price components, such as electricity tax, grid fees or the EEG surcharge. Depending on the respective industry and the actual exemptions, the price for electricity for those users is much lower than the household electricity price (Figure 19). This keeps German industry competitive on the world market.

While the EEG surcharge increased electricity bills for some end customers, more renewable generation had the effect of falling spot prices at the electricity market. Therefore, the sum of spot market prices for electricity and the EEG surcharge was relatively stable during the past 10 years. However, since 2021 drastic price increases of fossil fuels led to rising spot market electricity prices (Figure 20). To reduce the burden on electricity consumers, the government decided to finance the entire EEG surcharge of about 20 to 25 billion EUR per year via the Energy and Climate Fund and governmental budget from July 2022 onwards. Due to that decision, household customers need to pay 6.5 ct/kWh less for their electricity than before, a decrease of 20%.. The Energy and Climate Fund receives more than 12 billion EUR per year from the EU and the national ETS.

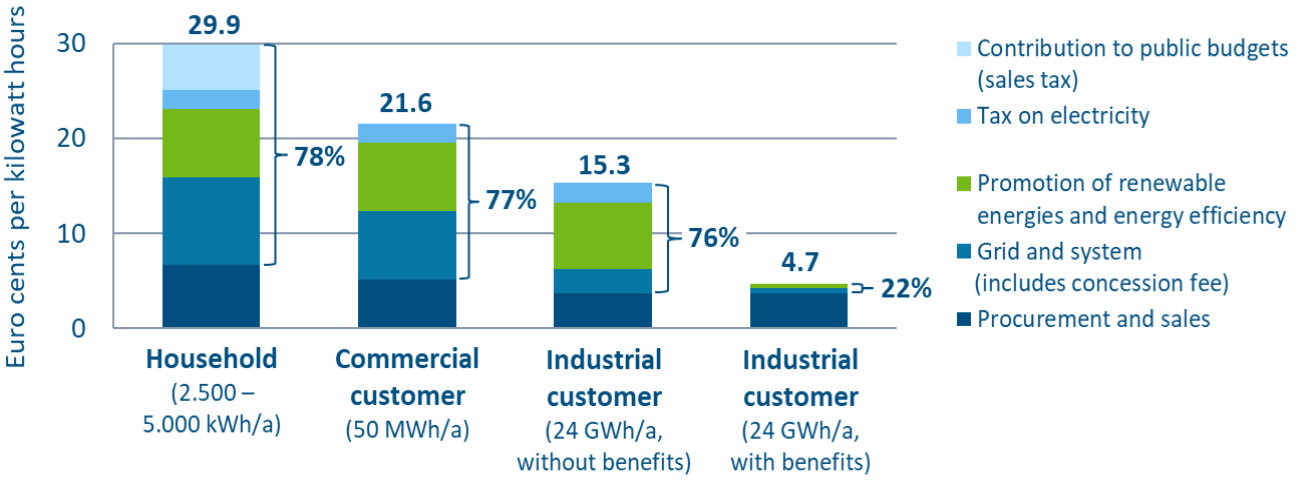


Figure 19: Electricity price components for different user groups in Germany in 2018[71]

71 BMWK, 2022b, International communication of the German energy transition

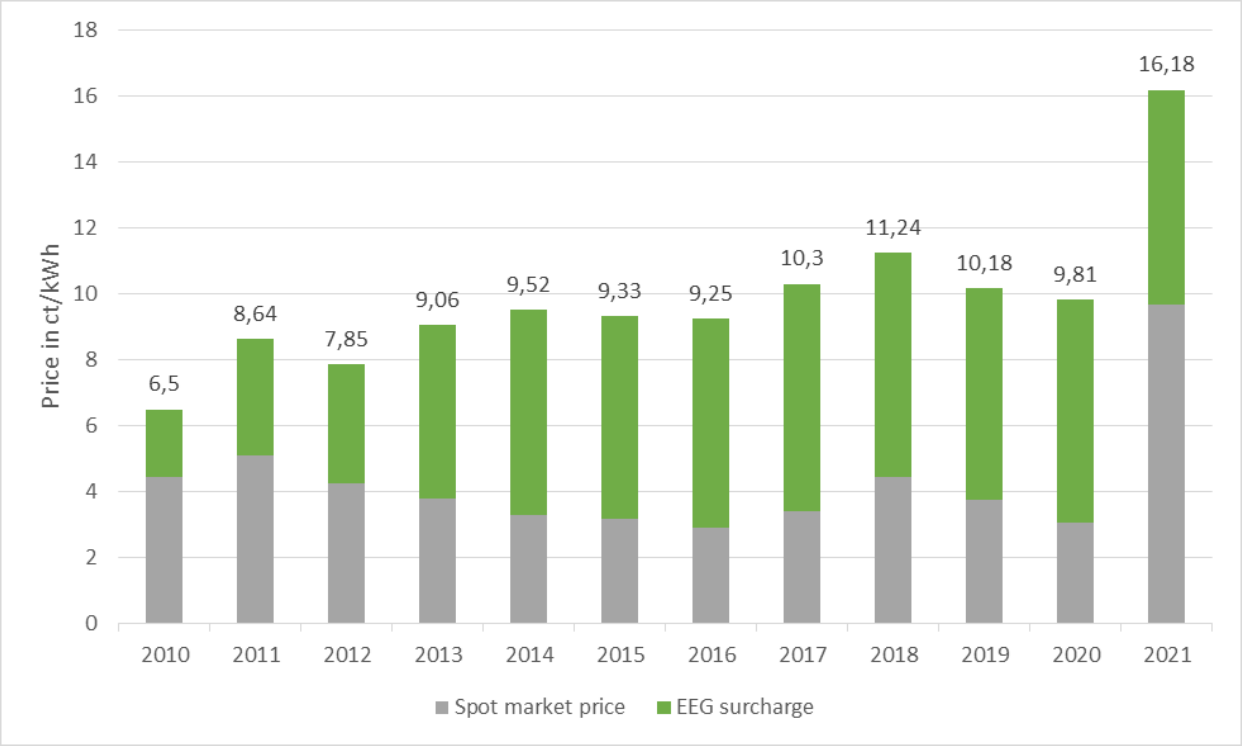


Figure 20: Development of combined spot market electricity price and EEG surcharge in Germany

There are additional impacts of high electricity prices at the spot market due to surging fossil fuel prices. RE generators can cover a large amount or all their guaranteed funding through sales at the spot market, thus reducing the financing need by the government. Higher electricity prices at the spot market also increasingly incentivise the construction of PV and wind power plants without financial support from the government at all. Especially industrial and commercial electricity consumers make use of long-term power purchase agreements (PPA) with RE plant operators: Investments into RE and procuring electricity from renewable power plants makes sense from a business perspective.

4.3 Reducing emissions on all fronts

The supply of energy must be compatible with the environment, the climate and nature throughout the entire life cycle of the respective technologies and underlying infrastructures. The implementation of the energy transition avoids GHG emissions as well as other air pollutants. Its success is closely linked to achieving environmental and specifically climate targets (compare Annex 2).

Avoided GHG emissions

Until 2022, the switch to RE, increased EE measures and the structural change of the German economy reduced GHG emissions by about 40% or 500 million tonnes compared to 1990. About half of these emissions reductions over the past 30 years are due to increased EE and structural change towards a more service-oriented economy. The other half is due to RE. The avoided emissions through utilisation of RE have increased almost eight-fold between since 1990: from 28 to over 230 million tonnes (Figure 21).

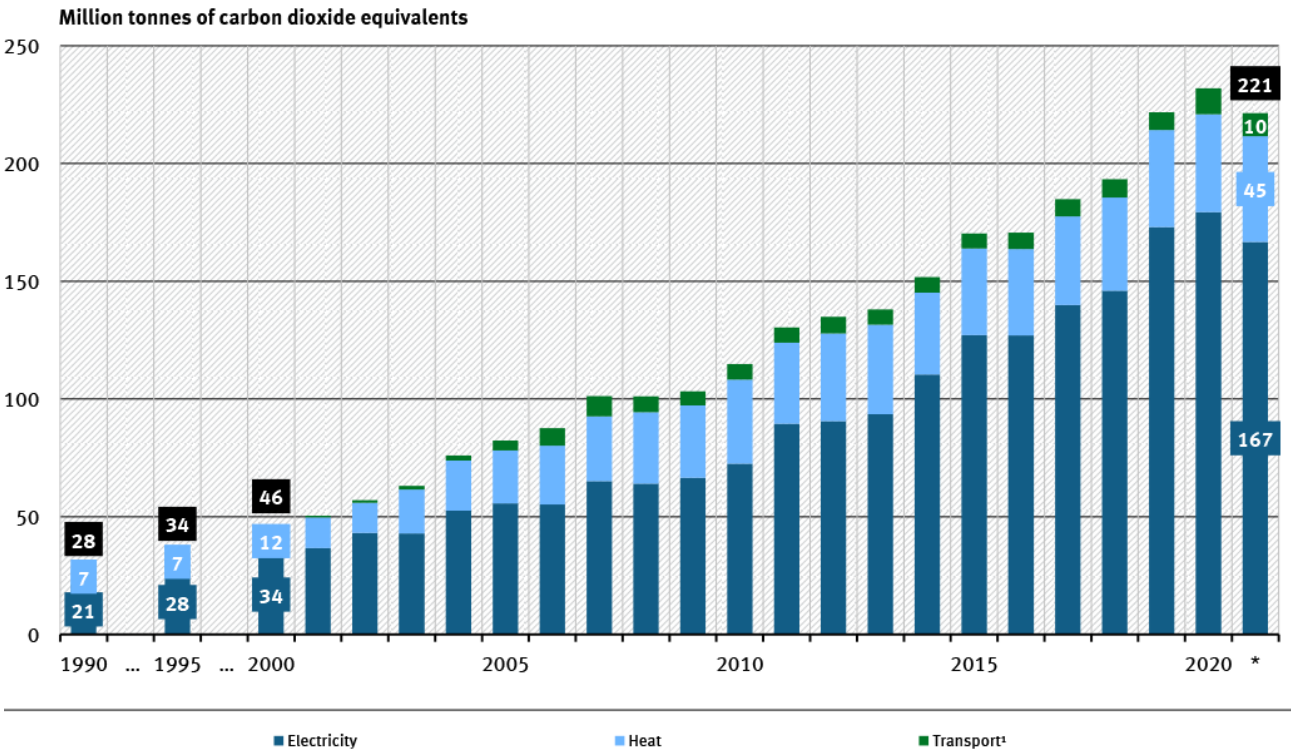


Figure 21: Avoided GHG emission through renewables in Germany[72]

RE in the electricity sector have the largest effect on avoided emissions with a share of about 75% of the total. This is not surprising, because the electricity sector has the highest share of RE and displacing coal-fired power generation avoids large amounts of GHG emissions. Roughly 20% of the avoided GHG emissions can be attributed to the heating sector, while the remainder comes from the use of biofuels and electricity in transport.

Zooming in to the RE carriers responsible for the avoided GHG emissions in 2020 reveals that the single largest contributor was wind energy with more than 40% – followed by biomass in all sectors with 32%. Increased direct utilisation of RE in the heating sector as well as the use of renewable electricity through sector coupling will reduce primary energy consumption from fossil fuels. In turn, even more GHG emissions can be avoided.

Reduction of air pollution

While the obvious effect of the German energy transition is the reduction of GHG emissions, the expansion of RE also reduces harmful local air pollution from burning fossil fuels. The release of pollutants such as nitrogen oxide, sulphur dioxide, mercury or particulate matter represents a negative side-effect of the current energy system based on burning fossil and biogenic fuels for energy, heating or transportation purposes.

In 2018, the usage of fossil fuels for energy purposes accounted for about 71% of nitrogen oxide, 64% of sulphur dioxide, 20% of particulate matter and 72% of mercury emissions of Germany. Due to strict environmental regulation, the implementation of efficient flue gas treatment and the replacement of inefficient and old boilers, the emissions of these air pollutants have been in decline since 1990, as Figure 22 demonstrates.

72 UBA, 2022b, Indicator: Greenhouse gas emissions avoided by renewable energies

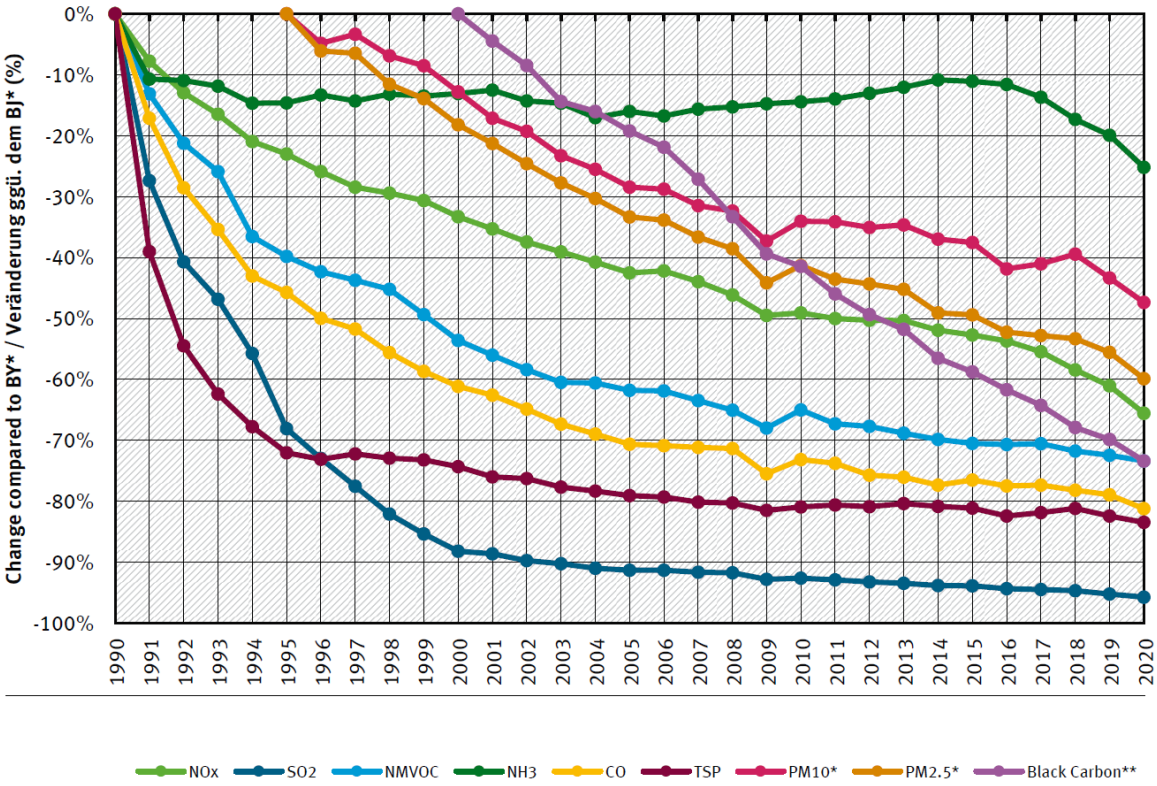
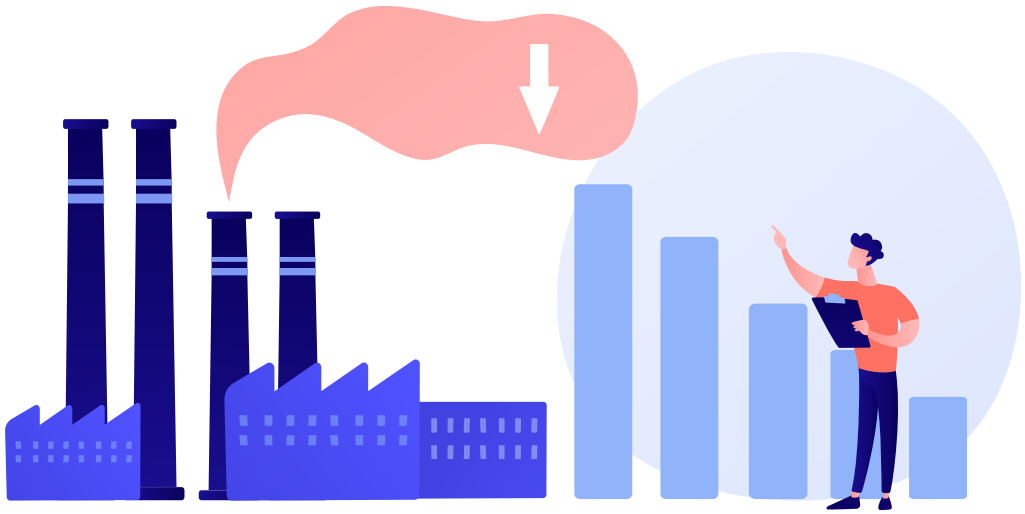


Figure 22: Reduction of air pollutants in Germany[73]

Coal-fired power plants produce a large part of the remaining air pollutants in Germany. The phase-out of coal-fired electricity generation will not only reduce GHG emissions, it will also have a marked effect on air quality and human health through the reduction of air pollution. The electrification of the heating sector through heat pumps and the transport sector through electric mobility, will alleviate local air pollution, especially in dense population centres.



73 UBA, 2021, Trend der Luftschadstoff-Emissionen

5 Greater ambitions: the future of the German energy system

The German energy transition is well under way. Progress has been made especially in the expansion of RE in the electricity sector. Developments concerning EE and sector coupling intensified during the past five years. However, future energy and climate targets call for higher ambitions. Additional efforts are required to achieve the new 2030 targets and to bring the energy transition on the path to long-term success.

The transformation accelerates until 2030

GHG emissions must fall by 65% until the end of this decade compared to 1990 to reach the targeted level of 438 million tonnes. Due to increased sector coupling, the Federal Government expects electricity consumption to rise by a quarter to approximately 750 TWh until 2030. While the energy sector still has the largest potentials to avoid GHG emissions, efforts in other sectors need to be strengthened as well.

Renewable capacity needs to expand faster than in the previous years to reach the target share of 80% of gross electricity consumption or 600 TWh of generation in 2030. The annual capacity additions for solar PV and onshore wind need to rise to unprecedented levels (Figure 23). To achieve the large expansion of more than 30 GW RE per year from 2025 onwards, the Federal Government increased the auction volumes and the feed-in tariff for selected PV plants. Permitting procedures are being streamlined and a process to make 2% of the land area available for wind parks has been initiated between the Federal Government and the federal states[74].

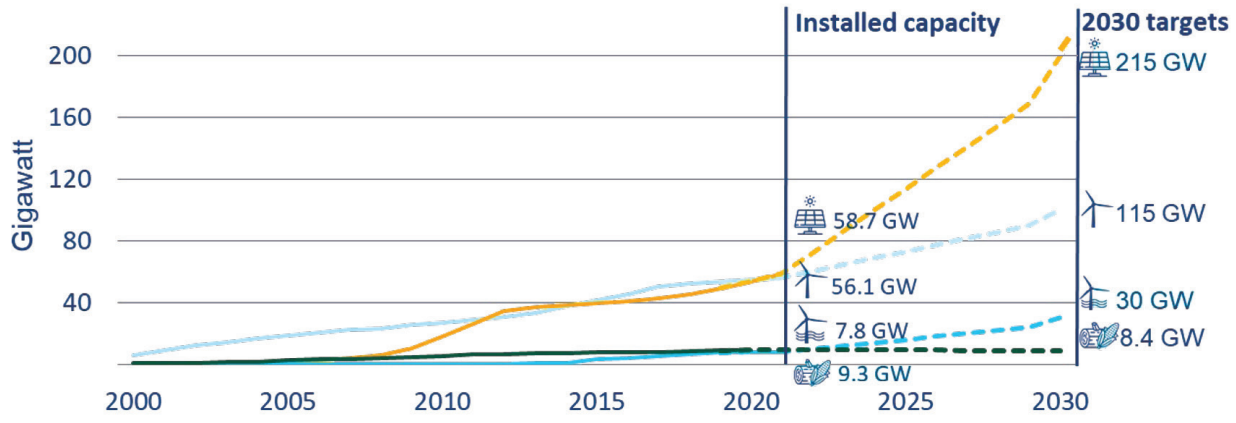


Figure 23: RE capacity in Germany and the new 2030 targets[75], adapted by author

74 BMWK, 2022f, Überblickspapier Osterpaket

75 BMWK, 2022b, International communication of the German energy transition

To reduce emissions in the building sector and to supply half of the heating demand in a climate-neutral manner by 2030, comprehensive measures are being prepared and implemented. The GHG emissions in the transport sector have to decrease drastically, where electrification of transport will play a major role. To achieve emission reductions in the industry, a Contracts for Differences approach will be tested in pilot programmes under the Hydrogen Strategy and the H2Global mechanism to compensate additional costs for climate-neutral industrial process innovations. Table 13 summarises important measures for accelerating the energy transition and to achieve emission reduction targets across the sectors building, transport and industry.

Table 13: Measures for emission reductions until 2030 in different sectors

Buildings	Transport	Industry
Municipal heat planning processes	Electrification of private passenger transport	Electrification of processes
The expansion of district heating networks	Increase electric heavy-duty transport	Energy-efficiency measures
New mandatory EE standards for new buildings and renovations	Expansion of public charging points	Utilisation of green hydrogen
Expansion of heat pump systems	Increase rail traffic	Implementation of contracts for differences
Emission reduction target	**Emission reduction target**	**Emission reduction target**
44% compared to 2020	42% compared to 2020	30% compared to 2020

Actions are also required in sectors that previously were less prominent in climate and energy policy. Efforts in the agricultural sector focus on increasing the share of ecologically farmed land to 30% and the reduction of fertiliser input. In land use, land use change and forestry the overall carbon sink function must double to achieve 25 million tonnes of negative emissions by 2030. Measures include the protection and restoration of ecosystems, such as bogs, swamps, forests and grasslands.

During this decade, more systemic and innovative approaches need to be implemented. Those will accelerate the reduction of GHG emission and prepare the path towards transforming Germany to a carbon-neutral economy. The current Federal Government's increased ambitions and programmes reflect the need for stringent and quick action.

Long-term developments towards carbon-neutrality

Energy forecasts and scenarios provide an indication of future developments in the energy supply. Forecasts predict the most likely development, while scenarios describe a future that could develop under certain assumptions. Energy and GHG emission forecasts and scenarios are both based on assumptions about long-term demographic, economic, technological and political developments. Models are used to develop a comprehensive picture of the future energy supply. Such forecasts and scenarios are limited in how well they can reflect the complex real world and are thus subject to simplification. Still, governments, organisations and companies use the results of such studies as a reference for devising economic policy or corporate strategies[76]. (BMWK, 2022f). Many different studies and scenarios that focus on the longer-term climate and energy transition development of Germany have been commissioned and published. Important scenarios on the future energy transition are published by research institutes, think-tanks and consulting groups, but also the German transmission system operators (TSOs).

The scenario framework of the German TSOs from early 2022 was developed as part of the national grid planning process[77]. It included for the first time a scenario up to the year 2045, the year when Germany must reach climate-neutrality by law. The scenario provides a comparison of studies and scenarios of research institutes and think-tanks on a few key parameters. Figure 24 shows the expected development of gross electricity consumption in Germany

76 BMWK, 2022g, Energy Forecasts and Scenarios

77 50 Hertz, Amprion, TenneT TSO, TransnetBW, 2022, Szenariorahmen zum Netzentwicklungsplan Strom 2037 mit Ausblick 2045, Version 2023

during the coming decades. Scenarios by different studies all expect an increase until 2045 and many end at or above 1000 TWh – almost a doubling of electricity consumption over the next 20 to 25 years. According to the TSO scenario, sector coupling will accelerate especially from 2030 and lead to an additional electricity demand of more than 500 TWh until 2045. This increase corresponds to roughly the current German annual electricity consumption. The additional demand will originate from electric mobility across all modes of transport, electrification of industrial processes, electrolysers producing green hydrogen and the utilisation of heat pumps for heat generation.[78]

Germany's path towards climate-neutrality and an energy system based on RE is feasible according to studies and analyses by a wide range of actors. Still, the complete transformation of the energy supply and demand system during the coming decades constitutes an enormous task. RE need to be expanded massively, new technologies need to be implemented on a large-scale and investments for EE and sector coupling must be unlocked across households, business and industries. Governmental steering through policy-making and adequate support programmes will be required. The successful energy transition in one of the world's largest economies will help alleviate climate change impacts, increase living standards, guarantee economic prosperity for Germany in the long term and can serve as an example to other countries as well.

Figure 24: Comparison of different energy transition scenario studies[78]

78 50 Hertz, Amprion, TenneT TSO, TransnetBW, 2022, Szenariorahmen zum Netzentwicklungsplan Strom 2037 mit Ausblick 2045, Version 2023

6 Insights and policy recommendations from Germany's energy transition for China

6.1 Insights from Germany's energy transition for China

Energy transition is an important element in the implementation of Chinese carbon peaking and carbon neutral strategies ("dual carbon" targets). The transition from fossil energy to RE can directly reduce carbon emissions and help synergise technologies and policies to promote EE, accelerate industrial upgrading and achieve a low-carbon transition.

With respect to conventional fossil energy sources, Germany has abundant coal reserves but basically relies on oil and natural gas imports. Germany conceived its transition to RE back in the 1990s, and in the beginning of the 21st century officially launched the energy transition to address climate change. After more than two decades of efforts, Germany's energy transition has achieved significant results: The share of RE in electricity consumption has increased from 6% in 2000 to 50% in 2020, national EE has increased by nearly 30% and GHG emissions went down by 40% compared to 1990. Germany has also set medium- and long-term goals of increasing renewable electricity generation to 80% by 2030 and achieving carbon neutrality as a country by 2045.

Germany's energy transition is a long-term strategy, not only for the transformation of the energy system, but also for the entire national economy and the way society operates. Drawing from the results and measures of Germany, this section analyses the implications of Germany's energy transition for China's goal of achieving peak carbon emissions (by 2030) and carbon neutrality (by 2060) and propose corresponding policy recommendations. The four main insights for China identified from the German energy transition are to strengthen top-level policy design, prioritise energy efficiency, enhance the active role of the market and focus on energy security and international cooperation.

Strengthen top-level design through legislation and policy

Germany's energy transition strategy is implemented through high-level policies and legislation providing the overarching framework and governance as previous chapters of this report show.

1. Monitoring implementation and policy continuity

Policy continuity of Germany's energy transition is at a relatively high level, creating sustained and moderate policy pressure to effectively drive smooth and orderly implementation of various plans and efforts. Germany ensures the achievement of targets through annual monitoring and compliance mechanisms. In accordance with the Energy Concept from 2010, a four-member independent energy expert team prepares an annual monitoring report on the implementation of the entire energy transition strategy. The report includes an assessment of the processes and policies, an evaluation of the overall progress achieved, the status of the energy transition in Germany and an outlook on key future energy transition indicators. The report is published by the German Federal Ministry of Economics and Climate Action and submitted to the German Bundestag and the German Bundesrat for consideration. The results and recommendations may be translated into relevant bills or policy measures, as appropriate. A similar annual monitoring process is in place for assessing the German progress towards its climate targets. Also at the EU level, Member States must report on their energy consumption, EE policies, long-term strategies and expected improvement measures to the European Commission annually under the National Energy Efficiency Action Plans and update these plans every three years to maintain policy continuity.

The Chinese Government issues five-year energy conservation and carbon reduction plans or action programmes to guide relevant national efforts and supervise monitoring. However, the implementation and follow-up in some regions or departments at the beginning of each five-year cycle is subdued due to the relatively light policy pressure. On several

occasions, some regions "sprinted" through the policy cycle at the end of the five-year period to ensure achieving targets, which in fact partially offset the overall energy conservation and emission reduction efforts and policies.

2. Enhance energy efficiency and renewable energy use through sector coupling

Germany emphasises coupling between different sectors (heating, transport and industry) by means of electrification – heat pumps, electric vehicle charging stations or new technologies, such as green hydrogen – in order to increase RE use, reduce primary and final energy demand and amplify efficiency gains between sectors. Sector coupling in households, businesses and industry needs to be supported through policy guidance and dedicated support to enable large-scale uptake of new technologies, accelerate application of RE and enhance EE investments.

China's policies on energy conservation, emission reduction and RE are divided among several departments such as the National Development and Reform Commission, the Ministry of Ecology and Environment and the National Energy Administration. Due to the differences in policy objectives among departments, policy synergies need to be uncovered and improved. Importance lessons can be learned from Germany's experience in promoting sector coupling with existing technologies.

3. Provide sufficient financial support for energy saving and emission reduction consulting services

Germany has several dedicated financial support programmes for EE measures, targeting households, business and government. Germany's National Action Plan on Energy Efficiency (2019) focuses on the energy demand side with measures at four levels:

- Providing information and advice to end users on how to save energy;
- Promoting investments in EE through tax incentives;
- Making energy audits mandatory for large companies;
- Setting standards for new facilities and buildings.

The financial support is earmarked to provide investment grants or low-interest loans for energy consultations, preliminary design, engineering and special funds. Specific services mainly for homeowners and SMEs exist on information, consulting, energy management and contracting. The EE service for homeowners entails several parts. First and preliminary consultations at the Energy Consumer Centre (special organisation that helps individuals to claim their rights on many consumer issues related to energy) are available while in-depth, on-site consultation by energy experts are organised through the German Federal Office of Economic Affairs and Export Control (BAFA). For implementation of EE measures, preferential loans or grants are provided by the KfW Construction Supervision Programme. Thus, homeowners can consult the energy experts at the Energy Consumer Centre or use the "on-site consultation" energy consulting service offered by BAFA to obtain a customised energy-saving retrofit programme[79]. It is estimated that the above consulting services contribute to 10% of the emission reduction in projects[80].

In contrast, EE consulting services in China receive less stable governmental financial support, and some service providers and practitioners are of mixed quality. This leads to poor quality in a considerable number of energy consulting services where audit or diagnostic reports are only formal: They mostly only deal with the status quo of energy usage, but do not sufficiently explore energy saving and emission reduction opportunities. Thus, they do not provide effective support for implementing measures[81].

Prioritise energy efficiency through practical initiatives

1. Incorporate the "energy efficiency first principle" into the policy

The "EE first principle" is contained in the EU's Energy Efficiency Directive (2012/27/EU). It is a guiding principle of German energy and industry policies as well as in the financial sector, where EE solutions are seen as the preferred option for investment decisions. According to the Energy Efficiency Directive, EU Member States should ensure that EE is considered in planning, policies and major investment decisions. Cost-benefit analysis are recommended for properly assessing the broader benefits of EE programmes from a societal perspective. Member States must also report to the European Commission on how the "EE first principle"

79 GIZ, 2019, German Energy Efficiency Policy Study

80 GIZ, 2022, German energy efficiency policy in the context of carbon neutrality

81 Zhang Di, 2019, Study on the Innovation of Energy-saving Monitoring System in Beijing,

is reflected in their planning, policies and major investment decisions.

Under China's policies, such as project energy assessment and planning review, the principle of EE first is well reflected in large, key energy-using entities, but often not fully reflected in small-scale industrial enterprises (e.g. 2-3 million tons/year of steel production capacity). In the context of the "double carbon" strategy, enterprises' independent decision-making on low-carbon investments needs to be more strongly guided and promoted.

2. Clarify legal energy audit requirements

Energy audits provide the basis for decision-making by systematically identifying priorities for energy saving and emission reduction. Clear energy audit requirements for large enterprises exist also in Germany: According to Article 8 of the EU's Energy Efficiency Directive large enterprises should carry out energy audits by December 2015 and again at least every four years thereafter. The German Government exempts companies from that obligation if they have obtained certification of their energy management system (DIN EN ISO50001) or EMAS environmental management system. Companies not covered by the exemption, and which fail to carry out an energy audit will be subject to a penalty of up to 50,000 EUR.

At the same time, the German Government provides financial support specifically for SMEs to carry out energy audits: SMEs can apply for funding for energy audits every 24 months, and energy auditors must provide SMEs with a detailed and verified analysis of energy-saving potential and recommendations for energy-saving measures. According to a survey by the German Energy Agency, SMEs have vast potential to save energy in general equipment, such as air conditioning and electrical equipment, generally up to 25-70%[82].

3. Publish action guidelines, technology lists and additional material

Information disclosure is an important measure for low-carbon capacity building, and the provisions of the German energy and climate laws combined with information disclosure have a positive effect on implementation. To make up for shortcomings regarding insufficient professional capacity and lack of information in some countries, the European Commission has publicly released documents such as the "Recommended Guidelines for National Energy and Climate Plans" for Member States' planning reference and incorporated the contents of the guidelines into measures and reports. The guidelines provide detailed information on the application of energy-efficient and low-carbon technologies for lay people (e.g. residents), building owners or enterprises assisting their choices under expert guidance. A large amount of professional and authoritative information is regularly released in the EU and in Germany. As it is easily accessible to the public, it facilitates research for relevant stakeholders, improves professional capacity of (customer-side) energy managers and energy service organisations and increases the effectiveness of energy-saving projects and management measures.

Through the EU's Energy Performance of Buildings Directive all Member States must ensure that "the technical, environmental and economic feasibility of efficient alternative systems is taken into account before the construction of new buildings begins". The German Buildings Energy Act mandates the use of a specified percentage of RE for heating in new buildings and clarifies options such as the use of solar collectors, heat pumps or biomass boilers, high quality insulated partition walls, the use of central heating systems or combined heat and power systems. The law also contains regulations on building energy performance and the issuance and use of energy certificates.

In contrast, technical information on technologies and measures issued in China lack wide-scale dissemination. Material released in China mostly describes a particular technology in general terms and lacks in-depth information on the integration of related system technologies and application cases. Most of the financially supported research results are only available as abstracts, and the full text is rarely disclosed to the public. Access for the public is difficult, thereby restricting promotion and application of the results.

4. Ensure high-quality work through certified energy consultants

The EU's Energy Efficiency Directive stipulates that only certified energy consultants are authorised to issue energy certificates for existing residential buildings, and that national schemes must be developed for professional qualifications related to building and energy technology. The

82 GIZ, 2022, German energy efficiency policy in the context of carbon neutrality

energy consultants must provide proof of participation in further training and continuing education: For practitioners engaged in energy consulting for buildings or SMEs, there are specific requirements on the content and scope of the professional training they need to attend. Training content for more than 200 modules are precisely defined and recognition of the expertise is subject to a final review. A large amount of professional energy consultants in Germany are trained by the European Society for Engineering Education (SEFI), ENGINEERS EUROPE, the European Federation of National Engineering Associations (FEANI) and the German Chamber of Commerce and Industry in Nuremberg (EUREM). They provide energy audits, evaluation of EE improvement, data analysis and funding and subsidy recommendations. Many funding programmes require EE improvement recommendations from certified consultants which are used as the basis for investment decisions and financial support (e.g. Federal Funding for Efficient Buildings – Non-Residential Buildings). The German certified EE consultant mechanism guarantees the professional quality of energy service practitioners and the authority of the services provided.

In comparison, since the end of the pilot programme for energy managers in Beijing, Shandong and five other provinces and cities under the 12th Five-Year Plan, the progress of high-level energy professional training and certification programmes in China has been slow. Some of the existing training programmes have catered to the market and relaxed quality requirements, resulting in poor reputation. In addition, energy- and emission-saving technologies are developing rapidly, and the integration of different technical solutions is necessary. As requirements continue to rise, there is a huge shortage of high-level professionals with solid basic skills and practical experience restricting progress[83].

5. Set up energy efficiency network groups and mobilise different parties

Germany's EE network groups are collaborative practices of on-site personnel of different companies supported by external experts. The groups are generally initiated by government agencies, industrial organisations or private company initiatives with clear targets: exchange of experiences on EE improvement and of ideas among participants on a regular but voluntary basis. The EE network groups often invite external experts and consultants to participate and moderated the process and help companies to identify and implement energy-saving projects.

Germany's EE network group activities have effectively stimulated and raised awareness in enterprise personnel with distinct results. According to an evaluation by the German Government, during 2008-2014, each of the 30 EE network groups proposed an average of 10 measures, achieving an average energy and GHG emission saving of 2,700 MWh/year and 940 tons/year, respectively[84]. China's Total Quality Management (TQM) system could learn from these experiences on EE improvements.

Enhance the active role of the market and the public

The German Government follows the model of legal requirements, supplemented by incentives and public information to combine relevant policy measures and guide enterprises to act on their own. Public participation and independent action along with the provision of guidelines (e.g. technical support) is used to stimulate energy saving and emission reduction (Figure 25). This approach is lacking in China and makes continuous energy saving and carbon reduction difficult to achieve.

Legal Requirements (Regulations, directives etc.)	Incentive Policies (e.g. incentives from grants or subsidiaries)	Information sharing (e.g. public communication, raising awareness.)
No Incentives	Main measures to long-term transition with market-oriented perspective	Including key message publishing

Figure 25: The three pillars of German energy efficiency policy[85]

1. Promote market mechanisms in the energy sector

The German Federal Network Agency is responsible for promoting market mechanisms in the field of energy network infrastructure. This includes outlawing practices that prevent RE projects and distributed generation from connecting to the grid, standardising processes such as independent selection or change of energy suppliers by customers or improving conditions related to grid connection of RE generation. Starting from 2015, Germany

83 Zhang Di, 2015, Post Evaluation of the Pilot System of Energy Manager in Beijing

84 GIZ. German Energy Efficiency Network Development Experience, 2021

85 GIZ, 2019, German Energy Efficiency Policy Study

no longer supports green electricity with a governmentally determined feed-in tariff, but a competitive auction mechanism determines the financial support of larger scale renewable projects.

The implementation of market mechanisms has promoted technological progress and cost reduction in RE use, while reducing the burden on consumers. In comparison, the market-based reform of China's energy system (e.g. the electricity market reform) still has a long way to go.

2. Establish dialogue mechanisms to guide effective public participation

Germany's Energy Efficiency Roadmap 2045 and Climate Neutral Germany 2045 constitute core dialogue platforms for stakeholder participation hosted by the German Federal Government. Stakeholders include representatives from industry, business, civil society, academia and the Federal Government. The dialogue format includes plenary sessions, working group meetings and workshops, covering topics related to grid expansion, coal power phase-out, reactive power compensation, electricity market design (compare Chapter 2.3). Stakeholder dialogue mechanisms not only help to build broad consensus on specific topics, but also ensure the protection of rights and information transparency for all stakeholders in the energy transition, allowing citizens and the private sector to provide effective input to the government and participate in the decision-making process.

The Chinese Government promotes its "management and service" reform by taking into account needs of energy users, such as enterprises, already in the policy design stage. The public participation mechanism in Germany can be used as a reference to establish a policy arrangement that is more conducive to listening to and understanding the voices and wishes of policy audiences while attracting wider public participation and support..

Focus on energy security and international cooperation

1. Diversification of energy supply

By accelerating the transition to an energy system dominated by RE, Germany fundamentally aims to reduce its dependence on fossil fuel imports such as natural gas and more effectively address the challenge of energy security.

Germany launched emergency measures such as the planning and construction of four floating storage and regasification units and three land-based LNG import terminals in 2022 to diversify gas import pathways as soon as possible. Some facilities are already running and other will be constructed until 2025. In the medium to long term, RE and multi-channel imports of green hydrogen will completely replace fossil fuel imports.

2. Improve electricity system flexibility and ensure security of supply

Maintaining security of supply efficiently even after a complete phase-out from nuclear and coal power and a large-scale expansion of RE generation is crucial for the success of Germany’s energy transition. Next to developing the necessary grid infrastructure such as cross-country high-voltage DC power lines, the further development and integration of European electricity spot markets improves not only Germany’s but the entire region’s energy security.

Electricity generation from wind and solar power plants is fluctuating. The increased share of RE places higher demands on the German grid. Suitable market mechanisms, flexible power system technologies along with policy framework adjustments allow the integration of fluctuation generation into the power system through, e.g. better forecasts. Specifically, a key component of an electricity system based on wind and solar energy is peak regulation capability and much of it is achieved through market mechanisms alone, while grid operators have several further mechanisms at hand to safely operate the grid. Figure 26 depicts renewable generation and the residual load curve to be provided by conventional thermal power plants during March 2023. While RE accounted for a large part of the grid load during some days, conventional generation is extremely flexible in its output. This peak regulation is primarily achieved through price mechanisms at the electricity spot market.

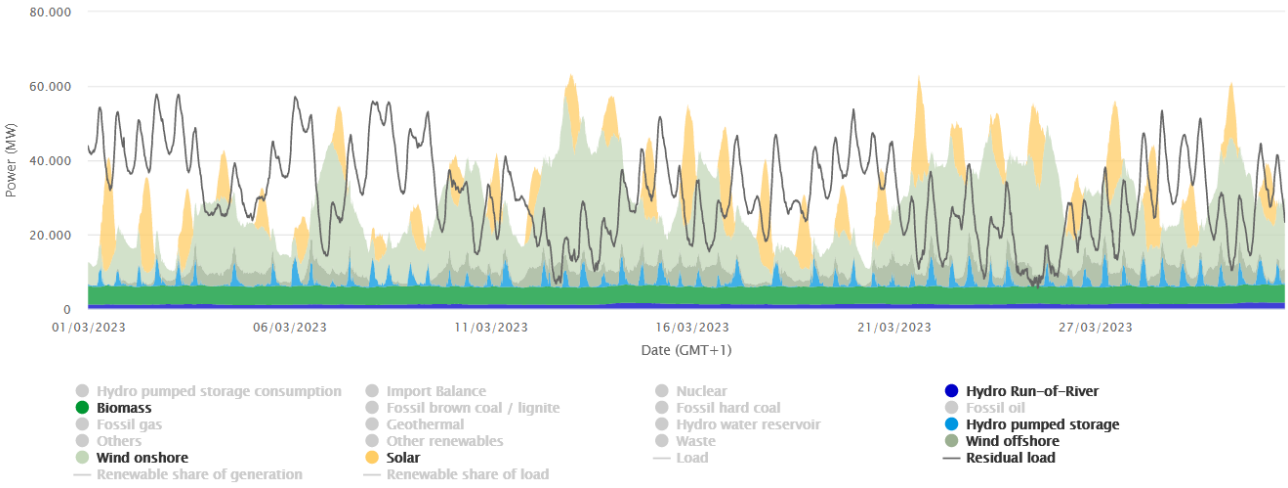


Figure 26: Renewable energy vs. residual load curve in Germany during March 2023[86]

The above-mentioned energy security strategy and the mechanisms to handle fluctuating renewable generation have important implications for China's electricity market reform. Especially the integration of RE through a range of flexibility solutions, spot markets and cross-border capacity (e.g. promoting cross-provincial or even cross-country grid capacity) will be instrumental in the utilisation of the ample renewable resources in China's north-western provinces and the transmission and supply of the south-eastern provinces with a high demand. While Germany's thermal power plants, both coal and gas-based, are running very flexibly due to price incentives from the electricity market, Chinese coal-fired units have limited incentive for flexible generation. The capacity of pumped-hydro storage plants in China should be drastically increased, while also changing the pricing scheme. Other means such as enhancing thermal power plants flexibility, battery storage and demand-side response also need to be promoted.

3. Strengthen international cooperation and promote the export of energy transition

International cooperation is a cornerstone of German climate and energy policy. Germany is the central hub of the European grid, and most countries in the EU are connected to Germany via the physical transmission grid and the European electricity market. Cross-border trading of electricity reduces prices for customers across Europe while allowing to balance electricity consumption between the countries and regions. Electricity is exchanged continuously between neighbouring countries, thus integrating fluctuating RE generation. In the medium to long term, more hydrogen and gas plants will make up for the loss of capacity due to the phase-out of coal. Future expansion of the German grid and increased interconnectivity with the rest of Europe will ensure security of supply.

Exporting the idea of an energy transition and associated solutions are an important part of Germany's international trade. Germany's dominant industrial sectors such as car manufacturers, mechanical engineering, electrical and electronics and chemicals are committed to meeting the international market demand for RE and EE improvement solutions. The utilisation of these technologies contributes to the energy transition in the relevant countries as well.

6.2. Policy Recommendations for China

Over the past decade, China's rapid economic development created strong energy demand, and the country's energy mix is predominantly based on fossil energy sources such as coal (58%) and imported oil and gas. China has however laid the foundation for a comprehensive transformation of its energy system by developing hydropower, PV and wind power at a large scale.

In the 20th National Congress report, the Communist Party of China pointed to an accelerated adjustment and optimisation of the industrial, energy and transportation structure. Based on China's energy resource endowment, carbon peaking needs to be implemented in a planned manner. This entails

86 Fraunhofer ISE, 2023, URL: https://www.energy-charts.info/charts/power/chart.htm?l=en&c=DE&legendItems=00011000000100011101000&interval=month

the reduction of energy intensity, a focus on controlling fossil energy consumption and a gradual shift to a "dual control" system for total GHG emissions and intensity. The main policy recommendations for China are to adopt integrated planning to ensure energy transition progress based on national conditions, promote emission reduction through focus on energy conservation and efficiency and to improve supporting measures to enhance policy synergy.

Adopt integrated planning to ensure energy transition progress based on national conditions

1. Take strategic decision regarding energy transition to ensure overall energy security

With the expectation of a continued economic growth in China, the “dual carbon” goal needs to be the starting point, with priority given to expansion of RE. Simultaneously, policies must consider energy import dependencies of oil and gas by improving domestic production. China should actively support industrial transformation, take a lead in new energy research and strengthen the security of supply for strategic resource supply chains needed for the transition, such as lithium, platinum, nickel, titanium, manganese, vanadium and rare earth metals.

2. Intensify reforms of the electricity system for security of supply

In 2020-2022, several Chinese provinces experienced blackouts and electricity rationing, due to a mismatch of supply and demand in peak periods. Preventing further security of supply issues are thus an important task. As electrification and digitalisation are promoted, domestic electricity demand is expected to increase in the coming years. Therefore, both the electricity supply and the demand side need to interact, building a smart grid, improving load forecasting and flexibility capabilities and develop demand-side integration of loads and storage. Investments into infrastructures and increased transmission capacities must ensure greater consumption of renewables as well as grid security in a RE based energy system.

Therefore, reforming the electricity system and establishing a national unified electricity market need to be accelerated. In that way generation resources can be allocated efficiently nationwide. Relevant tools to achieve such a reform are shown in Table 14.

Table 14: Mechanisms and tools for electricity market reform in China

Market design	Electricity markets
Equal competition and independent actors	Long-term markets to guide investment decisions
Cross-provincial and -regional resource allocation	Spot markets for short-term allocation
Renewable electricity transactions	Auxilliary service markets for security of supply
Demand side response and storage mechanisms	

3. Develop synergies between energy transformation and national conditions

Changing China's coal-dependent energy structure will be a difficult and lengthy process. A RE energy system needs to gradually replace fossil resources. Coal will remain an important source of energy for the coming years, so the promotion of its use in modern and efficient energy and industrial processes must go hand in hand with phasing out old and inefficient power plants while reducing the environmental impact of coal mining and utilisation. To avoid decoupling of policy decisions on energy from the reality of industrial energy users (e.g. coal, electricity and gas supply shortages), drafting of decision-making documents should pay attention to the views of other actors such as enterprises to effectively couple government policies and the decisions of market agents.

4. Support innovative solutions for the transformation

New disruptive technologies are emerging in the fields of oil and gas, energy storage, hydrogen and advanced nuclear energy. This includes small nuclear reactors in the United States or hydrogen in the EU, UK and Japan. Technological breakthroughs and application of these technologies can create benefits for the entire energy system.

China should therefore focus on its technological capabilities in key industries and promote research and development through the national science and technology innovation system. Furthermore, the ongoing digital transformation can leverage EE and GHG emission savings both on the supply and demand side. Large-scale adoption of new technologies is a prerequisite for having a first-mover advantage. Institutional innovation and the implementation of market-based systems in the energy system need to be advanced.

5. Strengthen international cooperation and improve strategic energy reserve capacity

Given that China's energy consumption is still growing and its import dependency for oil and gas remains high, strengthening international trade cooperation and promoting diversification of energy supply sources is vital. This includes developing land-based pipelines, coastal gas storage facilities while growing maritime transportation capacity to form a three-dimensional energy import system.

International cooperation in the field of RE, especially practical cooperation with European countries can assist in learning from the practices of energy transformation, technological innovation and industrial progress in those front-running countries. Working with the International Energy Agency, the International Renewable Energy Agency and other institutions will foster domestic innovation and allows China to actively participate in global governance of the energy sector.

Promote emission reduction through focus on energy conservation and efficiency

1. Revise the Energy Conservation Law and other overarching policies to provide legal guidance

The specific requirements for energy audits (energy-saving and GHG emission reduction audits) and energy conservation monitoring need to be clarified to provide high-level policy support. Criteria and policies also need to be aligned with the Anti-Unfair Competition Law and other compliance regulations.

The Energy Conservation Law and the Measures for the Administration of Energy Conservation in key energy-using units currently lack details for carrying out energy audits. The responsibilities and obligations of large enterprises, SMEs, industrial parks and service organisations are not clear enough and legal requirements for the energy audit cycle are missing. When revising these regulations, the following should be considered:

- Improve provisions related to energy audits;
- Enhance enforceability as an overarching legal requirement;
- Provide guidance and support for local regulations, rules and working standards.

Clarification is needed that audits are legally binding for large enterprises above a certain size. To support China's carbon peaking and carbon neutrality targets, the audit should be repeated every three years. The responsible authority and the tasks of the auditor need to be clarified. Three typical shortcomings in the energy report and auditing inspection exist: Utilised systems are not suitable, energy consumption is too high and recommended measures are not implemented. The conclusion of the audit report and the implementation of measures should provide details for major projects, new investments, innovation, demonstration projects and become mandatory components. Excellent reports or cases should be selected regularly for awards and other reputational support. Voluntary energy-saving and GHG emission reduction audits by SMEs and public organisation should receive awards and other support according to the report quality and implemented measures.

2. Establish a national energy efficiency database

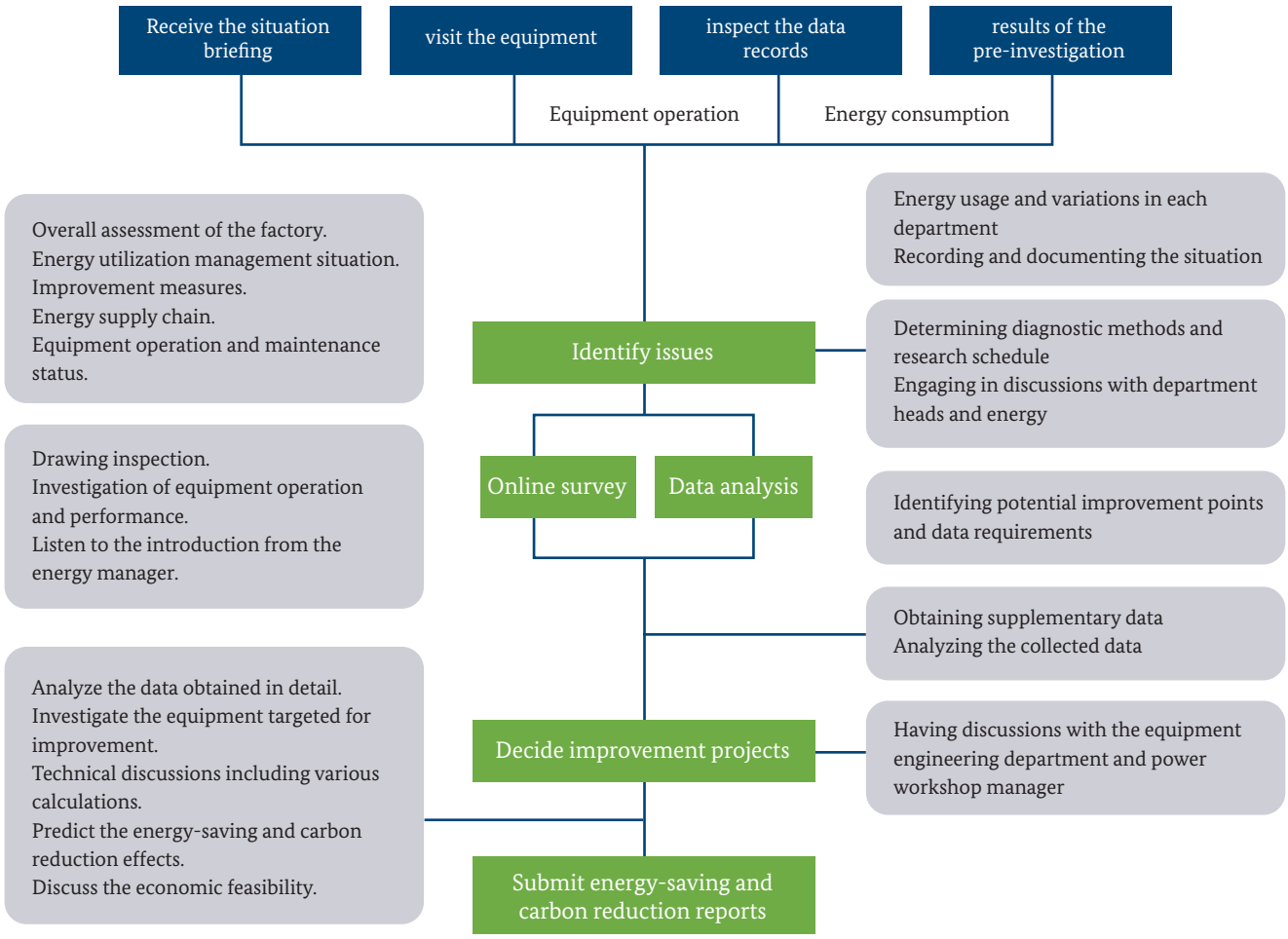
China still lacks authoritative institutions and dissemination practices to regularly release EE data compared to Germany. Insufficient EE data and public resources have to a certain extent restricted the smooth implementation of various policies and measures. This is especially evident for SMEs or real estate where professional capacity is insufficient.

The National Energy Conservation Centre or the Energy Research Institute of the National Development and Reform Commission should take the lead in regularly publishing best-practise cases, monitoring results as well as relevant technologies and EE data of general equipment. This will elevate the professional knowledge base while facilitating benchmark analyses. Websites of organisations such as the Energy Foundation, the Institute of Industrial Productivity and the Sino-German Energy and Energy Efficiency Partnership are regularly consulted by professionals.

3. Improve energy audit norms to promote energy efficiency

Periodic energy audits are the basis for improving EE in companies. At present, the standard specifications for energy audits or energy saving diagnosis in China are based on processes or project management but lack targeted analysis methods and testing requirements. Most energy audit reports just describe the status-quo. Insufficient depth for problem evaluation and potential analysis leads to resistance and negative feedback from audited entities[87]. Thus, domestic and foreign experts should review the following measures to improve the effectiveness of energy audits:

- Clear definition of energy audits in the Energy Conservation Law, the Energy Conservation Management Measures for Key Energy-using Units and other regulations to provide a legal basis;
- Technical specifications for energy audits should be improved through standardisation and enriched by advanced experience from Germany, Japan, UNIDO, etc.;
- Guidelines and rules for energy audits need to clarify analysis methods and testing requirements for key aspects such as heat, RE use, energy control systems, etc.;
- Suitable methodologies for energy saving diagnosis should be developed for the Chinese context drawing on the experience of Asian Development Bank/World Bank/ Global Environment Facility;
- Working templates and measurement/benchmarking databases for each process or energy subsystem in different industries should be compiled;
- Professional analysis software needs to be developed to assist personnel and to ensure the quality of diagnosis (Figure 27).



87 Zhang Di, 2019, Study on the Innovation of Energy-saving Monitoring System in Beijing

88 Zhang Di, 2022, A Methodology for Diagnosing Energy and Carbon Reduction in Enterprises Based on Lean Energy Efficiency Theory

4. Develop an energy efficiency expert database

A high-quality energy expert team is a prerequisite for achieving EE improvement goals. Drawing from the German EE consultant certification system, a public database of energy consultants should be established by a state-authorised authority. This system should receive public funding to provide professional services or guidance for the whole country. The selection and education of professional EE consultants (individuals and institutions) may take the form of special appointment or authorisation process with need for renewal every 1-3 years. Person-days or hours can be purchased to acquire professional guidance on energy and GHG emission reduction audits, project development and planning programmes including observation or verification of results of on-site audits or project implementation. EE consultants can be assigned to large-scale energy users to give direct guidance. Expert services may include the following:

- Give guidance on energy usage reports to improve quality;
- Accept commissions from local governments or institutions, analyse data, energy management systems or audit reports to provide guidance;
- Provide energy-saving diagnosis and assist in project demonstration and implementation of technological improvements on site or remotely;
- Complete relevant engineering and servicing tasks.

Energy users, service providers or local supervisory authorities can also request expert support. A service network combining physical offline and virtual online resources should be established to provide professional advice through hotlines, discussion groups or video conferences. The operational mode can mirror international institutions such as Asian Development Bank or World Bank where an expert work office manages the experts according to their qualifications. Regular evaluation should be conducted concerning the quantity, quality and user satisfaction of the services provided.

5. Improve quality of energy reporting, data analysis and energy management systems

The Chinese Government has promoted "dual integration" as the integration of information technology and industrialisation (Ministry of Industry and Information [2011] No. 164). An implementation plan exists for developing energy management centres for enterprises in the steel, petrochemical and building materials industries (Ministry of Industry and Information Technology Section [2015] No. 13). Guidelines for online monitoring and data collection have been issued (NDRC Environmental Resources [2017] No. 1711) while other policies promote the application of energy management systems (EMS) for key energy-intensive users at the national level. Their implementation took place in some provinces and major projects to form the path of "digital empowerment for energy saving and carbon reduction".

Most of the domestic energy monitoring or EMS only collect rudimentary data or perform preliminary analysis and reporting but do not meet requirements for energy "management, control and coordination". Problems with existing EMS are weak data analysis capabilities, imperfect functional module design, limited depth of data acquisition, lack of user-friendliness and intelligent control logic for integrating supply and consumption across different energy sources. The architecture of EMS should meet the requirements of management functions, and the breadth and depth of energy data analysis should reflect the management intention. Professional energy consultants along with data experts or analysis software can increase the level of energy data utilisation and effectively guide energy management. Big data applications can identify numerous data points such as load curves of major power-using equipment only from users' high-voltage distribution ports. Production and equipment management systems combined with other multi-source data can be used to analyse energy consumption and leverage opportunities such as load optimisation. Industry 4.0 also brings the advantage of creating a digital energy twin for analysis purposes. With expert guidance and real-time analysis, the main conclusions drawn from analysis in cooperation with the responsible authorities' feedback can encourage appropriate action. Such an interoperable system greatly enhances efficiency and effectiveness of policy implementation.

6. Provide financial support for energy-saving consulting services

One important lesson learned from Germany's energy transition is to provide information services (consulting) with financial support in the form of subsidies to ensure effective participation of different societal actors. Such an approach enables EE improvement and low-carbon transition by coupling technologies, cooperative projects and the development of new business model. Action and

investment from private entities is being incentivised by using only a small amount of public resources.

A dedicated study should be conducted on the implementation of small-scale, dedicated technical service funding possibilities to address policy gaps in China's existing energy saving and GHG emission reduction funds. Based on the results, the relevant policies at national and local levels can be unified to pool efforts. The funding can be in form of governmental procurement, project subsidies, investment grants or low-interest loans where Table 15 provides an overview.

Table 15: Overarching framework for providing financial support on energy efficiency and GHG emission reduction services

Purpose	Targeted entities	Supported content	Scope
Providing incentives for technical support on energy efficiency and GHG emission reduction services	Enterprises, industrial parks, real estate and buildings, governmental entities	Energy audits, feasibility studies, project design, engineering tests	Nationwide, selection based on project type, scale and reporting quality to avoid fizzling out of support scheme

Specific policy support should be provided to SMEs to carry out energy audits on their own, thereby guiding their decisions on EE and GHG emission reduction. Financial and IT support for SMEs to carry out energy audits might be necessary. A lower limit for energy consumption and an upper limit for the financial support for individual projects can be set or a certain number of professional consultancy services procured through government bidding can be provided. Based on compliance requirements such as fair competition, only services and projects covered by law should receive subsidies and other financial support. This needs to be supported by the top-level policy design where clear legislative and enforcement processes must be implemented.

7. Promote collaborative mechanisms such as "energy efficiency network groups"

Voluntary and collaborative energy saving and GHG emission reduction mechanisms such as "EE network groups" should be promoted within industries, industrial parks and large enterprises. With the support of expert teams this mechanism can be integrated into existing activities such as quality control circles, lean improvement weeks or zero-carbon industry alliances. In that way public participation including on-site personnel can be supported.

The National Development and Reform Commission can authorise the National Energy Conservation Centre and other organisations to coordinate the mechanism. The national EE and the national EE expert databases have great synergy. Experts should develop tools such as action plans, guidelines, workbooks, best cases, management methods or technology lists drawing on the experience of Germany and incorporate them into policies such as the "Comprehensive Work Programme on Energy Conservation and Emission Reduction" every five years.

To ensure that the groups' activities produce practical results and be sustained, communication with the top management of member companies is crucial. Top-level consensus and leadership commitment are the basis for implementing network group activities. EE network group activities can be included as a knowledge module in the training curriculum for energy experts at companies as well.

Improve supporting measures to enhance policy synergy

1. Strengthening projects prior to decarbonisation decision

The implementation of the "Guidance of the State Council on Accelerating the Establishment of a Sound Green Low-Carbon Circular Development Economic System" should be accelerated. Specifically, low-carbon and climate change adaptation pilots need to be promoted while improving emission data quality from different sources as well as their accounting, verification and the relevant regulatory system. Mandatory GHG reduction potentials need to be integrated into the environmental impact assessment of projects and planning. The "Green Finance Guidelines for the Banking and Insurance Industry" should be combined with other regulations to incentivise the financial sector in developing methodologies for classifying low-carbon investments. Such a classification can pave the way to guide investments into

green and low-carbon solutions and help make available much needed capital.

Several guides should be reviewed and implemented to allow for GHG emission assessment, alignment with the "dual carbon" targets and compliance demonstration of projects including the Feasibility Study Guide for Investment Projects from 2002, the General Outline for the Preparation of Feasibility Study Reports for Government Investment Projects, the Reference Outline for the Preparation of Feasibility Study Reports for Enterprise Investment Projects and the Notes on the Outline for the Preparation of Feasibility Study Reports for Investment Projects.

GHG accounting needs to be professionalised to conform to international standards when evaluating projects and their impact on the Chinese climate targets. Guidelines for industries are required to increase low-carbon awareness, strengthen GHG emission assessment capabilities across supply chains and integrate energy and decarbonisation assessments into decision-making processes in the private sector. Capacity building is necessary to prevent comprehensive company-wide energy saving and emission reduction strategies from being downgraded to small-scale actions of individual departments (e.g. only limited to environmental and energy-related departments, with little participation of procurement, R&D, production and financial investment which see decarbonisation as "other departments' business", thereby forming information silos or departmental barriers).

2. Eliminate restrictions on the development of RE

At present, the lack of power system and market flexibility poses constraints to high penetration of RE in China. Issues with available land for projects also led some local governments to introduce policies to restrict RE projects. Restrictions on RE (e.g. restrictions on roof-top PV and storage or grid-connection delays) should be eliminated in local-level policy documents. Dedicated channels for streamlining RE project permitting should be used for high-quality implementation while fair competition practices are necessary to break down local protectionism.

The German experience in energy (infrastructure) regulation can serve as a guide. The National Energy Administration should join forces with market supervision authorities to promote competition in the field of energy infrastructure through measures such as limiting practices that prevent RE projects from going online or by standardising processes around independent choice of energy supplier.

3. Empower oversight on energy-saving regulations

Authorities responsible for overseeing energy-saving related regulation in China are already making progress in guiding key industries to reduce their energy consumption, using EMS and adopt efficient technologies or processes with focus on EE. However, several problems were identified: Scope and depth of monitoring is insufficient as SMEs (consuming less than 5,000 tons of standard coal per year) are largely off the radar. The professional capacity of monitoring personnel is not adequate in terms of new technologies, methods as well as policies and regulations. Awareness for EE and saving in top-level management decisions is lacking.

Energy saving monitoring based on legal norms needs to be enhanced by new technologies, management models, best practices and other professional capabilities [89]. Proposed measures to counter the above shortcomings are to train relevant personnel with updated EE information and the purchase of private professional expert services to allocate them to energy monitoring departments as public service resources. Feedback to monitored companies needs to be specific and help reduce energy consumption and GHG emissions.

6.3 Energy transition outlook for China

For China to reach peak carbon emissions by 2030 and carbon neutrality by 2060, a fundamental restructuring of the entire country's energy and industrial system towards RE and energy efficient production is necessary. 25% of primary energy should be provided by non-fossil energy sources by 2030. To achieve those targets further growth of RE is required (compare Figure 28).

89 Zhang Di, 2019, Study on the Innovation of Energy-saving Monitoring System in Beijing

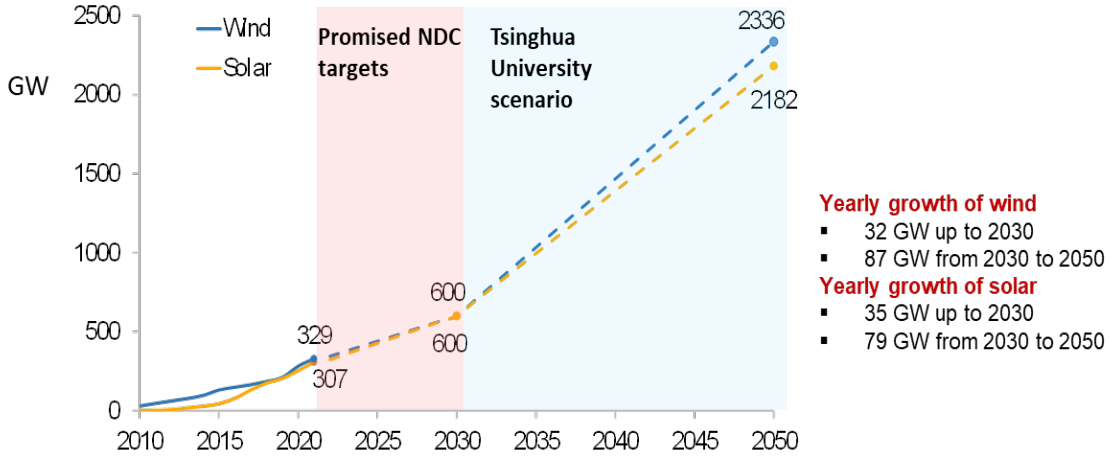


Figure 28: Targeted growth of renewable capacity by 2030 and Tsinghua scenario up to 2050[90]

Integrating this fluctuating generation by adequate technical and market mechanisms should be priority, and since 2021 power market reform are taking up speed again. With approximately 4 million new energy vehicles being sold in 2022 alone, progress in electric mobility is substantial. Efficient production and energy savings across sectors will also bring economic benefits through lower costs of energy provision. Stringent implementation of ambitious EE standards and modern technologies in industry as well as in buildings can reduce both energy consumption and GHG emissions.

Efforts on all levels are required for China to achieve its "dual carbon" targets. Insights from the implementation of energy transition in front-running countries such as Germany along with exchange between policymakers and practitioners play an important role both for international cooperation and for bringing the world on a Paris-aligned climate trajectory.

90 GIZ, 2022, China Energy Transition Status 2022

Annex 1:

Indicators for monitoring the energy transition

Subject areas	Indicators
The energy transition in the European and international context	· EU targets 2020/2030 · Emissions trading in the EU ETS · Effort sharing in non-ETS area · Global CO2 emissions · Global installed renewable capacity · Global investment in renewable energy sources and energy efficiency
Renewable energy	· Share of renewable energy sources (RES) in gross final energy consumption · Share of RES in gross electricity consumption · Renewable electricity generation by technology · Gross electricity generation by energy source · Share of RES in heating and cooling consumption · Share of RES in the transport sector · EEG surcharge by technology · Sum total of EEG surcharge plus electricity prices on the exchange
Energy consumption and energy efficiency	· Primary energy consumption · Primary and final energy productivity · Gross electricity consumption
Buildings and heat transition	· Share of final energy consumption of buildings in total energy consumption · Final energy consumption of buildings/heating final energy consumption · Specific final energy consumption for space heating · Primary energy consumption in buildings
Transport	· Final energy consumption in transport · Specific final energy consumption of the transport sector · Number of electric vehicles with more than two wheels · Number of vehicles with more than two wheels powered by fuel cells and natural gas · Shift to rail transport · Shift to local public transport
Greenhouse gas emissions	· Greenhouse gas emissions · Greenhouse gas emissions by source group · Energy-related CO2 emissions by sector · Greenhouse gas emissions avoided through use of RE · Specific greenhouse gas emissions in relation to the population and GDP
Power plants and security of supply	· Installed capacity of power generation plants · Distribution of power plant capacity across the federal states · CHP, including electricity generation · Conventional generation capacities: new construction and decommissioning · Capacity of pumped storage power stations · Nuclear phase-out roadmap · SAIDI · Conventional power plants currently under construction · Country comparison of power outage duration

Affordable energy and fair competition	· Final consumer expenditure on energy and as a share of GDP · Macroeconomic energy expenditure · Energy expenditure of private households · Electricity prices of private households · Energy costs for industry · Electricity prices on the exchange · Electricity prices of non-privileged industrial enterprises · Oil and gas prices · Energy prices compared with other countries
Environmental compatibility of the energy supply system	· Environmental monitoring of the energy transition
Grid infrastructure	· Projects under the Power Grid Expansion Act (EnLAG) and Federal Requirement Planning · Grid investments · Grid fees · Costs for ancillary services
Sector coupling and digitisation of the energy transition	· Number and electricity consumption of heat pumps · Number and electricity consumption of electric vehicles · Efficient heat networks · Innovative combined heat and power (CHP) systems · Digitisation barometer, including Smart Meter Gateway certification
Energy research and innovations	· Industry expenditure on R&D · Federal research expenditure in the Energy Research Programme · Project funding using EU funds · Patents · Market uptake of innovative technologies in energy consumption
Investments, growth and employment	· Investments in renewable energy sources and energy efficiency · Investments in grids and electricity supply · Primary fossil fuels saved as a result of using renewable energy sources · Energy imports saved as a result of expanding renewable energy sources and improving energy efficiency · Number of people employed in the energy industry · Number of people employed in the renewable energy sector

Annex 2:

Energy transition and climate targets

GHG emissions, RE and EE

	2020	Target 2020	Target 2030	Target 2040	Target 2050
GHG emission (vs. 1990)	-40.8 %	-40 %	-65 %	-88 %	GHG sink
Share of RE in gross final energy consumption	19.7 %	18 %	30 %	45 %	60 %
Share of RE in gross electricity consumption	45.2 %	35 %	80 %*	Climate-neutral*	Climate-neutral*
Share of RE in final energy consumption for heating and cooling	15.3 %	14 %	50 %*		
Share of RE in final energy consumption in the transport sector	7.6 %	10 %	32 %**		
Primary energy consumption (vs. 2008)	-17 %	-20 %	-30 %		-50 %
Final energy productivity (vs. 2008)	1.4 % p.a. (2008-2019)	2.1 % p.a. (2008-2050)			
Primary energy demand in buildings (vs. 2008)	-23.7 % (2019)				-80 %
Final energy consumption in transport (vs. 2005)	-11.4 % p.a.	-10 %			-40 %
Buildings – renovation rate	1 % p.a. (2017)	Doubling of renovation rate: 1.0 % to 2.0 % p.a.			

* targets in the new amendment of the Renewable Energy Sources Act from July 2022 and the coalition contract
**electricity in transport and other means of fulfilling the GHG quota partly count towards the 32 % target

Sector coupling

	2020	Target 2020	Target 2030
Electric vehicles registered in Germany in mil.*	0.59**	1	15
Publicly accessible charging points	36,500	50,000	1 million
Installed heat pumps in mil.	1.3	no target	4-6 million***
Installed capacity of electrolysers running green electricity	60 MW****	no target	10 GW*****
Generation of green hydrogen*****	3 GWh****	no target	28 TWh*****

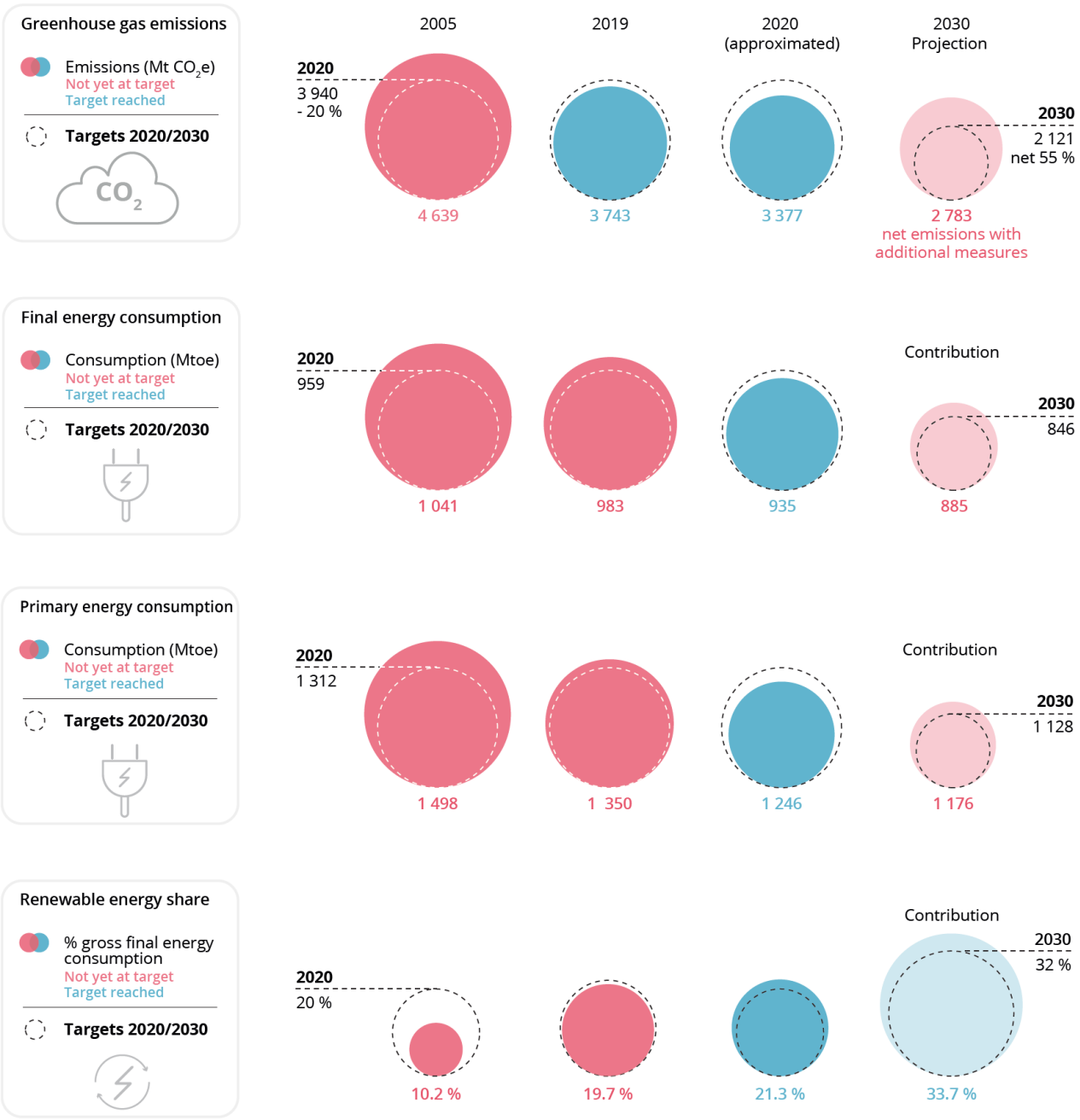
* the 2020 target included all electric vehicles including hybrid electric vehicles, the new target for 2030 only includes fully electric vehicles

** the numbers for 2020 in detail: 309k battery electric vehicles, 280k plug-in hybrid electric vehicles and 0.1k fuel cell electric vehicles
*** not an official target but an estimate by the current government

**** data from the monitoring report of the Federal Network Agency (BNetzA, 2022a)
***** new targets of the Federal Government doubling the previous ambition for 2030

Annex 3:

EU energy and climate targets and achievements until 2020[91]



91 European Environment Agency, 2021, Trends and projections in Europe 2021

Annex 4:

Energy Law Map in Germany

Federal Ministry for Economic Affairs and Energy

Energiewende Switch to the Future

Overview of legislation governing Germany's energy supply system

Key strategies, acts, directives, and regulations / ordinances

EUROPEAN LEVEL

STRATEGIES

EU CLIMATE AND ENERGY PACKAGE (20/20/20 TARGETS)

In December 2008, the European Union agreed on a host of directives and objectives. These set out specific targets which relate to the efforts to mitigate climate change and to reduce energy consumption and are to be reached by 2020: greenhouse gases emissions are to be cut by 20% compared to 2005, renewables are to account for 20% of gross final energy consumption, and energy efficiency is to increase by 20% compared to 1990.

2030 European Climate and Energy Framework

The new Climate and Energy Framework is centred on three main targets for 2030: to reduce greenhouse gas emissions from within the EU by a minimum of 40%, to increase the share of renewables in the EU's final energy consumption to at least 27%, and achieve energy savings of at least 27%.

REGULATIONS / DIRECTIVES

INTERNAL ELECTRICITY MARKET DIRECTIVE (DIRECTIVE 2009/72/EC)

This directive lays down rules on the generation, transmission, and distribution of electricity, and on consumer supply and consumer protection. Furthermore, it specifies requirements for tendering and authorisation procedures as well as for the operation of the grids.

EMISSIONS TRADING DIRECTIVE (DIRECTIVE 2009/29/EC)

This directive introduced the European system of greenhouse gases emissions trading. It sets out the rules on how certificates are to be allocated and traded and stipulates requirements concerning the provision of information.

INDUSTRIAL EMISSIONS DIRECTIVE (DIRECTIVE 2010/75/EU)

The Industrial Emissions Directive sets out emissions limit values (ELVs) and other requirements for the approval of certain types of industrial installations, including power stations.

ENERGY EFFICIENCY DIRECTIVE (DIRECTIVE 2012/27/EU)

The aim of this directive is to cut primary energy consumption in the EU by 20% by 2020 compared to baseline projections. Measures here include the annual requirement for government to improve the energy performance of 3% of its building stock and for energy distributors/sellers to cut their energy consumption by at least 1.5% every year.

ENERGY CONSUMPTION LABELLING DIRECTIVE (DIRECTIVE 2010/30/EU)

This directive sets outs pan-EU rules for the uniform, pan-EU labelling of energy-related products. The directive provides for clarity regarding the respective responsibilities of suppliers and traders, and member states' obligation to provide information. Products for which the well-known label is used include washing machines, heating systems, and TV sets.

ECODESIGN DIRECTIVE (DIRECTIVE 2009/125/EC)

This directive provides the basis for pan-EU ecodesign requirements for energy-related products, including TV sets, washing machines, and electrical engines. Only products which meet these requirements can be brought to market and used.

REGULATION (EC) No 715/2009 ON ACCESS TO THE NATURAL GAS TRANSMISSION NETWORKS

This regulation governs access to the natural gas transmission networks and gas and LNG storage facilities. Its aim is to work towards establishing a wholesale market for natural gas and to create mechanisms that will lead to a harmonisation of the rules governing the cross-border exchange of natural gas.

REGULATION (EU) No 994/2010 ON SAFEGUARDING A SECURE SUPPLY OF NATURAL GAS

This regulation sets out the respective duties of companies and Member States as far as a secure supply of gas is concerned; these include minimum standards for gas infrastructure, customer supply, preventative action and contingency planning.

INTERNAL MARKET IN NATURAL GAS DIRECTIVE (DIRECTIVE 2009/73/EC)

This directive lays down rules concerning the transmission networks and the distribution, supply, and storage of natural gas. It sets out criteria and procedural requirements which govern the (non-)approval of requests for the transmission, distribution, supply, and storage of natural gas, and for the operation of natural gas networks.

ENVIRONMENTAL IMPACT ASSESSMENTS (EIA) DIRECTIVE (DIRECTIVE 2011/92/EU)

This directive stipulates the requirement for environmental impact assessments (EIAs) to be undertaken prior to the approval of certain types of public and private sector projects.

HABITATS DIRECTIVE (DIRECTIVE 2011/92/EU) AND BIRDS DIRECTIVE (DIRECTIVE 2009/147/EC)

These directives specify rules on biodiversity and environmental protection.

TAXATION OF ENERGY PRODUCTS AND ELECTRICITY DIRECTIVE

This directive harmonises energy and electricity tax schemes within the EU, defines minimum taxation levels, and lays down criteria for tax breaks and exemptions.

RENEWABLE ENERGY SOURCES (RES) DIRECTIVE (DIRECTIVE 2009/28/EC)

This directive provides the legal framework for the promotion of renewables. It sets out binding national targets for the total share of renewables in each Member State's gross final energy consumption, and for the transport sector. Moreover, it specifies rules with regard to joint projects, administrative procedures, the requirement to provide information, and access to the electricity grid.

EU ENERGY PERFORMANCE OF BUILDINGS DIRECTIVE (DIRECTIVE 2010/31/EU)

This directive seeks to improve the energy-performance of buildings in the EU.

CONNECTING EUROPE FACILITY REGULATION

This regulation sets out the overarching rules for the "Connecting Europe" facility, which helps to fund investment in priority EU infrastructure projects in the transport, energy, and telecommunications sectors.

CRITICAL INFRASTRUCTURE PROTECTION DIRECTIVE (DIRECTIVE 2008/114/EC)

The Member States are required to regularly identify European infrastructures that are critical, for instance for the supply of electricity. They are to ensure that operators' security plans are available and that security liaison officers are designated for each of these infrastructures.

REGULATION (EC) No 714/2009 ON CROSS-BORDER TRADING

This regulation introduces a compensation mechanism created for cross-border flows of electricity, rules on the allocation of interconnector capacity, and principles for transmission charges. The regulation is supplemented by various network codes.

REGULATION ON GUIDELINES FOR TRANS-EUROPEAN ENERGY INFRASTRUCTURE

This regulation sets out rules designed to streamline authorisation procedures and increase public support, and rules relating to the regulatory framework and cost allocation for energy infrastructure projects. A list of the main infrastructure projects of community interest (PCIs) in the field of electricity, gas, oil and smart grids is provided in the annex to the regulation.

INTER-TSO COMPENSATION MECHANISM (REGULATION (EU) No 838/2010)

This regulation sets out guidelines with regard to the fees charged for cross-border electricity exchange. It also lays down rules governing the fees charged for access to the transmission grids.

DIRECTIVE FOR A SECURE SUPPLY OF ELECTRICITY (DIRECTIVE 2005/89/EC)

This directive stipulates certain measures to be taken to ensure a secure supply of electricity. These measures concern generation capacity, balancing supply and demand, and ensuring that there is sufficient generation and transmission capacity for the systems to work reliably.

CCS DIRECTIVE (DIRECTIVE 2009/31/EC)

This directive sets out conditions for the storage of carbon dioxide. It also keys down requirements for the selection, approval, and monitoring of storage sites.

EMISSION PERFORMANCE STANDARDS REGULATION

This regulation provides incentives for automotive companies to develop and bring to market energy-efficient vehicles and vehicles using alternative fuels.

ALTERNATIVE FUELS DIRECTIVE (DIRECTIVE 2014/94/EU)

This directive sets out a joint EU framework for the construction of alternative-fuel infrastructure, including charging points for electric vehicles, which is to reduce dependency on oil within the transport sector and its environmental footprint.

REPORTS / GUIDELINES

TEN-YEAR NETWORK-DEVELOPMENT PLAN

Every two years, the European Networks of Transmission System Operators for Electricity and Gas produce non-binding pan-EU 10-year network-development plans for the natural-gas networks and the electricity grids. These plans include projections on what exactly will constitute an adequate expansion of the networks.

PLANNED INVESTMENT IN ENERGY INFRASTRUCTURE

Every two years, the Member States furnish the European Commission with information on infrastructure projects that are at the planning stages or are currently being implemented. This data is provided for projects related to the generation, storage, and transport of natural oil and gas, electricity (including from renewable sources), biofuels, and CCS.

NATIONAL LEVEL

STRATEGIES

THE ENERGY CONCEPT OF THE FEDERAL GOVERNMENT

The energy policy of the Federal Government rests upon the Energy Concept of 28 September 2010, in which the Federal Government set out guidelines for ensuring an environmentally sound, reliable, and affordable energy supply,thus mapping the transition into the age of renewables, and upon the decisions of the German Bundestag in favour of phasing out the use of nuclear power.

ACTS

ENERGY INDUSTRY ACT

The Energy Industry Act sets out the regulatory conditions that are necessary for ensuring a secure, affordable, consumer and environmentally friendly supply of electricity and natural gas. It regulates the supply systems for electricity and natural gas in order to ensure that competition is effective and is not distorted. It also implements European Union law with regard to the network-based supply of electricity and natural gas.

COMBINED-HEAT-AND-POWER ACT

The act regulates the funding for the combined and particularly effi cient generation of electricity and heat in low-carbon CHP installations, especially on the basis of natural gas. It also provides for surcharges imposed to fund the construction and extension of networks und storage for heating and cooling.

ENERGY SECURITY OF SUPPLY ACT

This act defines how vital energy needs are to be met in the event of immediate threats or disruptions to the energy supply where these cannot be sufficiently addressed in time.

ELECTRICITY DUTY ACT

This law lays down the rules on electricity taxation and specifies cases in which reduced tax rates or tax exemptions apply.

ENERGY DUTY ACT

This law lays down the rules regarding tax rates on heating and motor fuels, and specifies cases in which reduced tax rates or tax exemptions apply.

METERING ACT

This law sets out the rules on the introduction and use of smart meters and on how the measurement values are to be passed on within the energy sector.

POWER GRID EXPANSION ACT

The Power Grid Expansion Act deals with the construction of extra-high-voltage grids. It sets out specific plans for grid projects that are designed to integrate electricity from renewable sources, establish better networks in the European Energy market, connect new power stations, and avoid structural bottlenecks in the transmission network.

GRID EXPANSION ACCELERATION ACT

This law sets out procedural requirements for the construction of cross-regional and cross-border extra-high-voltage lines. It also applies to high-voltage powerlines with a nominal voltage of at least 110 kV. The individual expansion projects are laid down in the Federal Requirements Plan Act. The aim of this act is to speed up planning and approval procedures.

FEDERAL REQUIREMENTS PLAN ACT

This act defines which measures are needed to expand and upgrade the extra-high-voltage grids in the next 10-15 years, supplementing the projects set out in the Power Grid Expansion Act.

ENVIRONMENTAL IMPACT ASSESSMENT ACT

This law specifies precautions to be taken in order to ensure effective environmental protection in the context of both public and private-sector projects.

ELECTRIC MOBILITY ACT

The act regulates the preferential participation of electric vehicles in road traffic in order to promote their use with a view to reducing the damaged caused to the climate and the environment by car traffic.

ENERGY AND CLIMATE FUND ACT

The Energy and Climate Fund was established in order to provide funding for the additional responsibilities associated with the Energy Concept of 28 September 2010.This Special Fund is used to fund measures in the areas of renewable energy and energy efficiency, as well as the national efforts to combat climate change. The Government Decisions of June and July 2011 stipulate that revenues from the auctioning of carbon emissions certificates are to be the only source of revenue.

ACT ON ENERGY CONSUMPTION LABELLING

The act regulates the enforcement powers and obligations of the Länder with regard to market supervision of product labelling. It also stipulates the general rules for the roll-out of the national efficiency labels for old heating systems.

ENERGY SERVICE ACT

The Energy Services Act was created to foster the development of a market for energy services and to ensure that final energy consumers are better informed about these services.

ATOMIC ENERGY ACT

This law is designed to protect life, health, and material goods from the hazards of the use of nuclear power and the harmful effects of ionising radiation. It defines basic rules for plant operation and for the structured phase-out of nuclear energy for commercial electricity production.

RENEWABLE ENERGY SOURCES ACT

This law is designed to promote the advancement of technologies that enable the production of energy from renewable sources at a lower cost. The share of renewables used in power generation is to be raised to 80% by 2050.

OFFSHORE WIND ENERGY ACT

This act is designed to encourage greater use of offshore wind energy, particularly in the interest of protecting the climate and the environment.

RENEWABLE ENERGIES HEAT ACT

This law is designed to help raise the share of renewables to 14 per cent of the energy used for heating purposes and to achieve this by 2020.

ENERGY SAVING ACT

This law sets out the basic legal requirements with regard to energy conservation in buildings.

GREENHOUSE GAS EMISSION TRADING ACT

This law provides the basis for the trading of greenhouse gases emission allowances within a pan-EU emissions trading system. The aim is to make a contribution towards the global effort to combat climate change through reducing the level of greenhouse gases emissions in a cost-efficient manner.

FEDERAL IMMISSION CONTROL ACT

This acts is designed to protect people, animals and plants, the ground, water, the atmosphere, as well as cultural assets and material goods from harmful environmental effects (caused by air pollution, noise, vibrations, light, heat, and radiation).

FEDERAL MINING ACT

This law sets out the legal framework for the exploration, extraction, and processing of mineral resources in Germany. It also applies to the construction and operation of underground storage facilities.

FEDERAL WATER ACT

This law specifies rules and requirements for the use and protection of water bodies. Most of the water used in the generation of energy (e.g. for cooling systems; hydropower) is surface water.

CARBON CAPTURE AND STORAGE (CCS) ACT

This act provides the legal framework for the piloting and application of technologies used in the sequestration, transport, and storage of carbon dioxide found in deep geological strata. It also contains rules on the examination, erection, operation, monitoring, and decommissioning of pilot storage facilities, and on the transfer of responsibility for these, as well as rules on connection and access to CO2 ducts and storage facilities.

FEDERAL NATURE CONSERVATION ACT

This act stipulates requirements for nature and landscape protection. It is comprised of rules that are designed to preserve biodiversity, a balanced ecosystem, regenerative capacity, the sustainable use of natural resources, and the diversity and beauty of nature and the countryside. The protection afforded under this act also covers the nurturing and, where necessary, restoring of these resources.

ENERGY-RELATED PRODUCTS ACT

In conjunction with the relevant EU legislation, this law defines the energy-related requirements that apply to products entering the market and being used. It also provides the legal basis upon which the Länder can exercise market surveillance.

ORDINANCES

ORDINANCE TO ENSURE THE SUPPLY OF GAS IN A SUPPLY CRISIS

This ordinance defines the powers of the Federal Network Agency and the Länder (as load distributors) that are necessary for ensuring that vital demand for natural gas is met. In a crisis situation, these load distributors can issue instructions both to gas companies and consumers.

ORDINANCE TO ENSURE THE SUPPLY OF ELECTRICITY IN A SUPPLY CRISIS

The aim of this ordinance is to ensure that vital needs for electricity are met. It also transfers the role of load distributor to the Federal Network Agency in the event of a supply crisis.

ELECTRICITY NETWORK ACCESS ORDINANCE

This ordinance defines the conditions for feeding electrical energy into the electricity grids and for the simultaneous take-off of electricity at remote distribution points. It also lays down the basic rules for grid balancing and balancing-group management.

ELECTRICITY NETWORK CHARGES ORDINANCE

This ordinance specifies the methods to be used for calculating charges for access to the transmission and distribution grids (grid fees), for the transmission of electricity to consumers, and for distributed feed-in.

GAS NETWORK ACCESS ORDINANCE

This ordinance defines the conditions under which grid operators shall provide access to their networks to those entitled to such access. It also covers the feed-in of biogas and the connection of biogas plants to the pipeline networks. Furthermore, this ordinance specifies requirements for efficient capacity utilisation, with the aim of ensuring that access to the networks is granted to those entitled to such access in a non-discriminatory way.

GAS NETWORK CHARGES ORDINANCE

This ordinance defines the methods to be used for calculating charges for access to gas pipelines and gas distribution networks for the transmission of natural gas to consumers via the networks of the gas network operators.

DISCONNECTABLE LOADS REGULATION

The purpose of the ordinance is to develop demand side management potential in the interest of the security of the electricity supply system at transmission system level.

GRID RESERVE ORDINANCE

This ordinance specifies the procedure to be used to create the grid reserve, to use installations that have been placed in the grid reserve, and the specifications to be met by installations placed in the grid reserve. Furthermore, it lays down detailed rules on how installations for the generation or storage of electricity are to be decommissioned.

ORDINANCE ASSIGNING PLANNING APPROVAL PROCEDURES

By way of this ordinance, the responsibility for conducting planning approval procedures for cross-regional and cross-border extra-high-voltage lines was transferred from the Länder to the Federal Network Agency.

INCENTIVE REGULATION ORDINANCE

This ordinance uses incentive-based regulation to stipulate the fees for access to the energy supply networks. Furthermore, it sets out requirements to be used to determine the total revenue that network operators may generate from grid fees (revenue cap), and also stipulates quality requirements.

CONCESSION-FEE ORDINANCE

This ordinance regulates the policy environment for concession fees for electricity and natural gas and the way in which these fees are to be calculated. Concession fees are paid by the energy utilities to the municipalities and districts. They are charged for the right to use public transport routes and to operate energy networks.

LOW-VOLTAGE-CONNECTION ORDINANCE

This ordinance specifies the basic conditions under which grid operators must connect end users to their low-voltage grid and provide the connection for the drawing of electricity. It comprises provisions governing the connection to the grid, the use of this connection, and the content of the grid connection contract.

CHARGING STATION ORDINANCE

The ordinance regulates technical minimum requirements for the safe and interoperable establishment and operation of publicly accessible charging stations for electric vehicles.

HIGH-PRESSURE GAS PIPELINE ORDINANCE

This ordinance specifies procedures and requirements for ensuring technical safety during the erection and operation of high-pressure gas pipelines. It also lays down rules for the accreditation of technical-safety experts.

ORDINANCE ON ENERGY CONSUMPTION LABELLING

The ordinance regulates administrative offences relating to the obligations of manufacturers and sellers in the context of product labelling and establishes the legal basis for the Länder to impose fines.

ORDINANCE ON THE ENERGY LABELLING OF CARS

The Ordinance on the energy labelling of cars introduces an energy label for cars that informs consumers about the car's carbon footprint. In addition to providing absolute figures on consution, the label also uses a colour-coded CO2 efficiency scale to show how efficient a car is compared to other models.

ORDINANCE ON THE CONNECTION OF POWER STATIONS TO THE NETWORKS

This ordinance lays down basic conditions under which facilities for the generation of electricity with a nominal capacity of at least 100 MW shall be connected to electricity supply grids with a voltage of at least 110 kV. It specifies requirements for the grid connection procedure and the bearing of the costs for connection, and also includes provisions as to what information TSOs must provide.

ORDINANCE ON GRID SYSTEM STABILITY

This ordinance is designed to prevent risks to system stability resulting from PV generation facilities. It sets out requirements for the retrofitting of inverters, as well as requirements regarding what information TSOs must provide.

ELECTRICITY DEFAULT SUPPLY ORDINANCE

This ordinance specifies the general conditions under which default energy utilities supplying household customers in the low-voltage range shall meet the need of the latter for electricity, charging standard prices. It sets out the rights and responsibilities of default utilities as well as the terms for supply and billing.

GAS DEFAULT SUPPLY ORDINANCE

As an equivalent of the default supply ordinance for electricity, this ordinance stipulates the general conditions for the default supply of natural gas to household customers in the low-pressure range.

LOW-PRESSURE-CONNECTION ORDINANCE

This ordinance lays down the conditions under which end consumers in the low-pressure range shall be connected to the general supply. It also sets out requirements for the grid connection contract.

PROTECTION OF TRANSMISSION NETWORKS ORDINANCE

This ordinance further fleshes out the Critical Infrastructure Protection Directive at national level. It stipulates the details of and deadlines within the procedure and specifies the requirements for operators' security plans and for the security liaison officers.

ORDINANCES IMPLEMENTING THE FEDERAL IMMISSION CONTROL ACT

The main purpose of these ordinances is to protect the environment from harmful environmental effects caused by air pollution and noise.

BIOMASS ELECTRICITY SUSTAINABILITY ORDINANCE

This ordinance applies to bioliquids used for electricity production under the Renewable Energy Sources Act. It sets out sustainability requirements with respect to the protection of areas for the production of liquid biomass and the certification of interfaces.

BIOMASS ORDINANCE

This ordinance regulates which matters are deemed to be biomass under the RES Act, which technical procedures for the production of electricity from biomass fall under the scope of application of the act, and which environmental requirements must be complied with in the production of electricity from biomass.

RENEWABLE ENERGIES ORDINANCE

This ordinance sets out rules on how electricity for which funding has been disbursed pursuant to the Renewable Energy Sources Act (EEG) is to be marketed, on how the level of funding under the EEG is to be determined and published, and on certificates of origin, certificates of regional production and the relevant registers associated with these.

AVERAGE ELECTRICITY PRICE ORDINANCE

The ordinance stipulates how the average electricity prices used to calculate the electricity cost intensity in the special equalisation scheme are calculated.

REGISTER-OF-FACILITIES ORDINANCE

This ordinance sets out requirements for the establishment and use of a register of facilities used to generate electricity from renewables and firedamp.

SYSTEM SERVICE ORDINANCE

This ordinance is designed to improve the safety and stability of the electricity grids, even when there are high shares of electricity from wind energy in the networks. Its goal is to raise the share of system services for the grids that is generated from wind energy.

CROSS-BORDER RENEWABLE ENERGY ORDINANCE

This ordinance defines the rules that apply for cross-border auctions for electricity from PV installations located within the Federal Republic of Germany or on the territory of another EU Member State.

ENERGY SAVING ORDINANCE

The technical standards stipulated in this ordinance are designed to improve the energy performance of buildings and to achieve this goal in an economically viable way.

HEATING COST ORDINANCE

This ordinance lays down the rules to be used to calculate energy costs based on the consumption of energy for heating and hot-water systems in buildings with more than one flat or other units.

ENERGY-RELATED PRODUCTS ORDINANCE

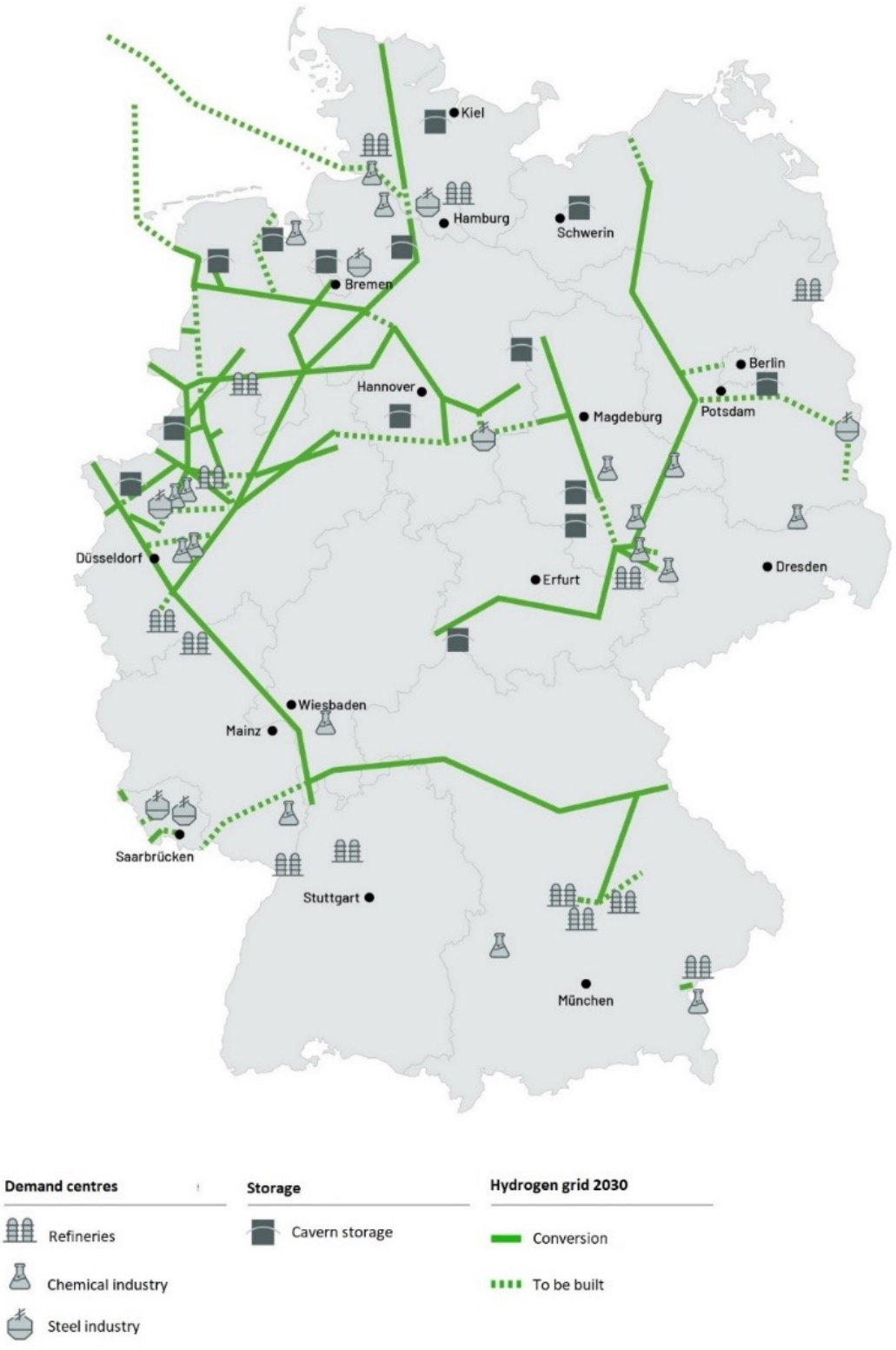
This ordinance makes it an administrative offence to bring to market and to use products that do not comply with the minimum energy-efficiency standards that apply under EU law. This makes it possible for the Länder to impose fines on those committing this offence, which is conducive to effective market surveillance.

LAST UPDATED: Jan 2017 www.bmwi.de/overview-of-legislation

KEY: CONSUMPTION | GENERATION | STORAGE | TRANSMISSION AND DISTRIBUTION

Annex 5:

Annex 5: Schematic layout of a potential hydrogen grid in Germany for 2030[92]



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