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NEW PATHWAYS FOR THE ENERGY TRANSITION ('PLAN B')

DIHK

Study commissioned by the German Chamber of Commerce and Industry
(Convenience translation – Original study in German)

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Client

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FOREWORD BY THE CLIENT

Dear Reader,

This study, "New Pathways for the Energy Transition ('Plan B')", presents an alternative approach to energy policy. At its heart is an energy transition that is open to all technologies, reduces costs, creates space for innovation, and takes economic feasibility as a serious prerequisite for effective climate protection.

This 'Plan B' deliberately avoids detailed government control and rigid technology requirements, focusing instead on clear goals, flexibility, and efficiency. It is the answer to the previous narrative of a supposedly unavoidable, centrally controlled energy transition that promises great economic opportunities but in reality often leads to considerable burdens. At the request of our members, we have subjected this narrative to a reality check. Frontier Economics was commissioned to conduct the study in February, and you now have the results in your hands.

Two further studies, which will be published in the autumn, will deepen the analysis: they will shed light on how individual industries are specifically affected by current energy policy and what advantages a new approach could bring. They will also examine what institutional adjustments are necessary to make the energy transition more successful and sustainable.

The results are clear: the energy transition is incurring enormous costs that can only be managed with a new political course. A reorientation must be more effective, more flexible, and more internationally oriented. At the same time, the study shows that Germany cannot benefit from cheap energy resources in structural terms, so our strength must lie in our know-how, our technological excellence, and our innovative capacity.

I hope you enjoy this interesting read and I look forward to discussing the implementation of the proposed approaches with you.

Dr Helena Melnikov

Chief Executive

German Chamber of Commerce and Industry

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LIST OF ABBREVIATIONS

BESS	Battery Energy Storage System
BEV	Battery Electric Vehicle
GDP	Gross domestic product
CAPEX	Capital Expenditure
CBAM	Carbon Border Adjustment Mechanism
CCS / CCUS	Carbon Capture and Storage / Carbon Capture, Utilisation and Storage
CfD	Contracts for Difference
COMET	Cross-Sector Optimisation Model for the Energy Transition
DAC	Direct Air Capture
EE	Renewable energies
EEG	Renewable Energy Sources Act
EnEfG	Energy Efficiency Act
ETS	Emissions Trading System
GEG	Building Energy Act
AI	Artificial Intelligence
LNG	Liquefied Natural Gas
nETS	National Emissions Trading Scheme
OPEX	Operating Expenses
PEM	Polymer Electrolyte Membrane (Electrolysis)
PtL	Power-to-Liquid
PtM	Power-to-Methane
PtX	Power-to-X
PV	Photovoltaics
SMR	Small Modular Reactor
GHG	Greenhouse gas emissions
TYNDP	Ten-Year Network Development Plan

EXECUTIVE SUMMARY

Germany’s energy transition is both its central contribution to mitigating global climate change and one of the largest economic transformation projects worldwide.

Considerable progress has already been made: the share of renewables in electricity generation has risen from just 3% to over 50% in the past 25 years. However, this transformation has come at a high economic cost. Energy prices for businesses and households have increased significantly and are now among the highest worldwide. This burden is likely to increase further in the foreseeable future.

This development poses growing risks to Germany’s competitiveness. More than one in three companies already see the energy transition as a threat to their competitiveness; in the industrial sector, the figure is as high as one in two. Early signs of energy-intensive production relocating abroad point to the risk of de-industrialisation. This could lead to lasting losses of well-paid industrial jobs that cannot easily be replaced, while also raising the danger of carbon leakage – a shift of emissions abroad without any climate benefit.

At the same time, Germany’s path to climate neutrality is still long. Despite strong growth in the electricity sector, renewables account for only 22.4% of total final energy consumption. The main demand sectors – residential heating, process heat, and transport – remain dominated by fossil fuels. Achieving climate neutrality will therefore require profound changes in end-use technologies and major investments in new energy infrastructure.

Continuing with the current policy (‘status quo’) will lead to significant additional costs and jeopardise the success of the energy transition.

To achieve climate neutrality by 2045, the current energy transition strategy relies on major efficiency gains, comprehensive electrification of energy use, and an almost complete shift of electricity generation to renewables. This trajectory, however, entails significant additional costs that will place further burdens on households and businesses in the coming years:

- **High investment requirements across all sectors**: Our meta-analysis of existing studies shows that the annual investment requirements for the energy transition will increase in the future and, for example, will be **between €113 and €316 billion in 2035**. By way of comparison, total gross private investment in Germany in 2024 – across all industries and sectors – amounted to around €770 billion. The maximum investment required for the energy transition is therefore in the order of around 40% of previous gross private investment.
- **Rising energy system costs**: To determine the energy system costs, we use the Frontier Economics energy model COMET in addition to evaluating published cost estimates. For the next ten years alone, we estimate the total system costs to be between €2.1 and €2.3

trillion.[1] The cost increase is permanent: if the current path continues, a further €2.7 to €3.2 trillion will be incurred in the following 15 years until 2050. This results in estimated **total system costs of around €4.8 to €5.4 trillion for the period 2025-2049.**

- **Bureaucratic burden**: The implementation of the energy transition is estimated to cause **around €10 billion** in bureaucratic costs **annually** at the federal level alone. Added to this are considerable bureaucratic costs associated with EU regulations and delegated acts that do not require national implementation, as well as municipal and state regulations.

- **Challenges in practical implementation**: In addition to the financial burden, there are considerable implementation risks. Long planning and approval procedures, bottlenecks in skilled labour and the limited availability of materials and land mean that the speed of system conversion assumed in the status quo is unlikely to be achievable in practice.

These factors underscore that the current course is not only costly but also fragile in a world of growing uncertainty. Without a change of direction, the pressure on the economy will intensify, undermining international competitiveness and threatening the affordability and social acceptance of the energy transition. The stakes are also global: Germany’s role as a climate pioneer – pursuing more ambitious targets than almost any other country, including within the EU – rests heavily on the expectation that others will follow its example. That expectation depends on the German energy transition being demonstrably successful.

New paths for the energy transition – time for a ‘Plan B’

Against this backdrop, we develop a fundamentally new concept for the energy transition – a simple policy framework built on innovation and competition. Its aim is to couple the transformation toward a defossilised economy with the strongest possible safeguards for prosperity, resilience, and globally effective climate protection.

The new concept takes into account the key insight that the future can only be planned to a limited extent and that it is therefore important for policymakers to create a ‘breathing’ framework (seeFigure 1). The proposed reorientation does not seek to break with the existing system, but could be developed gradually from the current status quo framework. We illustrate this with examples of implementation steps, but deliberately remain at a high level of analysis. The detailed design of specific conversion measures is not the subject of this study, but should be left to the political actors to discuss.

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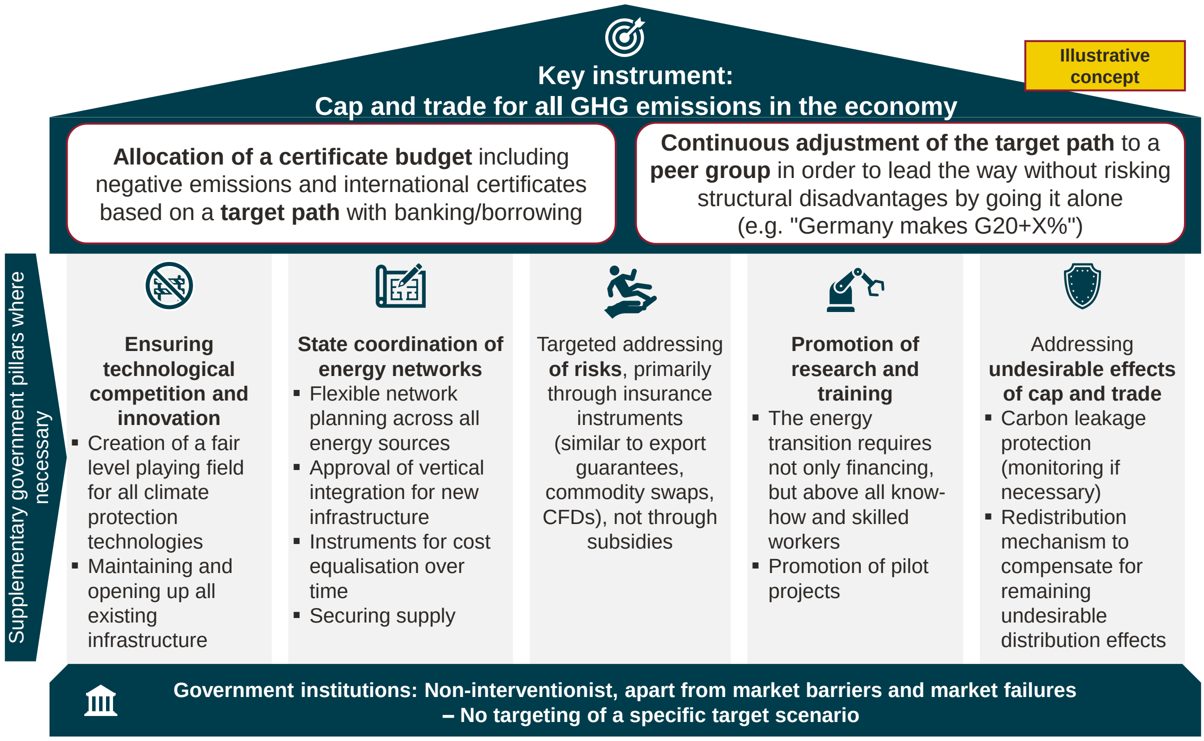
[1] Many studies base their assumptions for key technologies on the expectation that investment costs per kW of capacity will fall sharply in the long term due to economies of scale and technological advances. Recent developments show that global supply chain problems, the development of raw material costs, tariffs and increased financing costs could significantly limit the cost reduction potential of individual technologies in the short to medium term. We have therefore determined a cost range based on varying technology-specific learning curves, which explicitly takes into account the uncertainty surrounding future technology cost developments .

Figure 1 A fundamental new concept for the energy transition



Source: Frontier Economics.

At the heart **of the approach is a comprehensive cap-and-trade system that covers all greenhouse gas emissions (GHG emissions) across all sectors**. A **certificate budget** is set for all greenhouse gases emitted. The budget is calculated on the basis of a defined target path, but can then be used as freely as possible within the period until climate neutrality is achieved. The budget also takes into account negative emissions and the use of recognised international certificates. Concrete implementation could take place, for example, by expanding the existing EU Emissions Trading System (ETS) into a comprehensive cap-and-trade system (accelerated introduction of ETS 2, medium-term merger with ETS 1, expansion to previously unaccounted emission sources).

The target path will **be regularly adjusted to the development of a defined international peer group (such as the G20)** in order to create a game-theoretical incentive for more climate protection without creating disadvantages for Germany's competitiveness through structural unilateral action. One guideline could be: Germany reduces by a maximum of "G20+X%". This could be implemented in the ETS, for example, by introducing "checkpoints". These would be used to check whether the reduction level is within the target corridor compared to the efforts of the peer group.

In addition to the central cap-and-trade system, the state only takes on clearly defined tasks where there is market failure or a need for coordination. These include:

- **Ensuring technological competition and innovation**: The aim is to establish a fair *level playing field* in which cost-effective and efficient solutions can prevail. The market-based incentive to reduce emissions reflected in cap-and-trade makes additional subsidies and regulations superfluous. The existing subsidy framework (e.g. EEG) could be gradually phased out in this system.

- The state would continue to play a role **in coordinating network infrastructures and security of supply**. Cross-sector network planning – particularly for electricity, gas, CO_2 and hydrogen – should ensure that synergies are exploited and inefficient parallel structures are avoided. This could include the following elements, for example:

  - Systematic **integration of electricity, methane, hydrogen, CO_2** and other infrastructures – coordinated expansion at European level.
  - **Temporary approval of vertical integration** in the development of new infrastructures such as hydrogen or CCS.
  - Creation of a legal basis for CCS and other new energy sources.
  - Temporal compensation mechanism for the ramp-up of new infrastructures – for example, in the form of an amortisation account for CO_2 networks.
  - Adjustment of the grid fee system with a higher power price component based on the polluter-pays principle.
  - **Acceleration of approvals** (e.g. preferential connections for system-friendly feeders).
  - **Ensuring security of supply** – for example, by monitoring guaranteed capacity in the electricity market or by ensuring sufficient domestic reserves for imported energy sources.

- **Targeted risk hedging for new technologies**: The state supports investments in innovative climate protection technologies through specific insurance instruments – such as price hedging for CO_2 or hydrogen, or credit guarantees modelled on the template of the Hermes cover (export credit guarantees). These are purely insurance mechanisms for hedging the risks of new technologies and markets, not broad subsidies – in economic terms, there is no transfer payment, but rather a risk shift to improve investment conditions.

- **Investment in research and education**: Because Germany has a competitive disadvantage in renewable resources, these deficits must be compensated for, for example, through innovation and technological leadership. This could be ensured, for example, by:

  - **Training and study programmes** to meet the demand for skilled workers along the entire value chain.
  - **Focusing public funds on projects** with systemic relevance, especially where market players are reluctant to act.
  - **Support for pilot and large-scale projects** to test new technologies under real-world conditions and enable scaling (e.g. via CAPEX subsidies). However, subsidies in these

early market phases should always be subject to the proviso that the knowledge gained is made available to the entire industry and does not act as a barrier to competition for other players.

- **Complementing** the cap-and-trade scheme to avoid undesirable economic or social side effects through border adjustment measures and revenue redistribution:
  - If, despite peer group anchoring, a trend towards carbon leakage emerges, targeted border adjustment measures can be implemented – based on existing instruments such as the EU CBAM, but in a simplified and administratively leaner form.
  - In addition, a mechanism for redistributing potential revenues from emissions trading to households, businesses and EU Member States is envisaged. This should also be used to offset undesirable distributional effects – particularly of a social nature – and to strengthen social acceptance. This is particularly relevant for private households, which may incur high additional costs due to emissions prices.

Implementing the concept could result in significant cost savings

An exemplary model shows that the implementation of the new concept would result in considerable **cost savings.** However, it should be noted that the current energy transition follows a "master plan", while the new concept deliberately creates a flexible framework that can respond to uncertainties: the results of innovation, entrepreneurial initiative and competition, as well as new growth impulses, cannot be planned and calculated in detail. **Key advantages of the concept – adaptability and innovation incentives – are therefore not yet reflected in the following calculations based on illustrative assumptions.**

Simply by realigning the energy transition more efficiently – with greenhouse gas emissions in Germany remaining unchanged – the total system costs of the energy transition can be reduced by at least €530 to €910 billion by 2050 compared to continuing with the status quo (seeFigure 2). This alone corresponds to a **reduction of approximately 11% to 17%** of the estimated total costs of the energy transition. The savings are mainly achieved through **two key levers**:

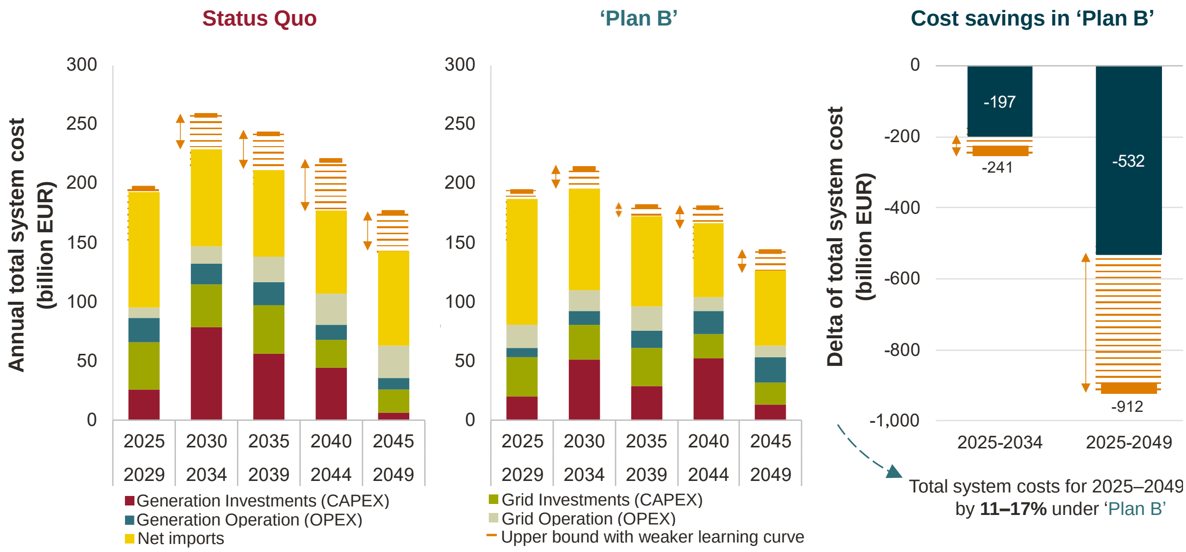
- **First,** the concept opens up the **solution space for all available low-emission technology options –** under the umbrella of a comprehensive cap-and-trade system. Fixed targets for the expansion of wind power (onshore and offshore) and PV are being abolished, and new power generation capacity is being added through competition between all technologies on the market. Taking into account the available potential, greater use of biomass and low-emission options that are not based on renewable energies but use fossil fuels and capture, utilise or store CO_2 ("carbon capture, utilisation and storage", CCUS), e.g. in the form of "blue" hydrogen or in the form of CO_2 capture in industry.

  This enables **a more efficient technology mix, in which cost-effective options such as biomass, CCS or even hydrogen imports can be used more extensively**, while requirements for more expensive and less efficient processes – such as certain expansion paths for wind or solar technologies – are eliminated. As a result, the phase-out of coal (market-driven) will take place earlier, but gas will be used more extensively. Expensive domestic production of renewable 'green' hydrogen will be replaced by imports and blue hydrogen. As a result, electricity consumption will increase less sharply than under the status quo, and grid expansion can be made more cost-efficient. Overall, investments in renewable electricity generation capacity will be lower, especially in wind and rooftop PV, even though significant expansion is still necessary.

- **Second, moving away from rigid interim targets** (e.g. 90% emission reduction across the EU by 2040) **towards a cross-sectoral emissions budget** allows for better timing of investments. What counts for the climate impact is the total emissions until climate neutrality is achieved, not the exact time at which each interim target is reached.

  The budget approach makes it possible to prioritise cost-effective measures, while expensive technologies can be spread out over time or implemented later. This avoids the risk that rigid interim targets set ex ante will force inefficient and premature investments, even though more cost-effective alternatives would be available later. **Investments are aligned with natural reinvestment cycles, cost curves are smoothed, and unnecessary price spikes are avoided** – while the overall greenhouse gas reduction target remains unchanged.

Figure 2 Reduction in system costs through the new concept ('Plan B') by 2050



Source: Frontier Economics.

Note: The energy system costs considered here include new investments in generation capacity (CAPEX), ongoing operating costs (OPEX), grid infrastructure costs (CAPEX & OPEX) and energy imports. Necessary demand-side investments in the building, transport and industry sectors are not taken into account. Modelling of the status quo and 'Plan B' is based on the same final energy consumption according to the BMWK O-45 electricity long-term scenario. Cost savings in 'Plan B' are therefore achieved exclusively through more efficient provision of final energy, not through a change in consumption structure or a "fuel switch".

Results under certain technology assumptions: ***It is expressly not the aim of 'Plan B' to pursue a specific technology scenario or to imply that the technology mix shown in the analyses below would be the optimal one. These exemplary results are based on the current state of knowledge and parameters that are highly likely to change in the future.***

Additional savings potential arises in the form of a third major lever through greater global integration of climate protection efforts:[2] On the one hand, through the crediting of more cost-effective climate protection measures abroad while maintaining the same climate targets, and on the other hand, through flexible adjustment of the pace of transformation to the development of international peer groups. This international integration could ultimately result in Germany having a larger emissions budget at its disposal than currently planned. This would generate further cost savings: expanding the German budget by an amount corresponding to a two-year postponement of the net-zero target would save a further €80-220 billion – with corresponding scaling potential.

Overall, depending on the degree of international cooperation, the concept could potentially generate savings of well over €1 trillion by 2050.

It is important to note that the savings potential identified only relates to cost reductions in the energy system itself (i.e. lower overall costs for domestic production, transport, storage and import of energy). In reality, the cost reduction potential will be significantly higher – for example, through the more efficient use of cost-effective avoidance options in the end-use sectors

2 Calculated in the model using the example of an expansion of the national (and EU-wide) emissions budget by around 10%, which corresponds to a two-year extension of the German climate target.

of industry, buildings and transport, and not least due to the greatly reduced bureaucratic burden on the state and businesses.

Conclusion: The concept developed ('Plan B') represents an alternative for a fundamental change of course in energy transition policy towards more innovation, growth, and global climate protection.

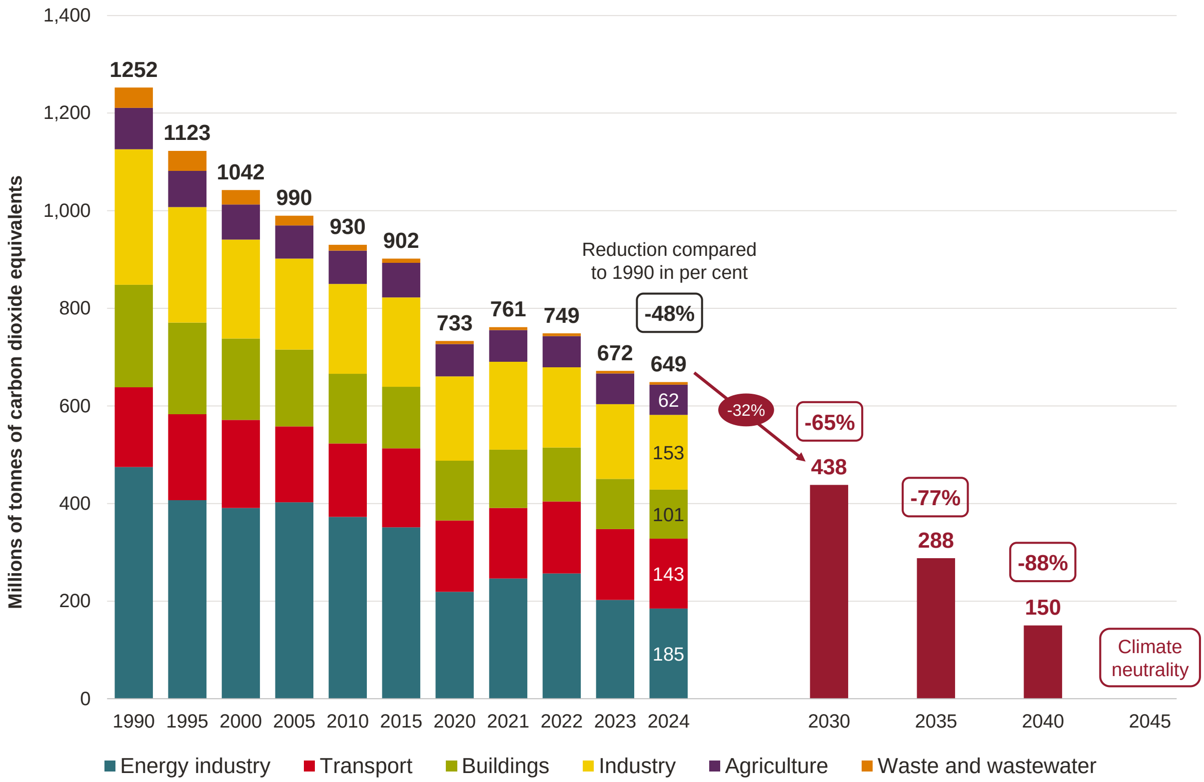
The analysis makes it clear that the current course of the energy transition is hardly sustainable. The new concept developed in this study offers an alternative that combines ambitious climate protection with economic strength, cost efficiency, and international effectiveness. The potential savings of well over €1 trillion by 2050 underscore the potential for a genuine change of course. Successful climate protection does not require rigid targets, but rather an innovation-friendly, market-oriented, and internationally compatible framework – and this is precisely where the new concept comes in.

1 Energy transition in Germany – time for new approaches

The energy transition is Germany's contribution to mitigating global climate change. At the same time, the German energy transition is one of the largest economic transformation projects worldwide: in hardly any other developed economy with high industrial value added and a strong export orientation has the energy supply been converted so comprehensively from fossil fuels to renewable energies.

Germany has set itself very ambitious climate targets in comparison with other European and global countries: national greenhouse gas emissions are to be reduced by at least 88% by 2040 compared to the reference year 1990. Germany intends to be completely climate-neutral by 2045 (see Figure 3).

Figure 3 Development of historical greenhouse gas emissions and the target path required to achieve climate neutrality



Source: Frontier Economics based on the German Federal Environment Agency (2025a).

Note: Emissions by sector according to the Federal Climate Protection Act, excluding land use, land use change and forestry (LULUCF); targets for 2030, 2035, 2040 and 2045 in accordance with the Federal Climate Protection Act

Based on final energy consumption in Germany of 2,300 TWh in 2023,[3] the political goal requires that electricity generation and large parts of industrial process heat, transport and building heating are sourced almost entirely from renewable energy by 2045.

Remarkable successes, but also high costs and still a long way to go to achieve climate neutrality

Remarkable successes have already been achieved: in the electricity sector, for example, the share of renewable energies, especially from solar and wind, has increased from 3% to over 50% in the past 25 years. Although the transformation to date has been unique worldwide, it has also been accompanied by considerable economic costs: under the Renewable Energy Sources Act (EEG), feed-in tariffs amounting to €220 billion were paid between 2000 and 2023 for the promotion of electricity generation, primarily from wind and photovoltaics (PV).[4] In addition, there was a high demand for expansion of the electricity transmission and distribution networks, which has led to rapidly rising grid fees in recent years. These higher grid fees were mainly borne by small and medium-sized enterprises, trade and commerce, and private households. Overall, electricity prices for end consumers in Germany are now significantly higher than those of European and international trading partners. This is increasingly perceived as a threat to Germany's competitiveness and is already leading to the relocation of production and investment abroad. At the same time, the climate impact achieved at great expense is limited: although the share of renewable energies in the electricity mix has risen significantly, Germany remains one of the six EU countries with the highest GHG emissions per kilowatt hour of electricity generated.[5]

At the same time, there is still a long way to go before the entire economy achieves climate neutrality. Despite the successes mentioned above in the electricity sector, renewable energies currently account for only 22.4% of total final energy consumption.[6] This is because in the major consumption sectors of building heating, process heating and transport, which are still dominated by fossil fuels, much of the change and the investment required to convert end uses and infrastructure is still to come. As Figure 4 shows, only around 19% of final energy demand in the heating sector has been defossilised to date. In the transport sector, the share is even lower, at around 7%. Although the share in the electricity sector is already 51%, it can be assumed that the second half of the defossilisation of electricity will involve a disproportionate amount of effort compared to what has been achieved so far.

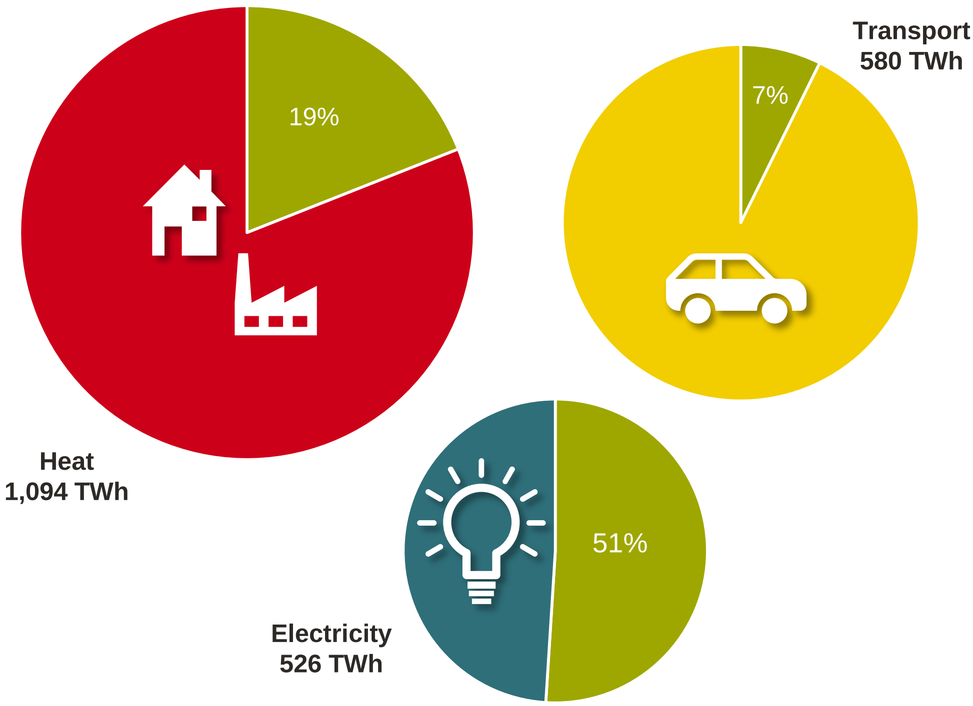
3 See Federal Environment Agency (2025b).

4 See Statista (2025).

5 See EEA (2025). In a comparison of GHG emissions from electricity generation in EU member states, Germany ranks sixth, with 329 g(CO2e)/kWh. The EU average is 210 g(CO2e)/kWh.

6 See Federal Environment Agency (2025c).

Figure 4 In most sectors of the economy, the energy transition is still in its infancy



Source: Frontier Economics based on the Renewable Energy Agency (2025).

Note: The figure shows energy consumption in Germany in 2023 by electricity, heat and transport. Electricity consumption in the heat and transport sectors is included in gross electricity consumption. The percentage shown in green indicates how much of the energy consumption in each sector has already been defossilised.

Burden on businesses and the population reaches a level that jeopardises prosperity and thus acceptance of the energy transition

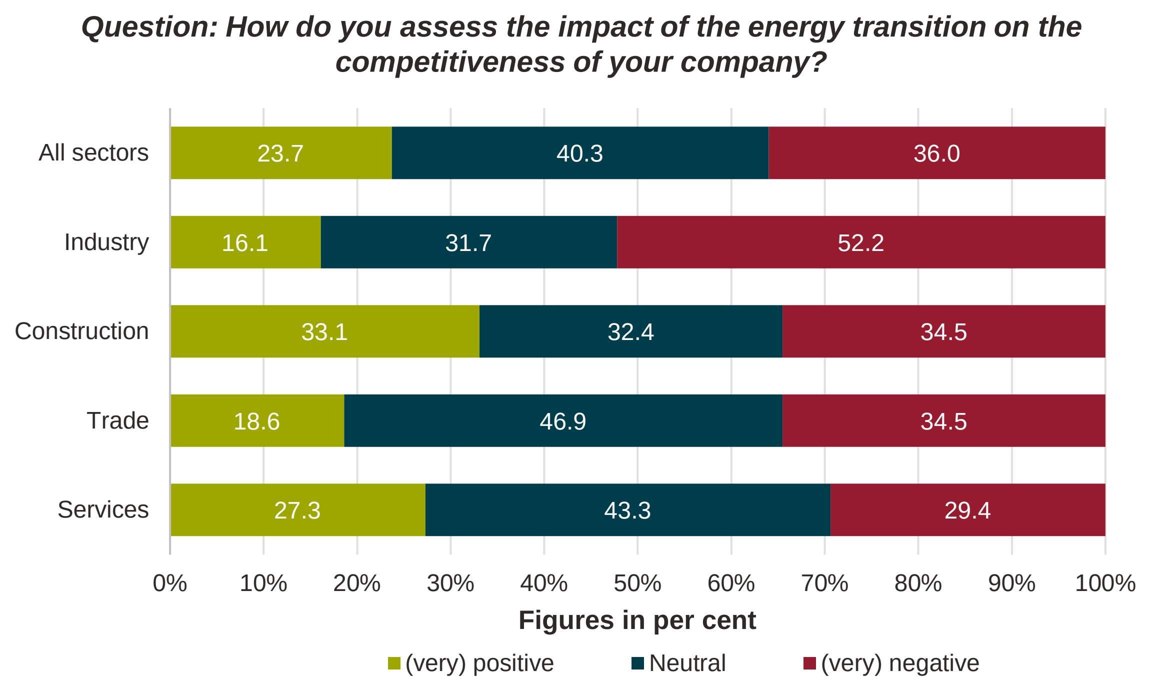
The energy transition is currently in a critical phase, placing a rising burden on the economy and individuals:

- **Increasingly negative assessment of the energy transition by companies in Germany:** According to the DIHK Energy Transition Barometer, companies are increasingly sceptical about the energy transition. In particular, high energy costs, inadequate infrastructure, lengthy planning and approval processes, and uncertainty about the political framework are criticised – and seen as a driver of declining competitiveness. More than one in three companies assess the impact of the energy transition on their own competitiveness as negative; in industry, it is even one in two companies (seeFigure 5).

- **Massive cost increases expected over the next two decades:** A number of studies published in recent months have come to the unanimous conclusion that the investments required for the energy transition will increase significantly in all sectors. Many studies also emphasise that, in order to achieve Germany's climate targets, a large part of these investments must be made in the next ten to fifteen years. This will result in rising costs for companies and consumers.

- **Numerous signs of deindustrialisation:** There are already increasing signs that energy-intensive production is being relocated abroad and that new investments are being planned outside Germany. Production in energy-intensive industries has been declining for years (seeFigure 6). In the first half of 2025 alone, numerous companies, e.g. in the chemical industry but also in other sectors, announced closures or relocating German production facilities abroad.[7] As a result, there is a threat of structural losses of hundreds of thousands of well-paid industrial jobs, which cannot be offset by rapid structural change on this scale. Due to this carbon leakage effect, the exodus of industry ultimately has no positive impact on the climate.

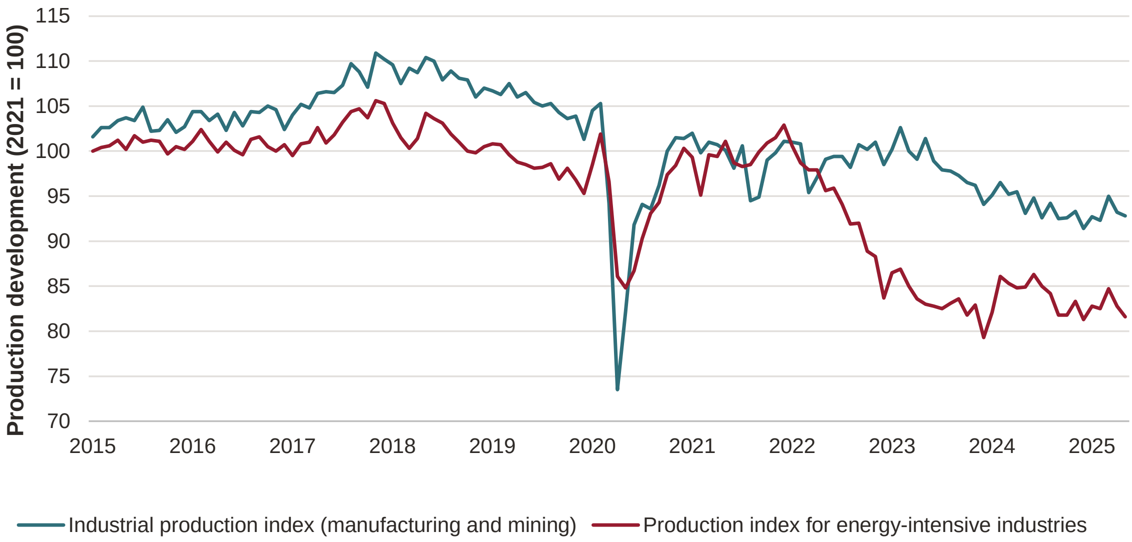
Figure 5 For many companies, the energy transition has a negative impact on competitiveness



Source: Frontier Economics based on DIHK (2025).

7 For example, the chemical companies Ineos and Dow have announced the closure of plants in North Rhine-Westphalia and Saxony-Anhalt. The solar glass manufacturer GMB has filed for insolvency. In all cases, the decisions were largely justified by energy costs that were not competitive on an international scale.

Figure 6 Production development in energy-intensive industries



Source: Frontier Economics based on Federal Statistical Office (2025b).

As a result, the current policy approach risks overburdening the economy. Losses in prosperity and job losses jeopardise the social acceptance of the energy transition. All in all, there is a threat of increased burdens that could jeopardise the successful implementation of the energy transition as a whole.

Time to rethink the energy transition

The considerable economic costs are offset by potential benefits: on the one hand, lower climate-related costs could arise in the long term if Germany and Europe substantially reduce their emissions. On the other hand, there is an opportunity for a new technology sector for energy transition technologies to develop, which will contribute to value creation as an export industry in the future.

However, the long-term effects of these efforts depend on uncertain external factors. Only by sustainably limiting global emissions can the costs of climate change be kept low: Germany and Europe can make a significant contribution here. However, a relevant lever for global emission reduction only exists if all major current and future emitters make substantial efforts. In addition, the development of an internationally competitive industrial sector depends less on the existence of a domestic pilot market and more on the economic conditions of the location – in particular energy prices, the regulatory environment and the availability of skilled labour. This is exemplified by the case of the German solar industry: although strong domestic demand initially led to the emergence of a corresponding supply industry, this was almost completely displaced by Asian producers within a short period of time, in part due to competitive disadvantages.

While the potential benefits of the energy transition will only materialise later and remain uncertain, the short- and medium-term costs of the transition are very high: the energy transition is already leading to noticeable additional costs for businesses and households, and energy costs are continuing to rise.

Against this backdrop, the key question is how far and by what means the additional burdens of Germany’s energy transition can be avoided or at least reduced.

To this end, this study analyses the areas in which the current course of the energy transition (hereinafter referred to as the "energy transition status quo") may be subject to structural and technical errors, and identifies a ‘Plan B’ equipped with a few key levers, the implementation of which could make the energy transition in Germany more cost-effective and efficient in terms of global climate protection. As part of the study, various workshops were held with representatives from different industries and academia to discuss the analyses and results and to test the practicality of the proposed new approach.

The study contains:

- an **analysis of the upcoming burdens resulting from continuing on the current path** of the energy transition and the key drivers (Chapter 2);
- a **recalibration of the energy transition**, taking into account the need to maintain Germany's competitiveness as an industrial and manufacturing location (Chapter 3); and
- the **development of a ‘Plan B’ as an alternative to the status quo in energy policy** in order to ensure the long-term and sustainable achievement of the energy transition goals (Chapter 4).
- Finally, we outline **how the new approach could be developed** incrementally from the current policy mix (Chapter 5); and
- draw a brief **conclusion** (Chapter 6).

2 Continuing the current energy transition policy will entail significant cost increases – while structural problems also jeopardise its successful implementation.

Energy is the basis of almost all economic activity. In an economy that is heavily based on industrial value creation, the secure availability of energy at competitive prices is a central pillar for creating and maintaining prosperity.

The energy transition requires a comprehensive transformation in all sectors of the economy. In particular, the restructuring of energy supply, industrial processes and end-use applications requires considerable investment. This requires the mobilisation of large amounts of capital, which is then not available for investment in other areas. A key challenge here is that the mere sustainable transformation of value chains often generates little or no additional economic value in itself:[8] Existing plants and infrastructure are often replaced rather than newly created. For example, the conversion of steel production from coal to hydrogen as a reducing agent is currently being promoted. This can reduce CO_2 emissions, but the necessary investments are not offset by additional steel production (in contrast to a situation in which investments are made to increase the capacity available in the economy). Put simply, even with a successful energy transition, the overall economic value added in the then defossilised sectors will remain similarly high – but without climate-damaging emissions.[9]

The necessary comprehensive new investments in energy generation and distribution, as well as the conversion investments in businesses and households, go far beyond normal reinvestment cycles in terms of both time and scope. All in all, this will lead to a high additional economic burden, at least in the short term. Businesses and citizens will therefore face cost increases, which will manifest themselves, for example, in further significant rises in energy and product costs.

In this chapter, we analyse the expected cost developments if the current status quo of the energy transition continues and highlight the key technological and structural cost drivers. To this end, we evaluate the results of ten recent studies on the energy transition.[10] In addition, we supplement and validate the existing cost estimates with analyses using Frontier's own European energy market model COMET. Unless otherwise stated, all euro values in the following are given in real 2024 euros and do not include future inflation.

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8 One possible contribution to value creation would be to avoid the follow-up costs of climate change. However, these measures have only a minor direct impact on preventing climate damage in Germany, as global greenhouse gas emissions are decisive in this regard and Germany has little influence on their volume. Furthermore, such benefits would only materialise in the long term and therefore cannot contribute to value creation in the short term.

9 Although the establishment and provision of energy transition technologies themselves lead to value creation (e.g. in the field of mechanical and plant engineering), similar value creation could be achieved if these investments were made in other areas, which in turn would generate their own additional value creation.

10 An explanation of the model can be found at the beginning of Chapter 2.2 .

2.1 Comprehensive investments are necessary to transform the economy towards climate neutrality.

The costs of the energy transition in Germany and future investment requirements have been examined in a number of recent studies. Although these analyses differ in terms of methodology and assumptions, they all show the same result: the expected investments required to achieve the energy transition targets are enormous. Based on an evaluation of ten recent studies, we estimate the annual investment requirements for the energy transition across all sectors to be at least €113 to €316 billion in the year 2035 alone. By way of comparison, gross private investment in Germany totalled around €770 billion in 2024. To implement the energy transition, annual private investment would therefore have to increase by at least 15% to 41% in real terms compared with today's level.

The current energy transition assumes high efficiency gains, comprehensive electrification of energy consumption, and almost complete electricity generation from renewable energies only.

The path to achieving the climate targets, as last defined by the German government in 2022 with the so-called ‘Easter package’,[11] forms the basis for the following analyses. The key cornerstones of this path are reflected in the BMWK long-term scenario O45-Strom, which forms the basis for our modelling of the future energy system in Germany.[12] The development of the German energy transition in the status quo is based on a number of key prerequisites and assumptions:

- **Comprehensive efficiency gains:** The current energy transition policy anticipates high efficiency gains and, as a result, a sharp decline in final energy consumption. Based on an estimated final energy consumption of 2,400 TWh in 2025, the O45-Electricity long-term scenario predicts that the demand of industry, households, transport and buildings in 2045 will decline by 650 TWh, corresponding to a demand reduction by almost 30% over the next 20 years.[13]
- **High degree of electrification:** Future energy consumption is expected to become largely electrified. According to the long-term scenario O45-Electricity, the share of electricity in final energy demand will rise from around 20% today to over 50% in 2045. In

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11 The Easter package passed by the German Bundestag on 7 July 2022 comprises several bills on the expansion of renewable energies and amendments to the Federal Nature Conservation Act. An overview of the measures contained in the Easter package can be found in BMWK (2022).

12 The "Long-term scenarios for the transformation of the energy system in Germany" model scenarios for the future development of the energy system on behalf of the Federal Ministry for Economic Affairs and Climate Protection, with which the energy and climate policy goals can be achieved. The O45-Electricity scenario of the current Long-term Scenarios 3 examines a development towards climate neutrality that is heavily based on the use of electricity. See Fraunhofer ISI (2025).

13 See Energy demand of the O45-Electricity scenario in the BMWK Long-Term Scenarios Scenario Explorer (Fraunhofer ISI, 2025).

addition, electricity will be needed on a large scale for the production of green hydrogen and hydrogen derivatives, which in turn will serve as fuel in applications that cannot easily be electrified.

- **Significant expansion of renewable energies:** According to the Easter package, the share of renewable energies in gross electricity consumption is expected to be at least 80% by 2030 and almost 100% by 2035.[14] To achieve this, the expansion of renewables is politically guided by a technology-specific path.[15]

- **Achieving climate neutrality by 2045:** The German Climate Protection Act sets out an ambitious emissions reduction pathway. By 2040, CO_2 emissions in Germany are to be reduced by at least 88% compared to 1990 levels.[16] Germany aims to be climate neutral by 2045[17], five years earlier than the European Union's target and well ahead of many international trading partners.

Aiming for such a change in just 20 years illustrates the extreme ambition of the current plans for the energy transition. In other words: to transform Germany into a (net) climate-neutral country by 2045, an approximately linear reduction path would result in a total residual greenhouse gas budget for Germany that is only ten times higher than today's annual emissions for the remaining 20-year period until climate neutrality is achieved.

Estimates of the annual investment required for the energy transition across all sectors for the year 2035 range between 113 and 316 billion. €

Numerous studies on the energy transition have been published in the recent past. We have reviewed these studies listed inTable1 with regard to the cost estimates for Germany.

Table1 Overview of the studies included in the meta-analysis

Authors/Editors (Year)	Study title
Agora Energy transition (2024)	Investments for a climate-neutral Germany. Financial requirements and policy options.
Ariadne (2025)	Making the energy transition cost-effective: scenarios for climate neutrality in 2045
Aurora Energy Research (2025)	Path to climate neutrality in the electricity sector in 2040 with reduced system costs

14 See BMWK (2022), pp. 3-4.

15 The expansion paths set out in the Easter package envisage an increase in capacity for onshore wind to 115 GW, offshore wind to 30 GW and PV to 215 GW in 2030. See BMWK (2022), p. 3.

16 See Section 3(1)(2) KSG.

17 See Section 3 (2) KSG.

Authors/Editors (Year)	Study title
BCG/IW/BDI (2025)	Getting the energy transition on track. Impulses for a competitive energy policy.
BDEW/EY (2024)	Progress monitor 2024 Energy transition
DNV (2025)	Energy Transition Outlook Germany 2025
ewi (2023)	Investments in the energy transition until 2030. Investment requirements in the transport, building and electricity sectors.
Fraunhofer CINES (2025)	How do investments in renewable energies and energy infrastructures support a climate-neutral and competitive industry in Germany and Europe?
Prognos (2024)	Climate protection investments for the transformation of the energy system by sector and application
PwC (2024)	Accelerated investment in climate protection pays off – economically too

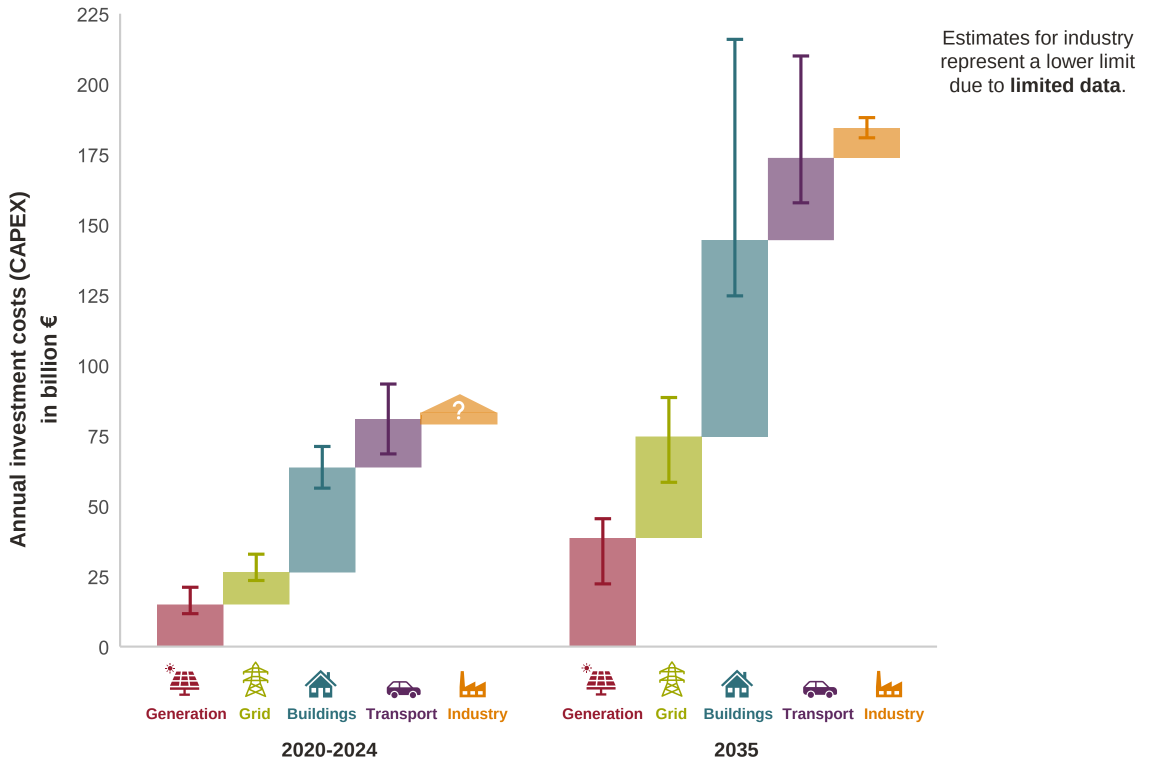
Source: Frontier Economics.

The studies we evaluated agree that implementing the energy transition will entail considerable additional costs. Not only does the energy system need to be almost completely transformed, but the restructuring of the energy system also requires high levels of investment in all energy-consuming sectors in order to reduce energy demand and convert end uses to (green) electricity or hydrogen, as well as to minimise residual emissions, e.g. through the use of carbon capture and storage (CCS).

Figure 7 summarises the estimated annual investment requirements (CAPEX) for the energy transition from the ten studies examined in the meta-analysis. The left-hand side of the figure shows the annual investment requirements – broken down into the sectors of energy generation, energy networks, buildings, transport and industry – for the period 2020 to 2024 as a historical comparison value. The right-hand side of the figure shows the estimated annual investment requirements in 2035. The figure illustrates that the total annual investments related to the energy transition in the years 2020 to 2024 averaged around €82 billion.[18] In contrast, achieving the targets in 2035 will require average annual investments of around €184 billion (represented by the end of the stacked bar). This corresponds to more than a doubling of the annual investment level in 2035 compared to the current level. The increase in annual investment requirements makes it clear that, from a cost perspective, the energy transition is still in its relative infancy.

18 The total range of investment cost estimates from the studies considered is between €56 billion and €115 billion per year.

Figure 7 Annual investment requirements for the energy transition based on a meta-analysis of 10 studies



Source: Frontier Economics based on the studies listed inTable1.

Note: The bars show the arithmetic ***mean values of the investment estimates*** *per sector, while the vertical lines show the respective* ***range (minimum to maximum****). For better comparability, the values are presented cumulatively, with each category positioned relative to the mean value of the sectors below. The external cost estimates were harmonised by means of a uniform categorisation of the sectors and the plausibility check of key assumptions.*

The estimates in the individual studies show a high degree of variation, which illustrates the high uncertainty of future cost developments and the underlying assumptions. The range of cost estimates in the individual sectors is represented by the vertical lines in the figure. Taking into account the uncertainties, the estimated annual investment requirements across all sectors in 2035 range from €113 billion to €316 billion.[19]

The figure illustrates that the costs incurred in the demand-side sectors account for a large part of the economic costs associated with the energy transition. It should be noted that such cost estimates are very complex, particularly in the industrial sector with its vast number of individual processes, and therefore often only a small portion is taken into account in the analyses.

19 The range of investment estimates is calculated by adding the respective lower and upper limits of the estimates in the individual sectors (represented by the uncertainty bars).

In the following sections, we present the key drivers of economic cost increases. Chapter 2.2 deals with the cost drivers in the energy system, while Chapter 2.3 addresses the cost increases resulting from the necessary transformation of the demand side.

2.2 The restructuring of the energy system is accompanied by high cost increases

The energy system is the backbone of any economy's energy-based value creation. It encompasses all elements from energy generation to conversion, transport, storage and distribution, which have been built up over decades in line with demand. If the energy transition changes energy sources, transport routes or storage requirements, there is an immediate need for adjustment, the costs of which can be quantified accordingly.

To determine the energy system costs, we use published cost estimates and, in particular, Frontier Economics' COMET energy model.[20] With the help of this model, we first present the system costs of energy supply in this chapter, assuming that the current status quo of the energy transition will continue.

In order to map the expected costs under the status quo, the model was parameterised with the existing political framework conditions and objectives as well as assumptions about technology costs.[21] The results of the modelling were compared and validated in a review process with the results of the evaluated studies (see aboveTable1).

The energy transition will cause energy system costs to rise significantly in the coming years. In the next 10 years alone, total system costs will amount to around €2.1 to €2.3 trillion (see Figure 8). The cost increase is permanent: if the current path continues, a further €2.7 to €3.2 trillion will be incurred in the following 15 years until the beginning of 2050. This results in total system costs of around €4.8 to €5.4 trillion for the period 2025-2049.[22] The total system costs include new investments in generation capacity (CAPEX), ongoing operating costs (OPEX), grid infrastructure costs (CAPEX & OPEX), and energy imports. We will discuss the individual cost components and their main drivers in more detail below.

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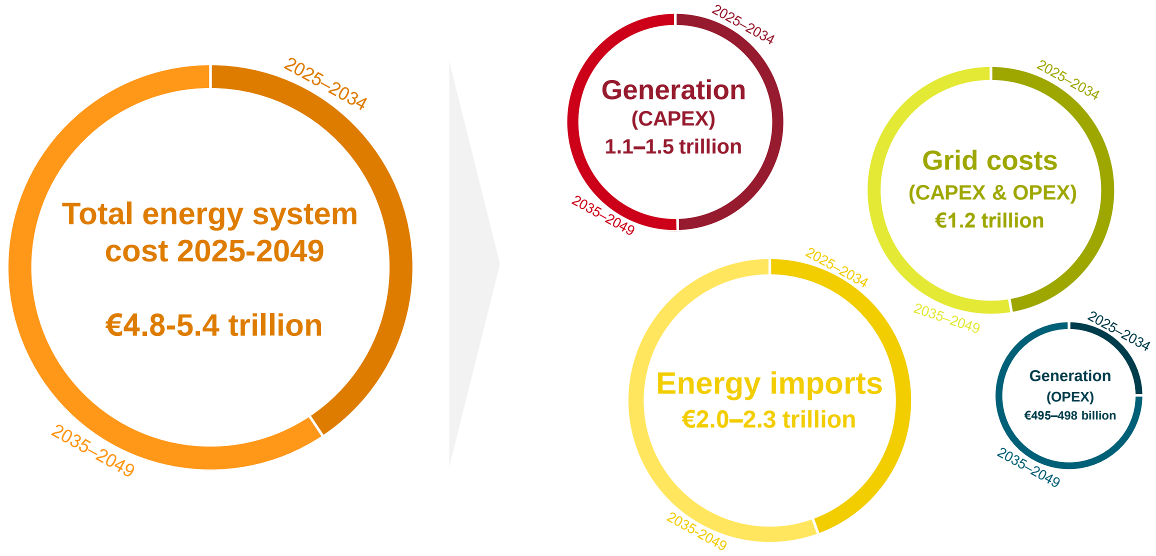
20 Frontier Economics' COMET energy system model is an optimisation model that calculates the system costs of the energy transition for Germany and Europe. It maps all relevant energy sources – from electricity and hydrogen to synthetic fuels – and the associated infrastructure. COMET simulates investment decisions under various scenarios and minimises the total system costs while covering energy demand on an hourly basis. The model has high geographical resolution and takes into account cross-sector energy flows, bottlenecks in the transmission grid and extreme situations such as "cold dark doldrums". Key results include complete energy and emissions balances, marginal prices, investment requirements and the composition of energy costs over time.

21 For Germany, these are based on the 2022 Easter Package, the BMWK long-term scenarios, and, at European level, the latest available TYNDP report. The key technology cost assumptions are based on IEA (2024).

22 Deviations from the sum of the already rounded subtotals are due to rounding.

Figure 8 Total costs of the energy system due to the energy transition if the status quo continues, 2025-2049



Source: *Frontier Economics.*

Note *The cost ranges shown are based on different assumptions about future technology costs (learning curves). The total costs of the energy system in the period 2025–2049 are based on model calculations assuming a continuation of the status quo of the energy transition.*

System costs depend heavily on future technology costs

Many studies base their assumptions on optimistic learning curves for the key technologies of the energy transition, such as wind power, PV, electrolysers, and batteries, reflecting the expectation that investment costs per kilowatt (kW) of capacity will fall sharply over time due to economies of scale and technological advances. However, these assumptions are subject to a high degree of uncertainty. Recent developments show that global supply chain problems, the development of raw material costs, tariffs, and increased financing costs could significantly limit the cost reduction potential of individual technologies in the short to medium term. For example, the real investment costs per kW of power for wind turbines have risen again since 2020 instead of continuing to fall.[23] Empirically observed learning rates also fluctuate considerably in the long term: a meta-analysis by Rubin et al. (2015) shows that historical learning rates vary greatly depending on the technology and region and have slowed significantly over time.[24] We have therefore determined a cost range based on varying technology-specific

[23] See Deutsche WindGuard (2024), p. 17, for the costs of onshore wind turbines, or Danish Energy Agency (2025), p. 5, for the significantly increased costs of offshore wind turbines between 2022 and 2025.

[24] See Rubin et al. (2015).

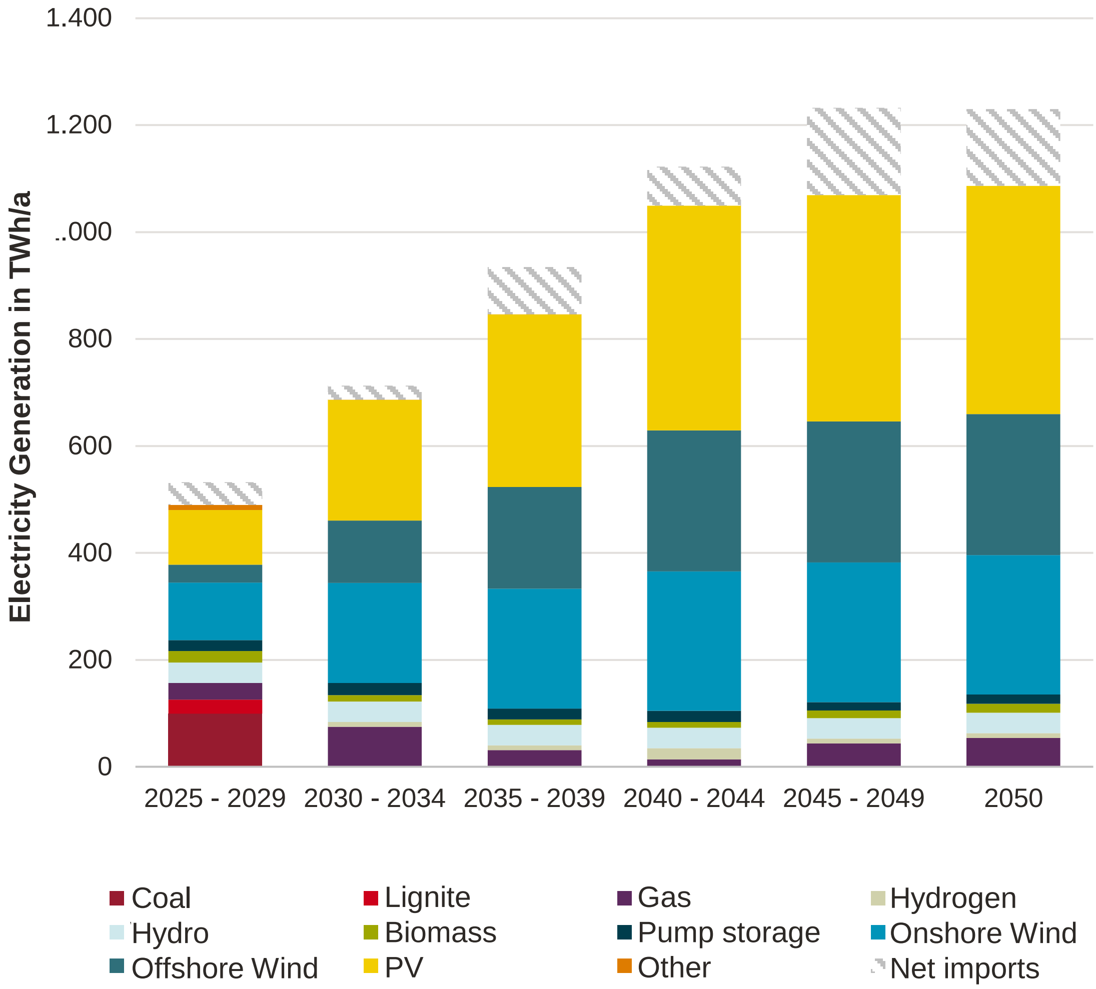
learning curves that explicitly takes into account the uncertainty surrounding the future development of technology costs.[25]

If the status quo continues, the future electricity mix will be dominated by wind and PV

Due to the electrification of end uses in all sectors, electricity consumption would have to double over the next 25 years if the status quo of the energy transition were to continue. The specified technology-specific expansion targets for renewable energies will lead to a massive increase in electricity generation from wind and PV – from around 240 TWh in 2025 to around 950 TWh in 2050 (see Figure 9). By 2045, the remaining use of (fossil) natural gas for electricity generation will also be completely replaced by renewable alternatives (biomethane and hydrogen or its derivatives such as power-to-methane (PtM)). The model forecast also shows a significant increase in net electricity imports to 144 TWh in 2050 to compensate for the volatile generation of wind and PV.

[25] Specifically, we assume lower learning curve effects for the calculation of the upper limit of the cost range for all technologies, so that the investment costs (CAPEX) of the technologies per kW of capacity only decrease by 20% of the reduction assumed by the IEA (2024) each year.

Figure 9 **Modelled annual electricity generation mix in Germany if the energy transition status quo continues, 2025-2050**



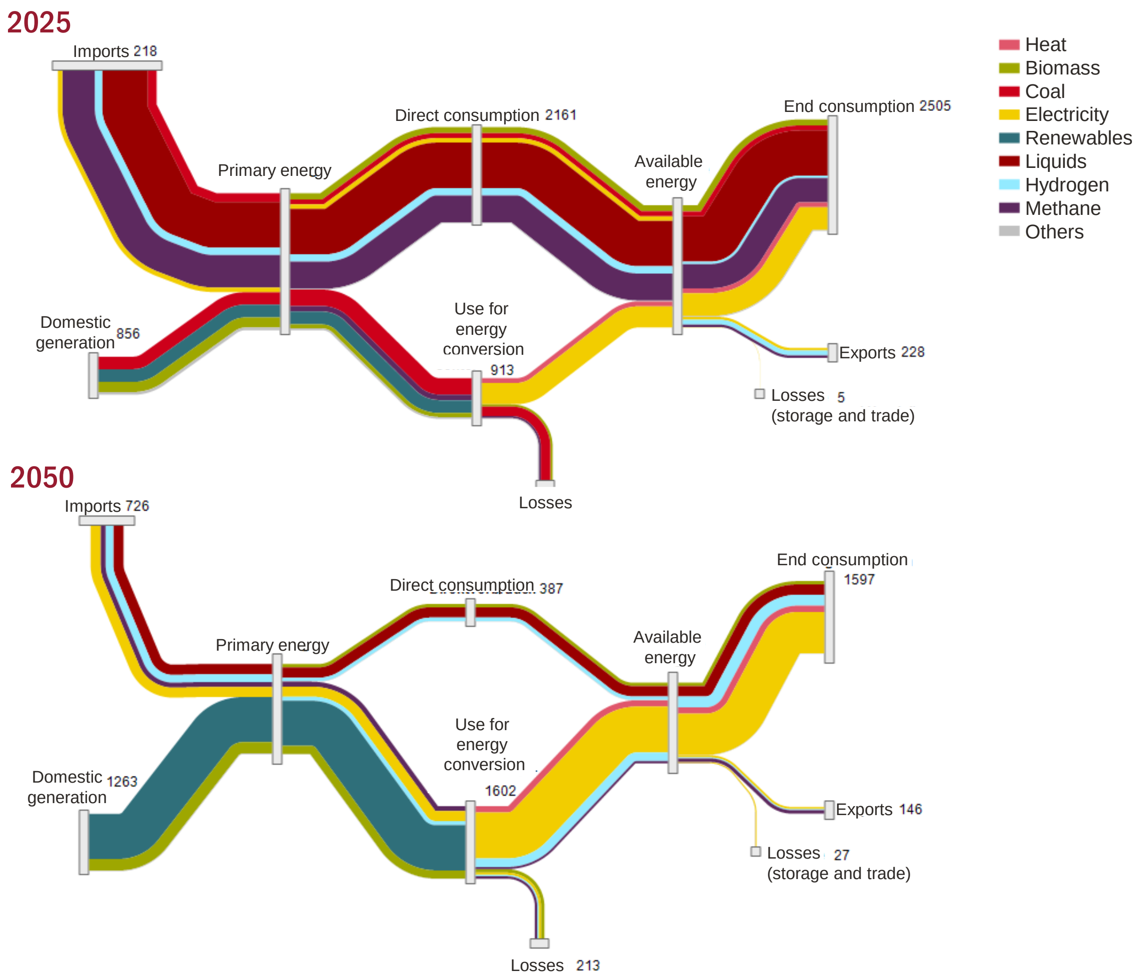
Source: Frontier Economics.

Note: The electricity generation mix changes only slightly when technology cost assumptions vary. We therefore only present the generation mix based on optimistic learning rates here.

Fossil fuels are replaced by electrification, PtX and biomass; CCS is used only to a very limited extent.

In addition to defossilising electricity generation, end consumption of fossil fuels would also have to be replaced by renewable alternatives. If the status quo were to continue, end consumption of liquid (shown in dark red) and gaseous energy sources (primarily methane, purple) would decline significantly due to widespread electrification – from 1,559 TWh in 2025 to 226 TWh in 2050 (see energy flow diagrams at Figure10). Biomethane and hydrogen (derivatives) would be used to replace fossil fuels in end uses that cannot be electrified (e.g. high-temperature processes in industry). The use of fossil fuels in combination with carbon capture and storage (CCS) would not be envisaged. CCS would only be used for residual emissions that are difficult or unavoidable, such as in cement production or waste management.

Figure 10 Development of energy flows in Germany if the energy transition status quo continues, 2025 and 2050



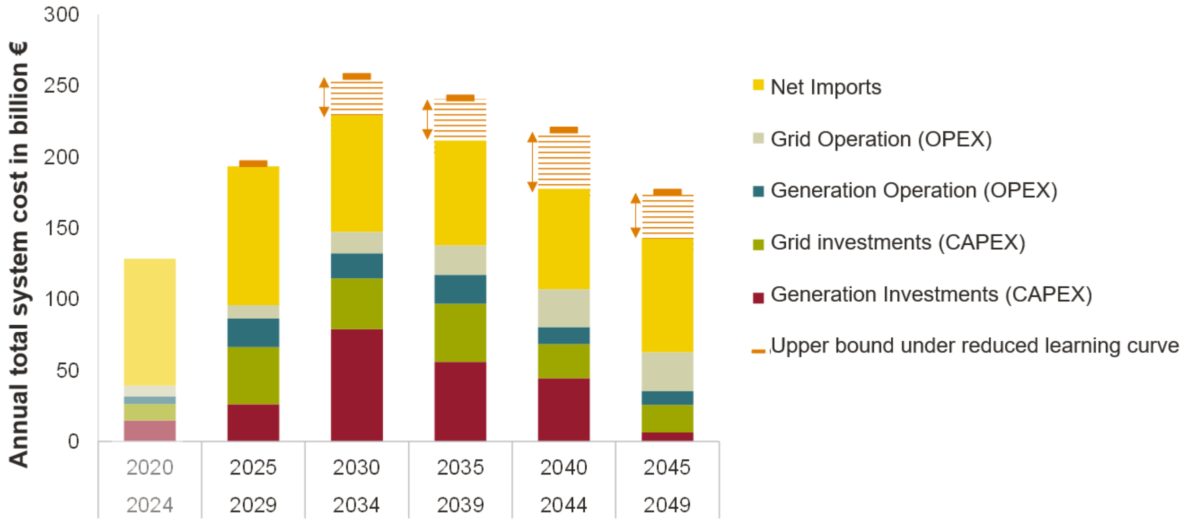
Source: Frontier Economics

Note: Representation of energy flows in TWh for scenario with optimistic learning curves, also includes material use of energy sources.

Investment costs in generation and grid infrastructure drive up additional costs in the energy system

Continuing the status quo of the energy transition – with a strong focus on the direct use of wind and solar power generated in Germany – requires massive new investments in energy generation and grid infrastructure. In order to achieve the interim climate policy target (88% reduction in greenhouse gas emissions by 2040) and the goal of climate neutrality by 2045, the transition must also take place very quickly. A large part of the new investment must be made within the next 15 years – and even earlier in the plants and power stations regulated by the EU ETS due to the expiry of CO_2 certificates. Figure 11 shows the development of annual energy system costs up to 2049, which will rise significantly in the coming years.

Figure 11 The energy transition is leading to a sharp rise in the annual costs of constructing and operating generation and grid infrastructure.



Source: *Frontier Economics based on COMET energy model and external studies (seeTable1).*

Note: *The chart shows the average energy system costs per year within the five-year periods. The energy system costs considered here include new investments in generation capacity (CAPEX), ongoing operating costs (OPEX), grid infrastructure costs (CAPEX & OPEX) and energy imports. Necessary demand-side investments in the building, transport and industry sectors are not taken into account. For the period 2020–2024, the investment costs (CAPEX) in generation and grid infrastructure are based on a meta-review of external studies. Operating costs (OPEX) were additionally estimated using our own approximation, and the costs for energy imports are based on Matthes (2025). The upper limit (orange marker) shows the annual system costs for the construction and operation of generation and grid infrastructure, assuming that the techno-economic learning curves are flatter.*

Compared to the annual investment costs of €26 billion in the recent past, the necessary annual new investments[26] (CAPEX) in energy generation and grid infrastructure will multiply by a factor of 4 between 2030 and 2039, even with optimistic cost developments. Including the ongoing costs of operating and maintaining the plants and grids (OPEX) as well as net energy imports, the annual costs in the decade from 2030 onwards will average €212 to €229 billion. With less optimistic learning curves, the annual system costs could even rise to €257 billion. In the following decade from 2040 onwards, annual new investments in generation and grid infrastructure will decline, as most of the expansion required for defossilisation will already have taken place. Nevertheless, even with optimistic technology cost developments, they will remain at a high investment level of €68 billion per year from 2040 and €26 billion per year from 2045 to 2049 (seeFigure 11).

Although the annual investment volume will decline again from around the mid-2030s, actual expenditure will remain high in the long term: if we consider the sums of annual depreciation

26 At this point, we consider the total costs for the new investments realised in the respective years. These will then also be available in subsequent years in accordance with their respective technical service life.

costs (investment costs spread over the lifetime) and other annual costs for maintenance and operation, these will rise continuously over time until 2050. Even after most of the necessary new investments have been completed, the annual cost burden affecting energy prices will remain high well into the future.

The comprehensive expansion of new, predominantly renewable generation capacities in Germany will reduce net energy imports compared to today (see imports and exports at the top left and bottom right ofFigure 10). Nevertheless, if the status quo of the energy transition continues, Germany will remain a significant net importer of energy.

The significant cost increases in energy generation and supply are driven by numerous factors, which we explain in detail below.

The transformation costs of the energy system are being unnecessarily driven up by inefficient government regulations and market interventions

A key driver of investment costs in electricity generation and grids if the status quo continues is the technology-specific design of the expansion targets for renewable energies. The politically determined expansion paths for wind (onshore and offshore) and PV (ground-mounted and rooftop systems) – combined with sometimes very generous subsidies – as well as the widespread exclusion of alternative options (e.g. blue hydrogen or natural gas use in combination with CCS) limit the scope for solutions and technological competition.

This leads to an inefficient generation mix, for example when cost-intensive technologies account for a high proportion of the total costs but at the same time make only a comparatively small contribution to electricity generation. One example of the inefficient design of the energy transition is the disproportionate expansion of rooftop PV compared to ground-mounted PV. By the end of 2023, around two-thirds of the installed PV capacity in Germany was accounted for by rooftop systems.[27] A key reason for this was a subsidy logic that favoured smaller, decentralised systems, even though these tend to involve significantly higher specific investment costs than ground-mounted systems. According to estimates, the specific investment costs in 2023 were around €1,525/kW for rooftop systems compared to around €845/kW for ground-mounted systems. The currently high proportion of small rooftop PV systems also leads to a greater load on the distribution grids, as rooftop PV systems typically do not regulate their feed-in. Feed-in from these systems always takes place when PV power generation exceeds the building's own consumption. The high temporal and spatial correlation of these feed-ins results in corresponding point loads on the distribution grids.

Regulatory requirements for other technologies and energy sources also drive up costs. For example, in order to achieve climate targets by 2045, fossil natural gas is to be largely phased out as an energy source, but at the same time there is a lack of cost-effective alternatives:

[27] See Dünzen et al. (2024).

- **Green hydrogen and synthetic methane** are expensive, particularly due to strict regulatory requirements for electricity procurement[28] and unfavourable location conditions in Germany.[29]

- However, the use of possible low-carbon alternatives such as **biomethane, blue hydrogen, or natural gas with CCS** is kept to a minimum in the status quo – especially since blue hydrogen could also be subject to strict requirements that limit the availability of cost-effective potential.[30]

The model results show that the current policy guidelines, with their rigid targets and regulatory requirements, will lead to significant additional costs for the energy transition – without making any additional contribution to climate protection compared to more cost-effective low-carbon alternatives.

Electrification requires comprehensive expansion of the electricity grids, while at the same time the value of existing transport infrastructure for molecules is declining.

The comprehensive electrification of all sectors requires a significant expansion of electricity grids and electricity storage facilities. Many decentralised generation plants must be connected to the electricity grid and the electricity generated must be transported to consumption centres, which are often located far away. The scale of the expansion is unprecedented: within a few years (taking into account achievable efficiency gains), the future electricity grid must replace the transport capacity of the existing gas networks and oil transport infrastructure, which have been built up over decades. Figure 12 illustrates this using the example of current energy import capacities: while around 365 GWh/h are available for natural gas and oil combined, the import capacity for electricity is only around 30 GW.

28 See, for example, Frontier Economics (2021).

29 See, for example, Bähr et al. (2023).

30 In August 2025, for example, the European Commission proposed a delegated act on the methodology for assessing emissions from low-carbon fuels (IP/25/1743). According to this, hydrogen is only considered "low-carbon" if it reduces greenhouse gas emissions by at least 70% compared to fossil fuel reference values. The proposal is currently under review by the European Parliament and Council.

Figure 12 Comparison of existing import capacities for gaseous and liquid energy sources and for electricity to Germany

Source: Frontier Economics based on EMBER (2025), ENTSOG (2025), en2X Wirtschaftsverband Fuels und Energie e.V. (2024) and information provided by the operators of the various infrastructure facilities.

Note: Schematic representation of Germany's technical import capacities for crude oil (and petroleum products), natural gas and electricity. For operational or commercial reasons, actual import capacities may be lower in certain periods.

This highlights a structural feature of the electricity infrastructure: In terms of energy efficiency, electricity applications are particularly efficient (e.g. electric drives vs. combustion engines, heat pumps vs. gas heating), but the construction and maintenance of electricity capacities, both in terms of supply and grids, is significantly more expensive than for molecule-based energy sources such as oil and gas. As a result, electrification can achieve cost advantages above all when the comparatively expensive infrastructure experiences high utilisation for as long as possible. However, in areas characterised by a high level of necessary power reserve, electrification leads to disproportionately high infrastructure costs. This includes, for example, building heating, where capacity must be designed for extreme situations ("1 in 20 winters") but in most cases is not fully utilised. The same applies to the charging infrastructure in view of significantly fluctuating charging behaviour and traffic volumes.

The necessary expansion of the electricity grid is reflected in more than a doubling of annual investment costs in grid infrastructure in the coming years (see Figure 11).[31] In order to finance the electricity grid investments, specific electricity grid charges will have to increase significantly in the future, even if the total costs are allocated to higher electricity demand in the future. At the same time, the economic value of the existing but increasingly underutilised gas infrastructure is declining, which in the medium term will also result in rising specific gas grid charges for the shrinking number of users.[32]

An energy system with higher volatility requires controllable capacities and seasonal storage options

In addition to the conversion and expansion of the electricity generation and transport infrastructure, the energy transition is placing new demands on the energy system. Since the feed-in potential of wind and PV varies seasonally and depending on the time of day and weather conditions, controllable capacities such as power plants, storage facilities or flexibility solutions must be added to secure the electricity supply in the event of so-called dark doldrums.[33] The development of guaranteed capacity until 2050 in the modelled status quo energy transition scenario is shown inFigure 13 and illustrates the growing contribution of large battery storage facilities and gas-fired power plants, while the importance of coal-fired power plants is declining. In our status quo energy transition scenario, for example, the following capacity expansions are projected for 2045:

- Net expansion of the existing gas-fired power plant fleet from currently around 30 GW by an additional 46 GW of (hydrogen-compatible) power plants, and
- nearly 450 GWh of battery storage capacity and utilisation of short-term load shifting potential on the end-use side.

In addition to the costs of developing wind and PV generation technologies, this will result in significant costs for electricity generation: between 2030 and 2040, an average of €6 billion per year will be required to ensure security of supply in the electricity system with the help of controllable capacity.[34]

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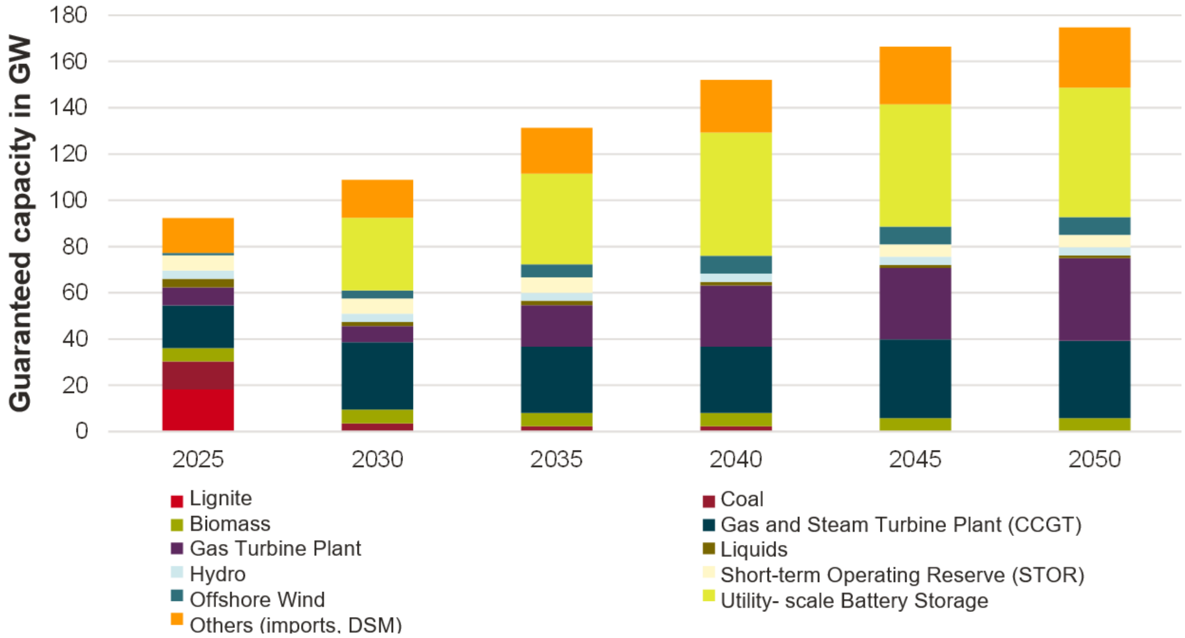
31 The modelling is based on the expansion requirements set out in the BMWK's long-term scenario O45-Strom and the BNetzA's network development plans, which include both additional and reinforced line kilometres: In the transmission grid, an expansion requirement of around 54,000 km is assumed for the period 2025–2045, and in the distribution grid, an expansion requirement of around 451,000 km is assumed by 2045.

32 The impact of future energy system costs on grid fees will be examined in a follow-up study.

33 A dark doldrums period is defined as a period of darkness and calm winds, during which feed-in from photovoltaic and wind energy plants is greatly reduced and volatile renewable energy sources can therefore only make a limited contribution to the electricity supply.

34 These costs are included in the reported energy system costs as CAPEX and OPEX (see, for example,Figure 8).

Figure 13 Development of guaranteed capacity in the energy transition status quo scenario, 2025-2050



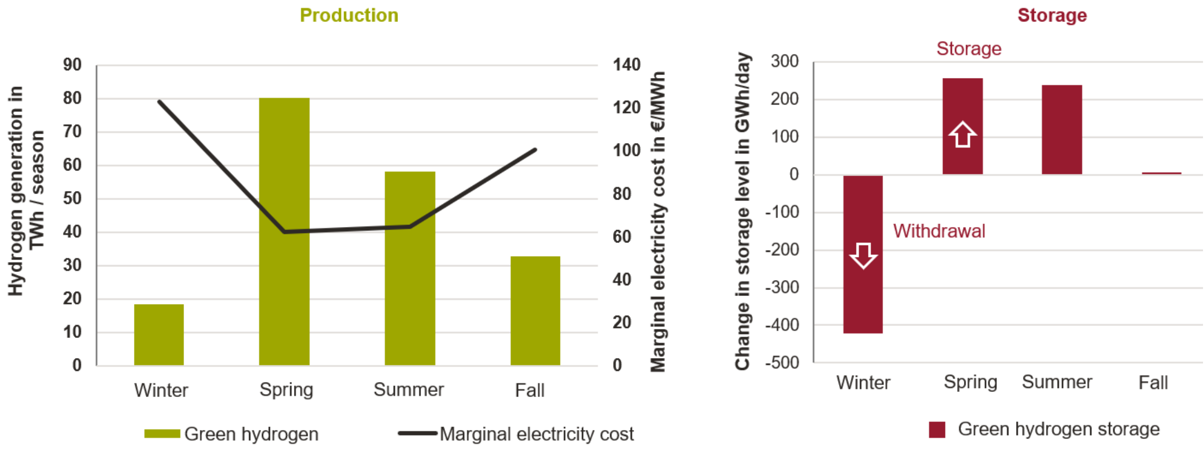
Source: Frontier Economics.

In addition to the necessary provision of guaranteed capacity, an energy system that is based primarily on PV and wind power on the generation side and increasingly on electrical applications on the demand side must create seasonal flexibility and electricity storage options on a large scale. These create a balance between the higher demand for electricity in winter – e.g. due to space heating requirements – and lower electricity generation (primarily from PV) at the same time, and the reverse situation in summer. Seasonal supply is primarily provided in two ways:

- The temporary storage of hydrogen produced in summer from (additional) PV and wind power generation in cavern storage facilities. This is released to meet the seasonally higher demand in winter and, if necessary, converted back into electricity.
- The additional import of energy (electricity, hydrogen) in winter.

Figure 14 illustrates the seasonal relationships between energy generation and storage based on the modelled status quo scenario in 2050: The left-hand graph shows the seasonal development of green hydrogen production in our models, which reaches high levels in spring and summer and declines significantly in winter; parallel to this, electricity prices move in the opposite direction, with higher levels in winter and lower levels in spring and summer. The graph on the right shows seasonal storage operation: hydrogen is stored on a large scale in the spring and summer months, while significant amounts are withdrawn in winter.

Figure 14 Seasonal energy production and storage, 2050 (schematic representation)



Source: *Frontier Economics.*

Note: *The marginal costs shown (unlike the annual values given in Chapter 4) do not include levies for guaranteed capacity and renewable energies.*

The future capacity requirements and costs of hydrogen storage depend on a number of uncertain factors, including:

- The extent of hydrogen use in end-use sectors, particularly in industry;
- The seasonal supply and price fluctuations of hydrogen imports; and
- The expansion potential and costs of large-volume hydrogen storage facilities.

Existing studies currently show a range for the required hydrogen storage capacity in 2050 of approximately 30 to over 100 TWh.[35] In our scenarios, we assume a hydrogen storage capacity of approximately 45 TWh in Germany in 2050.

2.3 A large part of the cost increases results from the necessary transformation in the end-use sectors.

For a future climate-neutral energy system to function, comprehensive investments are needed on the demand side – in industry, transport, and the building sector. Not only are the costs involved considerable, but the amount is also subject to considerable uncertainty. This is due, on the one hand, to the diversity of possible technological paths and sectoral developments and, on the other hand, to uncertainties about the specific cost developments of individual technologies. The range of cost estimates is correspondingly wide, as shown above (seeFigure 7 in Chapter 2.1).

[35] See ewi (2024).

In this study, we focus on the energy system – various options for defossilising the end-use sectors are therefore not analysed in depth quantitatively, but are always taken into account when developing an alternative concept for the energy transition. In the following, we provide a brief overview of cross-sector challenges and specific challenges in the building, transport, and industry sectors.

Structural factors and heterogeneous incentive systems represent a significant barrier to transformation in the end-use sectors

In all end-use sectors, the large scale of the transformation required creates a significant barrier. On the one hand, individual actors must take action: particularly in the case of energy transition measures aimed at converting end uses such as heating systems, vehicles, and industrial plants (as opposed to measures that make an energy source increasingly climate-neutral, e.g. by adding renewable quantities), millions of owners and corporate decision-makers must actively bring about change.

Similar to the expansion of energy generation and grid infrastructure, the predominantly private infrastructure in these areas is characterised by long investment cycles and is correspondingly sluggish. Regulatory provisions and financial subsidies or levies can be used to create incentives. However, the pressure cannot be increased indefinitely if the social consensus on the energy transition is not to be jeopardised. Furthermore, aside from incentives and regulations, the necessary transformation is subject to a natural speed limit, as planning and participation procedures take time and, at the same time, skilled workers, materials, and technology are not available in unlimited quantities. According to estimates, at least 550,000 skilled workers with various levels of qualification will be needed to implement the transformation in the coming years, with a shortage of available skilled workers already existing in a number of the identified occupational groups.[36] Last but not least, there is also a certain amount of competition for financial and human resources between energy system-driven investments and the investment needs that continue to arise in an economy independently of the energy transition.

In addition, the relevant sectors are subject to different regulatory frameworks. While emissions from parts of industry are already priced through the European Emissions Trading System (EU ETS), CO_2 prices in the building and transport sectors have so far only been applied within the framework of national emissions trading schemes (nETS) and will only be applied within the framework of EU ETS 2 from 2027 onwards – with significantly lower planned price signals.

[36] According to an analysis by Prognos, a quarter of the occupations identified as necessary for the transformation are already classified as bottleneck occupations. There are signs of an impending bottleneck in another quarter of the identified occupations. See DIHK/Prognos (2024).

Industrial sector often a blind spot in investment planning for the energy transition

The defossilisation of industry requires a comprehensive technological transformation, which necessitates high investments in equipment, infrastructure, and processes. In contrast to the building and transport sectors, there are currently only a few concrete estimates of the investment requirements (CAPEX) in industry resulting from the energy transition.[37] The existing studies only cover selected sub-sectors of industry, such as the emission-intensive cement and steel industries, while other sectors are hardly taken into account. In addition, market-ready climate-neutral technologies are lacking for many industrial applications, which means that the resulting investment requirements are only partially taken into account in the analyses, if at all. In addition, there are different sectoral boundaries (e.g. in the allocation of building renovations), which sometimes mean that certain investments are not attributed to the industrial sector, but ultimately accrue to industrial companies. Against this background, the investment requirements for the energy transition-related transformation of the industrial sector presented inFigure 7 represent a conservative lower limit – the actual investment requirement is likely to be significantly higher. Existing studies also show that in the industrial sector, the additional costs for energy requirements dominate, for example for hydrogen and its derivatives, while capital costs play a lesser role.[38] InFigure 7 , only CAPEX investment requirements are shown. The energy cost increases to be borne by industry are presented in detail in Section 2.2.

Uncertain technology choices and high costs as key obstacles to the transformation of industrial companies

For a follow-up study, we are currently analysing the further effects of the energy transition on the costs and competitiveness of companies, for example through rising prices for intermediate products and increasing administrative and personnel costs. Initial interviews conducted for this purpose already show that, in addition to the comprehensive cost burden, the challenges also lie in the lack of or insufficiently scalable alternative technologies and barriers to practical implementation:

- A plastics processing company with high thermal energy consumption is faced with the question of how processes in the temperature range of 300–500°C can be operated in a climate-neutral manner in the future. The switch to electricity-based processes fails due to technical feasibility (insufficient plant standards, unclear process stability), and the necessary grid connection capacities would also not be available. As an alternative to electrification, the use of hydrogen is also being considered in principle. However, this is also not currently an option – the unclear availability of hydrogen at competitive prices and the necessary transport and storage infrastructure that still needs to be built do not provide a reliable planning basis for investments with the prospect of future economic operation.

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37 These include Ariadne (2025); Agora (2024); PwC (2024); and Prognos (2024), seeTable1 .

38 See, for example, Ariadne (2025).

- A second example can be found in the chemical park: here, decarbonisation measures such as the commissioning of large-scale PEM electrolysis have already been implemented in order to replace natural gas in the long term. However, the expansion of technological alternatives has failed so far: above all, the lack of economic viability, but also unclear regulatory conditions, are preventing rapid scaling. The possibility of avoiding fossil CO_2 emissions through the use of CCS, which is also being discussed within the company, does not represent a real alternative due to the high costs and lack of a reliable political and regulatory planning basis. As the energy industry framework conditions did not allow for economic continuation, central processes such as local ammonia synthesis had to be discontinued. In other production areas of the chemical park, too, uncertainty is increasing massively due to competition from countries with lower energy costs and, in some cases, less stringent defossilisation requirements (e.g. in Asia).

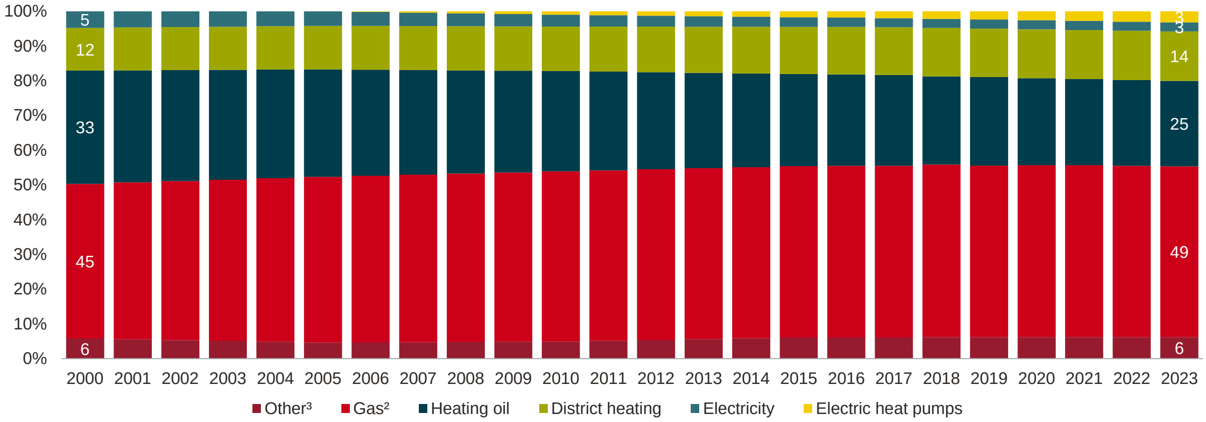
These and other case studies will be presented in detail in a follow-up study. Even these few examples show that investment decisions in industrial companies are less likely to fail due to a fundamental unwillingness to invest, but rather because the measures available to companies in economic and technical terms (including process conversions and optimisations, electrification, alternative energy sources) are often simply not sufficient to completely defossilise operations. The foreseeable high energy and transformation costs in Germany represent a major locational disadvantage, particularly for the numerous energy-intensive companies that compete internationally. As a result, energy-intensive processes at German locations, e.g. in the chemical sector, have already been or are being discontinued or are at acute risk. Due to a lack of market-ready technological alternatives and practical and structural implementation hurdles, the companies surveyed are focusing their investment planning on making replacement investments at German locations, but increasingly carrying out future development steps and new investments abroad.

Building sector as a key area of the energy transition characterised by slow progress and structural hurdles

A significant proportion of the foreseeable energy transition-related investments on the demand side will be made in the building sector, as our meta-analysis shows: between 2020 and 2024, the average annual investment in the building sector was around €37 billion (range: €30–45 billion, seeFigure 7). This figure is expected to almost double by 2035: the studies predict an average of €70 billion per year (ranging from €50 billion to €141 billion). The majority of these costs will arise from necessary energy-efficient renovations to the building envelope to reduce energy consumption, as well as the replacement of fossil fuel heating systems with alternatives such as heat pumps, district heating connections or the use of biomass. In 2023, the building sector was responsible for around 15% of German greenhouse gas emissions. [39]

[39] See Federal Environment Agency (2025a) .

Figure 15 Heating structure of the housing stock[1] in Germany



Source: Frontier Economics based on BDEW / Statista.

Note: Shares for the years 2001-2004, 2006-2009, 2011-2014 interpolated on the basis of the reference years 2000, 2005, 2010 and 2015.

[1] Number of dwellings in buildings with living space; heating available; partially estimated.

[2] Including bio natural gas and liquefied petroleum gas.

[3] This includes solid fuels (wood, wood pellets, other biomass, coke/coal and other heating energy).

However, progress in renovations and heating system replacements has been slow in the past – the inertia of change is exemplified byFigure 15 for the German housing stock: between 2000 and 2023, the heating structure of German homes remained largely unchanged, with a persistently high share of fossil fuels. The reasons for this are not only the high investment costs but also the serious structural challenges of this fragmented sector (see below). In addition, price uncertainties for heating technologies and the limited availability of installers make reliable investment planning difficult – the replacement rate of heating systems required to achieve the targets in the status quo would require many times the current capacity of skilled tradespeople.

Energy transition in the transport sector requires increasing investment

The investment required to transform the transport sector is increasing significantly in the wake of the energy transition, as our meta-analysis of the available studies shows: according to our meta-analysis, the average annual investment in 2024-2025 will be around €17 billion (range: €5 to €30 billion). By 2035, this figure will rise to an average of €29 billion per year, with a range of €13 to €65 billion.

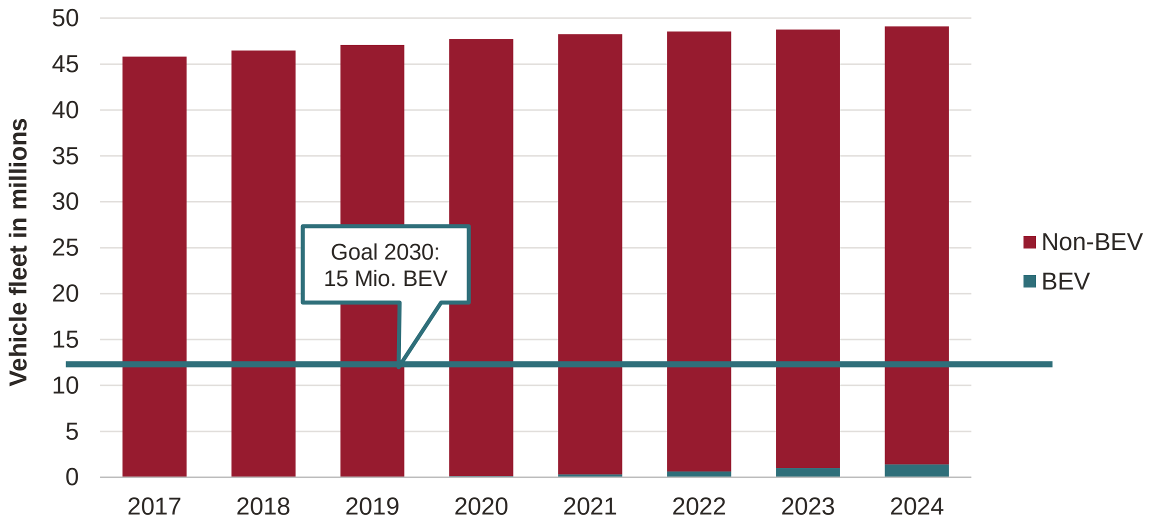
The modal split – the distribution of traffic volume across different modes of transport – has remained largely constant in recent years;[40] the share of road traffic (cars and trucks) therefore remains high. Consequently, in order to achieve Germany's climate targets, investment in the transport sector is focused on the procurement of cars and trucks and the expansion of the associated fuel and charging infrastructure. In the context of the energy transition in the status

40 See Eisenkopf (2025).

quo, the focus is primarily on the electrification of the vehicle fleet. The transformation in the transport sector is characterised by long investment cycles. It is true that some of the vehicle purchases are made as part of necessary replacement investments at the end of the service life. However, if, for example, the speed of the ramp-up of electromobility is to be significantly increased, vehicles would have to be replaced prematurely.

The associated additional costs compared to vehicles with combustion engines, as well as acceptance problems, have led to a hesitant ramp-up of battery electric vehicles (BEVs) to date. Figure 16 shows that although the number of BEV passenger cars will reach a new high of around 1.4 million vehicles in 2024, this is still far below the politically set target of 15 million BEVs by 2030.

Figure 16 Share of purely battery-electric passenger cars in the German fleet



Source: Frontier Economics based on Federal Motor Transport Authority (KBA) (2025).

Note: The figure shows the share of purely battery-electric vehicles (BEVs) in the German passenger car fleet compared to non-battery-electric vehicles (non-BEVs).

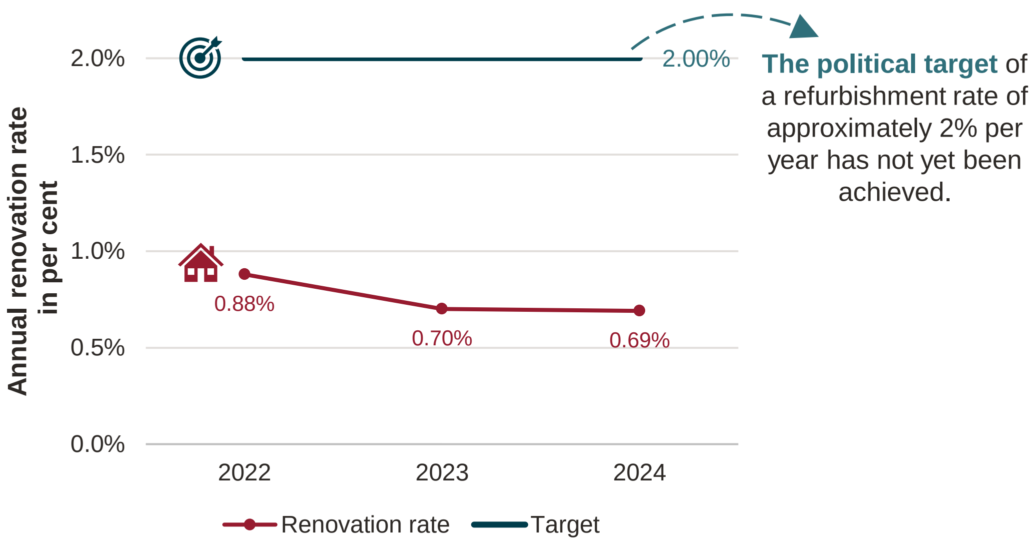
The future increase in investment in the transport sector will be borne primarily by companies. On the one hand, the conversion of the truck fleet, which according to the studies analysed accounts for around 35% of total transport investment, is characterised by considerable costs and uncertainties, e.g. with regard to the suitability of the technology. In addition, companies finance two-thirds of all new car registrations for the first years of operation through fleet vehicles and company cars and contribute to the development of the charging infrastructure, among other things, through company charging stations.

2.4 Cost risks of the energy transition increase if efficiency gains fail to materialise and/or economic growth increases

The energy system costs arising from a continuation of the current energy transition policy are based on an assumed path towards greenhouse gas neutrality, which, in the status quo scenario, assumes not only high electricity consumption but also a significant decline in final energy demand.[41] This assumes that a significant portion of the defossilisation efforts can ultimately be achieved through very ambitious efficiency improvements (e.g. through building insulation).

Figure 17: While an annual renovation rate of around 2% would be necessary to achieve the target, the actual rate in recent years has been significantly lower, falling from 0.88% in 2022 to 0.69% in 2024.

Figure 17 Development of the renovation rate in Germany, 2022-2024



Source: Frontier Economics based on B+L market data Bonn on behalf of the Federal Association for Energy-Efficient Building Envelopes (BuVEG) (2025)

Note: The figure shows the annual renovation rate for the building stock in Germany. The renovation rate takes into account renovations to roofs, facades and windows.

In the transport sector, too, the ramp-up of battery electric vehicles is lagging behind the ambitious targets (seeFigure 16): In order to still achieve the political target of 15 million BEVs in the fleet by the end of 2030, an annual increase of around 2.2 million vehicles would be necessary on a linear basis, which is more than the total number of BEVs registered in the German fleet to date.

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41 For example, the O45-Strom scenario assumes that energy demand will fall by a total of almost 1,000 TWh between 2025 and 2050.

Recent studies on the cost-reduction potential of the energy transition[42] and the new scenario framework for the 2025-2037/2045 grid development plans approved by the Federal Network Agency 2045[43] point to potential cost savings that could be achieved through a lower or slower than previously assumed increase in electricity demand and a correspondingly lower or delayed infrastructure expansion. At least some of these cost savings are based on the assumption of progressive deindustrialisation in Germany. Such savings would come at the expense of a loss of industrial value added and thus ultimately of overall economic prosperity. However, the goal of a successful energy transition should be to at least secure, or better still increase, value creation and prosperity through economic growth. For example, new developments in future markets – such as the increasing use of artificial intelligence (AI), which is usually associated with high electricity consumption in data centres – or planned investments in defence could create additional energy demand.

We are therefore analysing the effects of stronger economic growth combined with a slower pace of transformation in energy applications in a sensitivity analysis.[44] Our modelling shows that under these changed conditions, the net-zero target will actually be missed: in the event of a slower transformation combined with new energy demands, the solution space depicted in the model, based on technological constraints and the current political planning of the status quo energy transition, is not sufficient to achieve the desired climate targets.

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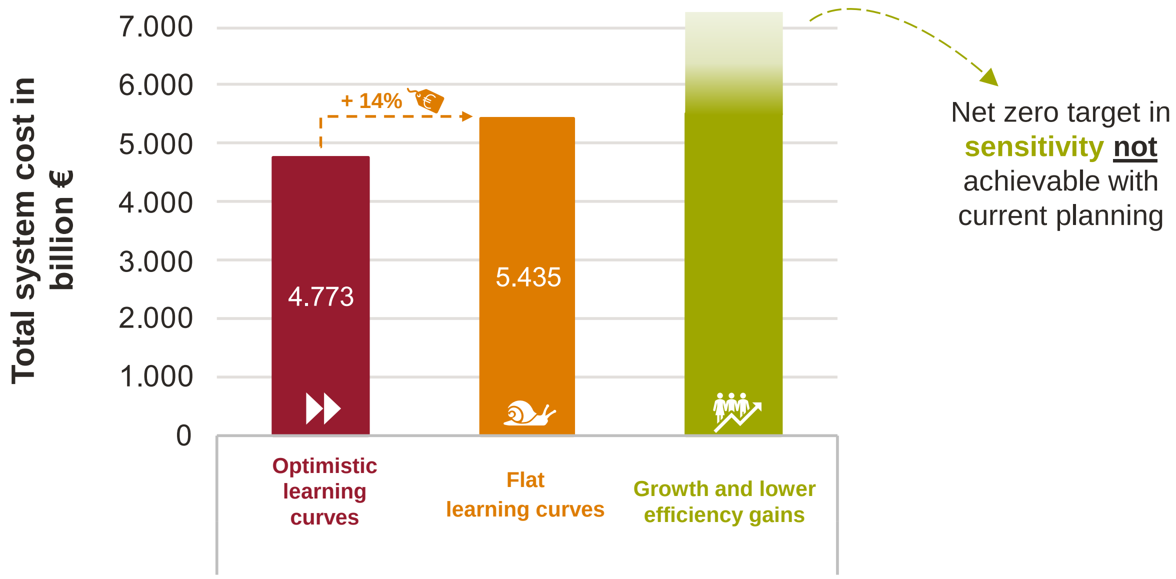
42 See, for example, Aurora (2025) and BCG, IW, BDI (2025).

43 See Federal Network Agency (2025).

44 Compared to the reference case, we assume slightly higher GDP growth of 2% per annum instead of 1.4%, as well as a halving of the assumed renovation rate and the transition rates to low-emission technologies such as heat pumps, district heating, battery electric vehicles and hydrogen-based processes. In addition, energy intensity in industry will decline only moderately, while electricity-intensive applications such as AI and data centres will increase. Overall, final energy demand will therefore decline significantly less than in the reference scenario.

Figure 18 Change in modelled energy system costs due to the energy transition under changed assumptions, 2025-2049



Source: Frontier Economics.

Note: The energy system costs considered here include new investments in generation capacity (CAPEX), ongoing operating costs (OPEX), grid infrastructure costs (CAPEX & OPEX) and energy imports. Necessary demand-side investments in the building, transport and industry sectors are not taken into account.

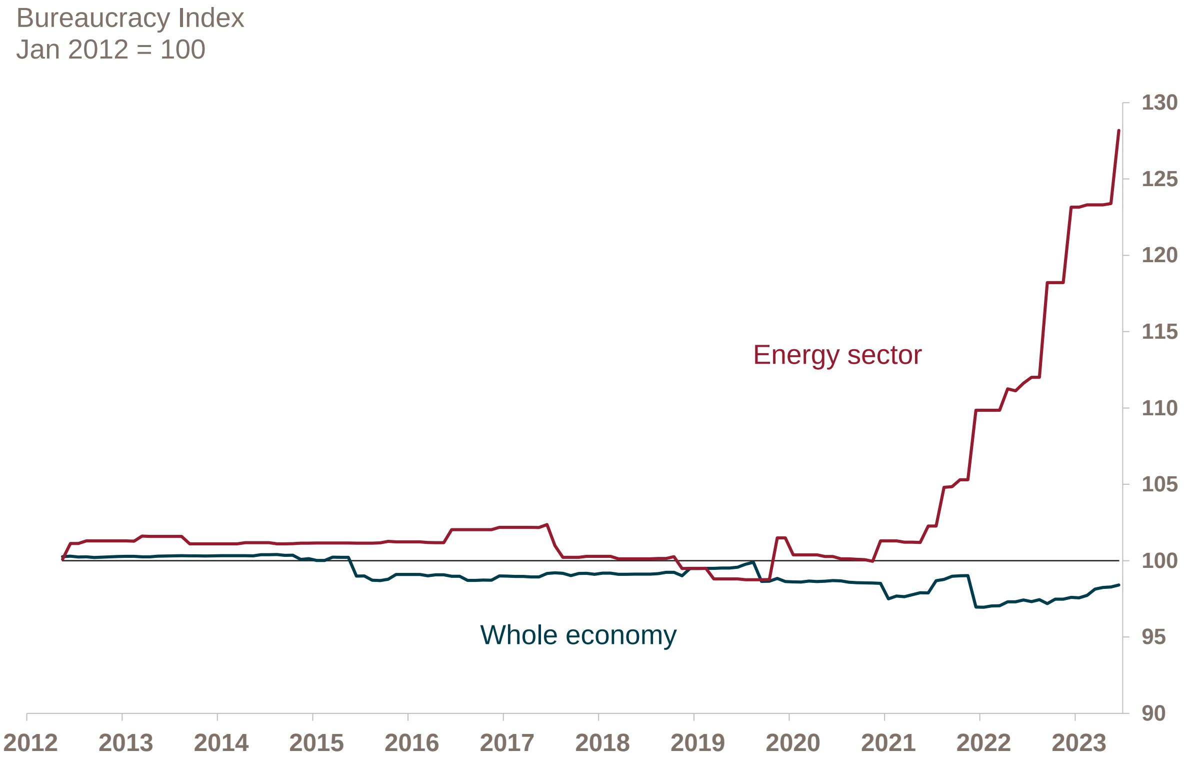
Figure 18. **The sensitivity illustrates that the energy transition in its current form is neither robust against slower transformation speeds nor can it scale in the event of more dynamic growth or slower efficiency gains.**

2.5 Excessive energy transition bureaucracy leads to further costs and inhibits investment and innovation potential

While previous analyses have focused primarily on the economic impact of the energy transition in terms of investment requirements and running costs, the energy transition is also an extremely ambitious political project. Ultimately, the energy transition in its current state serves to meet a multitude of politically set climate protection targets as well as downstream sector and technology targets, and therefore requires considerable government control and management efforts. Accordingly, the current status quo also gives rise to considerable costs from bureaucracy driven by the energy transition.

The total amount of compliance costs associated with the implementation of energy and climate policy requirements and laws is difficult to measure, as these vary from company to company and household to household. A rough indication of the level of these costs can be derived from the database of the Federal Statistical Office.[45] Estimates of the bureaucratic costs for companies have been documented since 2006. In recent years in particular, numerous new laws and regulations have been introduced that have significantly increased the bureaucratic costs for the energy sector.

Figure 19 Bureaucracy cost index for the energy sector compared to the economy as a whole



Source: Frontier Economics based on Seeliger (2024) and Federal Statistical Office (2025a).

Note: The bureaucratic cost index of the Federal Statistical Office standardises the bureaucratic costs of companies to the 2012 level. Costs for households and administration as well as other compliance costs are not included. Industry-specific indices are not created automatically and require manual processing of the values contained in the database.

Figure 19 shows that bureaucratic costs for the energy sector increased significantly between 2020 and 2023, while the average costs for the economy as a whole remained relatively constant – with a continuing upward trend.

45 The online database of compliance costs published by the Federal Statistical Office is available at this link.

The bureaucratic costs associated with energy and climate policy requirements amount to over €10 billion per year

Currently, the database contains 135 standards with over 1,500 relevant requirements in the areas of energy and climate regulation alone, which generate bureaucratic costs of around €1.6 billion per year due to information obligations[46,47].

In addition, however, there are further significant follow-up costs for the economy, administration and citizens in the form of other compliance costs,[48] which amount to a total of around €8.9 billion€ per year. The total ongoing compliance costs resulting from energy and climate policy requirements are therefore roughly estimated at around €10.5 billion per year. In addition, there are one-off costs for individual requirements, which amount to a further €10 billion in total.[49]

A look at the individual requirements with particularly high bureaucratic costs shows that a number of very cost-intensive new laws and regulations have been enacted, especially in recent years. The Building Energy Act (GEG) alone causes total annual compliance costs of almost €6 billion – in addition to a good €750 million in one-off costs. Another example is the Energy Efficiency Act (EnEfG), which came into force in 2023 and requires energy-intensive companies to introduce energy or environmental management systems, publish the efficiency measures they have taken, and document CO_2 intensities and waste heat potentials, among other things. This law alone will result in one-off conversion costs of €818 million and, according to estimates by the Federal Statistical Office, will trigger additional annual direct compliance costs of just under €300 million.

In practice, the bureaucratic costs are likely to be significantly higher, especially for companies: the database only records compliance costs in connection with federal regulations and laws. Significant bureaucratic costs associated with EU regulations and delegated acts that do not require national implementation, as well as municipal and state regulations, must therefore be added.

The bureaucratic costs incurred highlight the extent to which the implementation of the energy transition is currently characterised by comprehensive detailed regulation and various reporting requirements. This not only causes direct costs and reduces investment potential, but also significantly restricts the scope for creativity and the possibilities for finding the most efficient and innovative solutions.

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46 Bureaucratic costs arising from information requirements include costs incurred, for example, due to documentation and reporting requirements to authorities or for controls in companies. See Section 2 (2) NKRG.

47 See Seeliger (2024).

48 The term compliance costs is broader and includes all the time and money spent by businesses, public authorities and citizens on complying with regulations and laws. See Section 2(1) NKRG.

49 See Seeliger (2024).

2.6 Conclusion: With the current energy transition, Germany has manoeuvred itself into a dead end – continuing with the status quo is not sustainable.

The implementation of the energy transition by companies and consumers is increasingly challenged by ambitious timetables with rigid targets, technological constraints, and excessive bureaucracy.

The current energy transition policy in particular means that individual players are not only burdened with high costs, but also have to cope with extensive regulatory intervention and additional requirements: these effects are difficult to quantify, but initial rough estimates show that the energy transition is leading to great burdens for individual companies that go far beyond pure energy cost increases.[50]

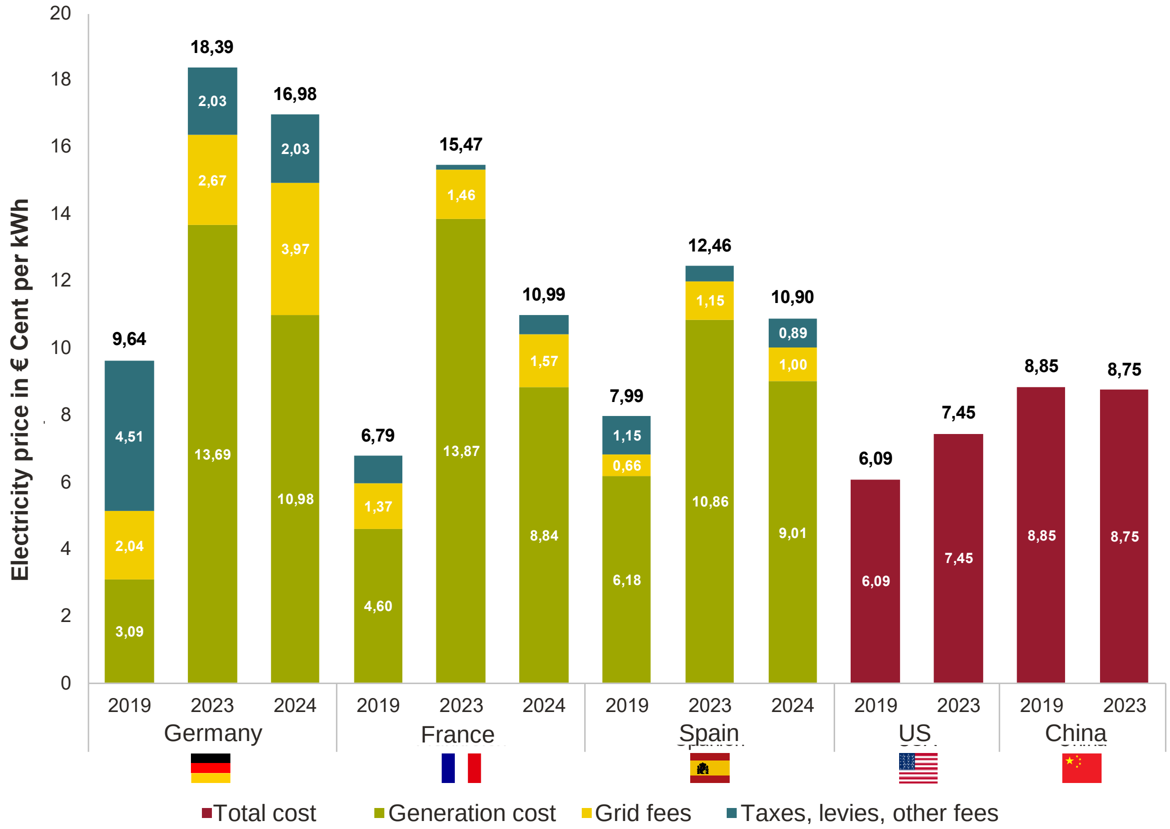
Large parts of the politically planned energy transition are subject to the caveat that they can also be put into practice. However, this is not only a question of costs and financing, but also of the availability of the necessary skilled workers. For example, in the core areas of solar, wind, and hydrogen alone, approximately 300,000 additional skilled workers would be needed by 2030 to drive forward the transition to climate neutrality.[51] The necessary capital goods and raw materials are not available in unlimited quantities either – especially the materials required for many new energy transition technologies, such as copper, cobalt, and platinum. Accordingly, there are justified doubts as to whether the necessary transformation can actually be implemented in practice within the estimated time frame. Current developments suggest that many of the political goals and assumptions overestimate the actual capacity and maximum speed of the transformation.

All in all, this places a heavy burden on businesses and consumers in Germany, who ultimately have to bear the costs of the transformation. In addition, a strongly export-oriented economy is constantly facing international competition. Energy costs for companies in Germany are already high by international standards. This is evident inFigure 20 that shows a comparison of electricity costs in selected countries. In 2024, Germany will have the highest prices among the five countries considered – mainly due to higher government levies and grid costs compared to other countries.

50 The further effects of the energy transition on the cost base and competitiveness of companies, for example through rising prices for intermediate products, as well as increasing administrative and personnel costs, will be addressed in a follow-up study.

51 See DIHK/Prognos (2024).

Figure 20 Electricity prices for companies with consumption volumes of 20 to 50 million kWh/a



Source: Frontier Economics based on Eurostat (2025a, 2025b) for the EU, DESNZ (2025) for the US and Afry (2023) for China.

Note: The figures show electricity prices for industrial customers with an annual consumption of between 20 and 50 million kWh, excluding refundable taxes, fees and levies. A general industrial price is shown for the USA, as it is not possible to differentiate according to consumption volume.

It should be noted that comparisons with non-European countries are only of limited significance. In the USA, industrial electricity prices can vary greatly from state to state and are partly controlled by industrial policy – in China, too, prices are often kept artificially low.[52] In future, the burden of high energy prices in Germany will continue to rise if the current course is maintained, as shown. There is great pressure to act, because the current energy transition policy is not only expensive, but also, as shown, structurally unfeasible in many areas. If no change of course is made, it is foreseeable that not only will the burden on the economy continue to increase at the expense of competitiveness, but it is also highly likely that climate targets will be missed. In addition, a resilient energy transition must be flexible and scalable – and should remain economically viable even in the face of uncertain future developments in technology supply and energy demand.

[52] See, for example, Prognos (2023).

For this reason, it is not only necessary to optimise various minor aspects of the energy transition, but also to activate major cost levers. Against this backdrop, the concept of a ‘Plan B’ presented below calls for a fundamental reorientation of energy and climate policy with a view to maintaining prosperity, competitiveness and climate protection in Germany.

3 The design of the energy transition must be rethought and aligned with key principles

After the previous analyses have highlighted the fundamental need for action arising from the continuation of the status quo of the energy transition, the second part of the study now proposes possible adjustments to the energy transition. In this chapter, we show that

- given the scale of the challenges identified, small and incremental adjustments will not be sufficient, but rather a fundamental rethinking of the energy transition is required (Chapter 3.1); and
- define key principles to guide a reorientation of the energy transition (Chapter 3.2).

These considerations form the basis for the formulation of a ‘Plan B’ for the energy transition in Germany in the following Chapter 4 (The Energy Transition Must Be Rethought).

3.1 The energy transition needs to be rethought; selective adjustments are not commensurate with the scale of the challenges

The analyses in the previous chapter show two things:

- The problems of the German energy transition are fundamental in nature and affect the long-term competitiveness of the economy; and
- the path of the energy transition politically prescribed for Germany has now reached a level of complexity with numerous interdependencies and feedback loops that makes the incremental optimisation of individual parameters virtually impossible.

The particular challenge arises from the fact that energy value chains are extremely complex: starting with the energy sources, through the various infrastructures for transport, storage and conversion, to the end uses, which are usually geared towards specific energy sources. The energy transition often requires that these chains have to be completely rebuilt, for example when switching energy sources.

Currently, various political control and incentive systems are applied at different points in the value chain, but they also interact with each other. For example, industry policy-motivated reductions in the price of CO_2 would have a dampening effect on the price of electricity, but at the same time would increase the need for subsidies for EEG-subsidised plants in order to ensure that climate targets are met overall. This means that relief in one area would lead to additional costs elsewhere in the system. These additional costs would have to be refinanced. The complexity and interactions involved now make it much more difficult to predict the effects of individual interventions in the existing system.

"Minor" selective adjustments to the existing system, such as a change in the proportion of underground cables in the expansion of the electricity grids or slight changes to the generation mix, are also unlikely to yield sufficient savings to make the energy transition viable. The expert discussions conducted as part of this study also quickly showed that it is more effective to envisage a 'restart' of the energy transition rather than discussing ever new incremental changes to the existing approach based on the status quo of the energy transition.

The second part of the study therefore focuses on the key question: "How would the energy transition be designed with today's knowledge and experience?" The new mix of instruments to be created 'from scratch' (see Chapter 4) then serves as a model for proposals for policy adjustments to transition the current climate and energy policy status quo towards the new concept (see Chapter 5). The new concept is based on a number of key principles, which we will explain in the next section.

3.2 Key principles can be established for a comprehensive reorientation of the energy transition

One advantage of the reimagined energy transition approach is that it breaks away from the supposed and actual path dependencies of previous policy measures. On the other hand, important lessons can be learned from the experiences of recent decades, which should be taken into account in a restart in order to avoid similar undesirable developments as those identified above. First and foremost, it must be noted that a successful energy transition is crucial for Germany to make an important contribution to mitigating global climate change. The reorientation therefore aims to make the energy transition more effective, cost-efficient, flexible and internationally scalable.

Nine key principles were therefore identified for the study and discussed in various workshops with representatives from industry and academia. These key principles summarise – ideally uncontroversial – findings and facts and form the starting point for all further considerations. They are presented inFigure 21 and explained below.

Figure 21 Key principles for a reorientation of the energy transition

No.	Principle	Implication
1	**Prosperity is based on a secure energy supply, and increasing prosperity ensures acceptance.**	**De-growth** as a means of achieving climate targets leads to a loss of prosperity. This also threatens **to undermine social acceptance** of the energy transition.
2	**The energy transition can only succeed on the basis of economic strength.**	The **speed of transformation** towards climate neutrality must be **geared** to the **performance** of the economy (the stronger it is, the faster it will be).
3	**Germany has a structural disadvantage in terms of natural resources.**	In order to remain **competitive**, structural **disadvantages** must be **offset as far as possible**.
4	**Technology is key to the energy transition.**	Long-term **innovation and technological development** make the energy transition more cost-effective. Broad use of technology helps to promote progress.
5	**The market and competition are the most effective drivers of innovation and technological progress.**	The regulatory framework should allow **room for market mechanisms/competition**, micro-management should be avoided and bureaucracy minimised.
6	**The energy transition is a long-term process with a high degree of uncertainty.**	**No rigid "master plan**" or target scenario for the future, but rather **effective risk management** (e.g. through options) and, above all, a flexible market enabling free and efficient choices.
7	**Energy supply chains are sluggish and cannot be restructured as quickly as desired.**	Achieving climate neutrality by 2045 requires **an unprecedented pace of transformation**. The ultimate goal must also be achievable.
8	**Climate neutrality can only be achieved effectively on a global scale.**	The **global effect on emissions** should be **the benchmark** for all climate protection instruments.
9	**Reduced complexity facilitates implementation and impact.**	**"Keep it simple"** – The desire to regulate every exception and eliminate every risk often leads to overloaded concepts that are impractical.

Source: Frontier Economics

Principle 1): Prosperity is based on a secure and competitive energy supply; increasing prosperity ensures acceptance of the energy transition.

A central basis for planning the energy transition must be the understanding that the energy sector is not an independent industrial sector. On the contrary, energy use is the basis of virtually all value creation processes in an economy. A large part of the prosperity created depends – especially in an industrialised economy such as Germany – directly on the secure availability of energy sources that must enable internationally competitive production. However, this means that a decline in energy use (beyond energy efficiency gains) is often associated with a decline in value creation. This could be observed, for example, in the slump in industrial production following the energy crisis caused by the war in Ukraine.[53]

[53] In particular, energy-intensive industries such as chemicals, glass, paper and metal production recorded significant declines in gross value added. Since the beginning of 2022, production in energy-intensive industries has fallen almost continuously. Due in particular to persistently high energy prices, production in energy-intensive industries fell by around 17% between February 2022 and July 2023 alone, while total industrial production recorded a decline of around 3%. See Federal Statistical Office (2025b) andFigure 6 .

The energy transition may appear easier to achieve through reduced energy consumption. However, without replacing value creation, this leads to a loss of prosperity, jeopardises social acceptance of climate targets and, last but not least, diminishes the performance of the economy, which is precisely what is needed to implement the energy transition (see Principle 2).[54] In addition, although a sustained decline in industrial production would reduce domestic emissions, there would generally be no positive effect globally if industrial production were simply relocated to other regions – often to places with lower environmental standards and higher emission intensities. As a result, global greenhouse gas emissions could actually increase, while Germany loses value creation, employment, and innovative strength. De-growth as a means of achieving the energy transition is therefore not effective. On the contrary, an energy transition should enable sustainable prosperity growth through a long-term secure energy supply.

Principle 2): The energy transition can only succeed on the basis of economic strength.

The explanations in Chapter 2 illustrate the high costs and investment requirements of the energy transition, which are not necessarily offset by immediate additional value creation. The energy transition is therefore a process that must be financed by value creation elsewhere in the economy. This is not primarily a matter of monetary financing, but also, in particular, of the provision of goods, labour and capital. The speed of the transition to climate neutrality must therefore be geared to the performance of the economy – the stronger it is, the faster the transition can be completed. A fixed timetable for the energy transition ignores this connection: the current design of the status quo energy transition thus risks overburdening the economy's ability to implement the transition. Instead, a 'breathing' system is needed that adapts to the respective maximum capacity. This would allow the energy transition to benefit from a strong economy, as the transition could be achieved more quickly from a position of strength.

Principle 3): Germany has a structural disadvantage in terms of natural resources (such as wind and sun).

The switch to renewable energy sources pursued by the energy transition is changing the relative global location conditions for energy, predominantly to the disadvantage of Germany. While fossil fuels such as coal, oil and gas have led to a certain (international) levelling of energy costs due to favourable transport options, this will change with a switch to energy sources that pose greater challenges in terms of interregional transport, such as electricity or pure hydrogen. In the context of the energy transition, the local availability of cheap CO_2-free energy sources will become more relevant. In Europe, and even more so globally, there are much more suitable locations for the use of wind and solar energy. With the phase-out of nuclear energy, the most important base-load-capable, climate-neutral technology is also

54 Reduced energy consumption would not be a problem if it were due to structural change – for example, a shift in economic activity from energy-intensive basic material production to less energy-intensive areas such as services. In such a case, a decline in energy consumption does not automatically mean a decline in value added and thus a loss of prosperity. However, such structural change takes time and cannot be enforced in the short term.

excluded from the range of solutions for Germany. The lack of cost-effective CO_2-free energy sources could jeopardise the long-term competitiveness of certain energy-intensive industrial production in Germany.[55]

In order to maintain the economic strength necessary for a successful energy transition, it must be structured in such a way that such structural disadvantages are minimised or can be offset. On the one hand, all available options should be able to contribute to providing cost-effective non-fossil energy – for example, through the increased use of sustainable biomass potential, the expansion of geothermal energy, or other complementary technologies. Low-carbon fossil fuel options such as blue hydrogen and CCS, possibly in conjunction with the use of domestic natural gas resources (which are relatively lower in emissions than imports), should also be included in the range of solutions.

On the other hand, the relative strength of the German economy in the past was based in particular on innovative strength, well-trained skilled workers, and high-quality industrial products – capabilities that will play an even more central role in future competitiveness. This means that there is also a certain degree of competition for financial resources for measures such as climate protection or innovation/education. This underlines the importance of a 'breathing' system.

Principle 4): Technology holds the key to the energy transition.

The defossilisation of an economy is a technological challenge: as with other historical global environmental challenges (e.g. damage to the ozone layer by chlorofluorocarbons (CFCs)), the key lies not primarily in renunciation, but in the development of technical alternatives, due to the necessary global social consensus. In recent decades, numerous new technologies have been developed that are already making a major contribution to the implementation of the energy transition, e.g. the development of powerful stationary batteries (BESS). A re-thought energy transition should therefore focus on creating incentives for long-term innovation and technology development, not least in order to make the energy transition more cost-effective. Since future technological developments are unpredictable, the widest possible use of technology makes an important contribution to promoting progress.

Principle 5): The market and competition are the most effective drivers of innovation and technological progress.

Experience shows that open technological competition based on market structures is an extremely effective environment for driving innovation and technological progress and actually achieving the learning curve advantages modelled in various studies. The energy transition – like industrial transformation processes in the past – depends on continuous technological progress. However, this cannot be planned on the drawing board or imposed by political targets. Rather, it has been shown time and again that innovation arises above all where there

55 This is demonstrated, for example, by the international comparison of energy costs for the production of selected energy-intensive raw materials based on renewable energies in Bähr et al. (2023).

is competition: for the best ideas, the most efficient solutions and the most sustainable business models. This is precisely where a functioning market mechanism comes in – through incentives for innovative pioneers, pressure to increase efficiency, and the natural selection process of supply and demand.

The regulatory framework should therefore provide scope for creative approaches, technological diversity, and entrepreneurial initiative. Instead of micromanagement, what is needed above all is a reliable market environment.

Principle 6): The energy transition is a long-term process with a high degree of uncertainty regarding the framework conditions.

The framework conditions for the energy transition are subject to a multitude of exogenous influences that are difficult or often impossible to predict – geopolitical developments, social moods, technological breakthroughs, and raw material prices are just a few examples. Therefore, a planning approach based on a single target vision defined today ('master plan') and attempting to follow this path under all circumstances cannot work. Rather, a clearly defined, robust framework is needed that primarily manages the risks associated with the development and implementation of new technologies and processes: by focusing on a variety of possible solutions, by pursuing technology-neutral paths and by thinking across energy sources. Flexible, decentralised decision-making processes in the market can respond better to new information and changing realities. An intelligent energy transition must therefore be driven not only towards short-term effectiveness, but above all towards long-term adaptability.

Principle 7): Energy supply chains are sluggish and cannot be restructured as quickly as desired.

Energy systems consist of complex, physically and economically highly interconnected infrastructures with long investment cycles, high capital commitment, and high requirements for operational and supply security. The complete restructuring of such supply chains – from energy generation, transport, and storage to distribution and use – cannot be achieved overnight.

Even under optimal conditions, planning, approval and construction times for infrastructure projects inevitably range from several years to decades. Realistic planning for the energy transition must therefore recognise that change processes have their own temporal logic and sequence. It may therefore be valuable to incorporate existing infrastructure into the transformation, especially if this can accelerate the transformation and potentially lead to cost-effective solutions in the long term. This could be achieved by converting energy sources in relation to the infrastructure rather than adapting the infrastructure to the energy sources – for example, by converting electricity into hydrogen and synthetic methane for further use in the gas networks. Excessive political pressure for transformation – for example, in the form of unrealistic targets – risks misallocations, inefficiencies and, ultimately, the failure of key projects.

Achieving climate neutrality by 2045 would require a pace of transformation never seen before. However, (excessive) political pressure for transformation – for example in the form of unrealistic targets – risks misallocations, unnecessarily high costs and possibly even the failure of key projects. What is needed instead is a long-term planning horizon with reliable framework conditions, but realistic phasing that takes existing infrastructure into account.

Principle 8): Climate neutrality can only be achieved effectively on a global scale.

Climate change is a global problem – therefore, the solution must also be global. National measures to reduce emissions are only effective if they actually contribute to global emission reductions or provide incentives for others to follow suit. The mere fact that all CO_2 emissions have a global impact makes it necessary to measure the effectiveness of climate protection measures not by national reduction balances, but by their global net effect. It follows that measures that merely lead to a shift of emission-intensive activities abroad (carbon leakage) miss the actual target. Furthermore, emission reductions should – as far as possible – be made where this involves the least effort. A strategic approach to the energy transition must therefore always take the international dimension into account: through technology exports, the establishment of global partnerships and the use of international cooperation opportunities.

Principle 9): 'Keep it simple' – simple solutions facilitate implementation and acceptance.

Excessive complexity is one of the greatest enemies of a successful transformation. Conflicting political goals, complex regulations, detailed exemptions and bureaucratic processes not only lead to unnecessary delays and additional costs, but also undermine social acceptance. A successful energy transition in Germany cannot be planned on the drawing board – it needs simple, comprehensible rules – for citizens as well as for businesses. Simplicity is achieved primarily through market-based instruments that can have a broad impact without regulating every detail in advance. As paradoxical as it may sound, less complexity often leads to greater controllability. Simplifying processes, regulations and funding logic is therefore not a secondary technical concern, but a key success factor.

Principles serve as the foundation for 'Plan B' in the following chapter

The principles described serve as the conceptual foundation for the following proposals for realigning the climate policy regulatory framework in Germany and Europe. All of the elements of 'Plan B' described below – from the central climate policy control instrument to ensuring investment incentives, coordinating energy infrastructures and the role of state institutions – can be derived directly from the various principles.

4 A fundamental realignment of the energy transition for greater cost efficiency and competitiveness is possible and creates the conditions for climate targets to be achieved

Based on the principles outlined above, in this chapter we derive a possible change of instruments for a fundamentally 'rethought' energy transition (Chapter 4.1). Using model-based analyses, we demonstrate by way of example that such a new approach promises considerable savings potential without significant compromises in climate protection (Chapter 4.2). Finally, we also show how businesses and consumers could benefit from the savings potential in the form of lower energy costs (Chapter 4.3).

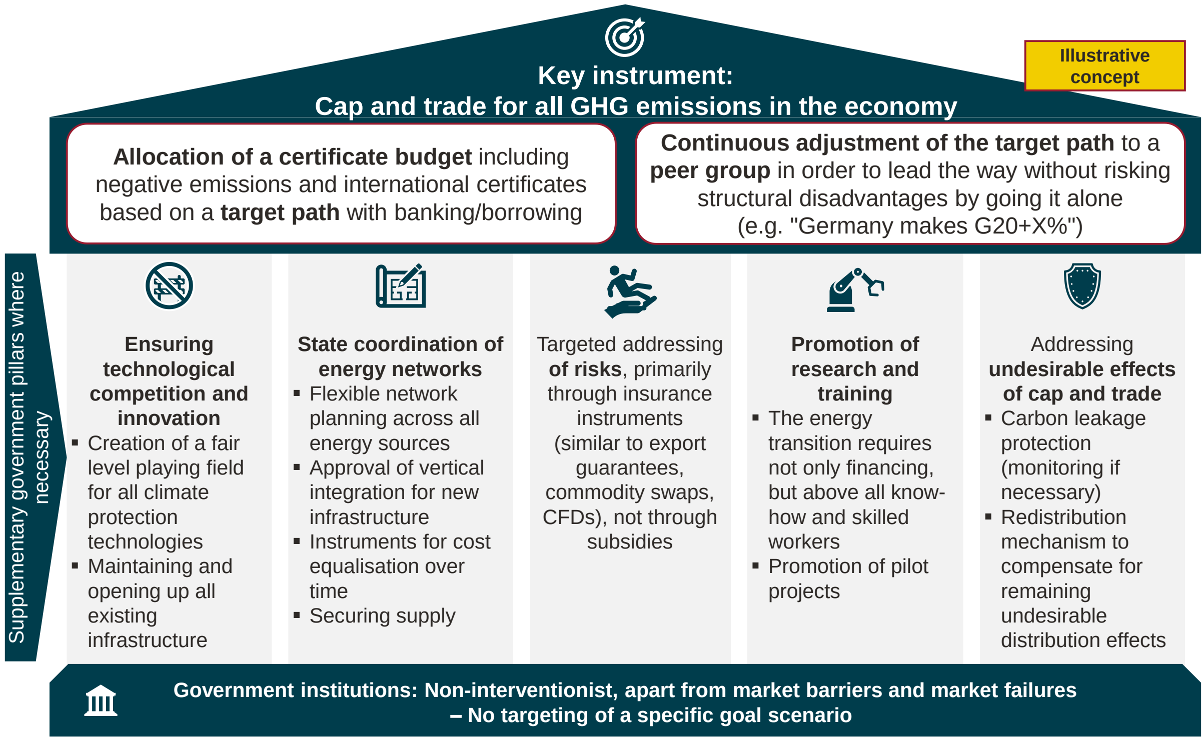
4.1 A fundamental concept for the energy transition based on overarching principles distributes roles between the market and the state in a targeted manner

These principles already provide the central outline for the concept of a 'reimagined' energy transition**: a simple policy framework focused on innovation and competition that optimally combines the transformation to a fossil-free economy with the safeguarding of prosperity, resilience and globally effective climate protection.**

The concept outlined below takes into account the key insight that the future can only be planned to a limited extent and that it is therefore important for policymakers to create a framework that can respond flexibly to technological, social and geopolitical developments. In line with the principle of keeping complexity to a minimum, we are trying to make the framework as simple as possible and minimise the need for regulation and bureaucracy-driven processes.

As a result, the concept uses a single instrument (an emissions trading system or 'cap-and-trade' system) to control and comply with the defossilisation target and limits the role of the state to ensuring five supporting pillars (seeFigure 22).

Figure 22 A fundamental new concept for the energy transition



Source: Frontier Economics.

Cap-and-trade system as a central control element for achieving climate targets

At the heart of the new concept is a comprehensive cap-and-trade system[56] that covers **all greenhouse gas emissions** in the economy. The specific design is based on several key operating principles:

- **Setting an emissions budget** for all greenhouse gases and allocating the corresponding allowances, whereby the budget is calculated on the basis of a fixed target path but can then be used as freely as possible over time. The budget also takes into account negative emissions and recognised international certificates. Flexibility over time is achieved through the possibility of *banking* (use of certificates in later years) and (limited) *borrowing*[57] (borrowing certificates from later years), so that companies can shift emissions between periods.[58]

56 A cap-and-trade system sets an upper limit for greenhouse gas emissions and issues a corresponding amount of emission allowances. One allowance is required for every tonne emitted in the covered sector. These allowances can be traded between market participants – those who emit less can sell their surplus allowances. Those who emit more must purchase additional allowances.

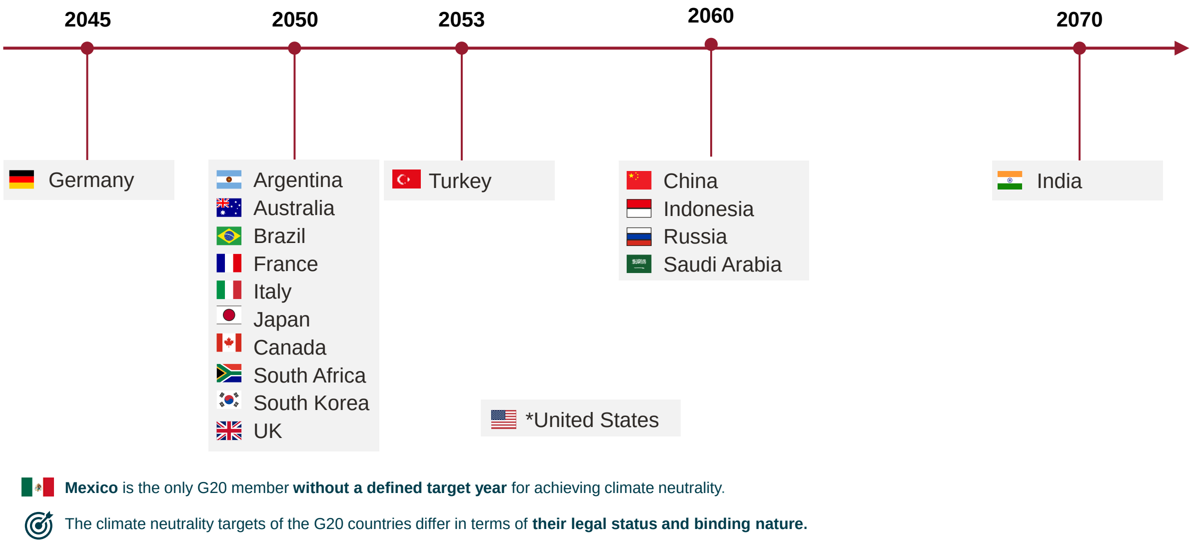
57 In order to reduce the risk of undermining the credibility of long-term target achievement through unlimited borrowing of emission rights, borrowing should be limited in terms of time (e.g. five years) and/or scope (e.g. max. 20% of the total annual budget).

58 Potentially undesirable distribution effects can be addressed separately if necessary; see Pillar 5 in the following section.

- The target path is regularly **adjusted** to the development of a **defined international peer group** in order to encourage ambitious climate protection without creating disadvantages for Germany as a business location through structural solo efforts. One guideline could be: "Germany reduces emissions by a maximum of G20+X%".[59] In the sidebar, we explain the game theory concept behind linking the target path to a peer group. This ensures that Germany always stays one step ahead of the relevant group of international competitors in terms of climate protection, without creating too large a gap – with the resulting risks for its own competitiveness.Figure 23 shows that Germany already pursues more ambitious climate policy targets than the majority of global industrialised and emerging countries. An effective peer group mechanism takes into account not only the respective policy targets but also other relevant indicators such as historical emissions trends (expressed as per capita emissions, where applicable) and general economic growth in the respective countries.

- This approach is coordinated across the EU wherever possible. Ideally, EU countries would jointly commit to such an approach with a uniform factor X. If this is not possible due to a lack of consensus, a differentiated approach would be conceivable (no legal review has been carried out in this regard).

Figure 23 Overview of G20 climate neutrality targets



Source: Frontier Economics based on official announcements and the Climate Action Tracker (2025).

*Note: *Under President Biden, climate neutrality by 2050 was considered an official goal of the US. However, in early 2025, the Trump administration initiated the withdrawal from the Paris Climate Agreement, which will take effect in January 2026. The continuation of the 2050 goal is therefore politically uncertain. The current US administration has not yet committed to the 2050 target or any other target year.*

Climate protection is a central goal of global sustainability policy. This makes it all the more important to identify potential conflicts with other sustainability goals at an early stage through

59 The G20 group comprises the world's 19 most important industrialised and emerging economies, as well as the European Union and, since 2023, the African Union.

monitoring when designing concrete measures. The 17 UN Sustainable Development Goals (seeFigure 24) could provide a starting point for this. Systematic **monitoring** can help **to avoid** unintended **negative interactions**. Many of the UN Sustainable Development Goals interact positively, at least in part, with the climate protection goal – e.g. the goals of "sustainable cities" or "sustainable consumption" and, to some extent, "life on land" and "life below water". However, conflicts of interest could also arise if, for example, the costs of climate protection measures place a burden on poor population groups (possible contradiction with the goal of poverty reduction) or if the cultivation of bioenergy crops competes with food cultivation for land and water (possible contradiction with the goal of combating hunger). Energy and climate measures that ultimately prioritise climate protection over other sustainability goals through a loss of prosperity (de-growth) should therefore be viewed critically. Monitoring should identify such conflicts of interest and initiate a political decision-making process to weigh them up. Such considerations and the achievement of consensus can be difficult. However, such conflicts of interest should be made clear, as it would be wrong to assume that all climate protection measures contribute equally to the achievement of other sustainability goals.

Figure 24 Overview of the UN Sustainable Development Goals

Source: UNRIC (2025).

The 'breathing' cap-and-trade system is the central control element in the new concept for achieving climate protection goals. It translates the derived climate protection goals into a market-based mechanism. It is therefore an instrument in which politicians create a regulatory framework and monitor compliance with it, but otherwise leave the achievement of the targets to economic actors with the greatest possible freedom – with corresponding opportunities for innovation, efficiency, and new business models.

If this system succeeds in covering as many economic sectors as possible and, by linking it to an international peer group, also ensures that the most important import products come from a climate policy regime with at least a similar level of ambition, the climate impacts would already be "priced in" for the majority of value chains. This would partially eliminate the need for complex calculations of life cycle emissions to represent climate impacts and simplify the weighing of alternatives in terms of climate impact. Responsibilities would remain decentralised with the companies at the respective stage of the value chain, where decisions on defossilisation measures could also be made in the best possible way.

This system would ensure that no further instruments would be necessary to achieve climate targets. However, there are other aspects that require central coordination and complement the overarching cap-and-trade system.

Digression: Mechanism for the global effectiveness of climate protection

Climate protection from a game theory perspective – a prisoner's dilemma

The challenges of effective international climate policy can also be analysed using game theory. In game theory, this is referred to as a prisoner's dilemma – a situation in which joint cooperative behaviour delivers the best overall result for all parties involved, but it seems rational for each individual not to participate. The result: without binding coordination, the actors decide against cooperation, even though collective action would be beneficial overall.

This dilemma is evident in global climate policy: those who reduce greenhouse gas emissions bear the full costs, but benefit only to a much lesser extent from the avoided global climate effects. Those who do not contribute bear no costs and still benefit from the contributions of others (free riding). This virtually eliminates the individual incentive to protect the climate, even though joint climate protection would be better for everyone.

In addition, global competition dynamics pose the challenge that national climate protection efforts by individual countries may be ineffective (i.e. may not lead to an overall reduction in global emissions) as long as not everyone is on board. One example is the unilateral introduction of CO_2 prices: companies with higher national costs due to regional CO_2 prices lose their global competitiveness and could therefore relocate emissions-intensive production to countries with less stringent regulations (carbon leakage). There, for example in the case of relatively more emission-intensive processes, emissions may even increase, resulting in less global climate protection and a simultaneous loss of added value and prosperity in the country with climate protection ambitions. Without international anchoring of comparable CO_2 prices (or corresponding compensation mechanisms), purely national climate policy therefore remains economically risky and, under certain circumstances, even ineffective for climate protection.

Possible solution: an international approach that sets a real example – leading the way without going it alone

The need for international coordination on climate protection has long been recognised and operationalised in the relevant UN processes (UNFCCC). However, achieving effective international coordination of climate protection measures is proving challenging, which can be explained by the prisoner's dilemma that exists in international climate policy.

To overcome this, our concept of a comprehensive cap-and-trade regime provides for a mechanism that creates mutual obligations and strategically incentivises implicit cooperation without the need for multilateral agreements: linking one's own emissions budget to the actions of other actors in a binding manner can create a global incentive for climate protection (based on formalised reciprocity). Freeriding by other countries without making their own efforts would be ruled out, as in this case the permitted emission levels in Germany (or Europe) would also be adjusted – conversely, savings abroad would have a disproportionate impact in Germany (or Europe) due to the guaranteed "exceeding" (+X%). In this system, the pursuit of opportunistic interests by individual countries could thus lead to increasingly coordinated international action.

The design of an international linkage should be based on two principles:

- **Recognition of a fair contribution** to global climate protection: Internationally, higher expectations are placed on Germany and the EU to contribute to climate protection – especially when criteria such as historical emissions (per capita or total), economic performance and technological implementation capacity are taken into account (analogous to the "fair share" principle of the Paris Climate Agreement). A more ambitious approach and a pioneering role in climate protection are appropriate – and enshrined in international law within the framework of international agreements.

- **Ensuring global impact:** At the same time, it is clear that national measures and 'setting an example' are not enough on their own to achieve globally effective climate protection (due to the prisoner's dilemma explained above). Ambitious climate paths for Germany or Europe will only be effective if they are part of a coordinated international framework.

In concrete terms, this means that (1) Germany (or ideally the EU) should take the lead – but (2) not as an unconditional solo effort, but within a mechanism that creates reciprocity and commitment. The detailed design of such a mechanism is not the subject of this study.

One conceivable approach would be to align Germany's own reduction targets with the climate protection efforts of other major economies. The G20 group could be a starting point here, as this group of countries is responsible for a large proportion of global emissions and also includes the most relevant countries in terms of international location competition. Due to their pioneering role, climate protection ambitions should be higher than those of the peer group – for example, the reduction path could be "G20 + X%". The X would have to be determined in such a way that the competitive disadvantages of Germany as a business location compared to other countries would not be so great as to lead to migration effects.

The proposal offers great opportunities, but of course also certain risks:

- **Opportunities:** If an effective mechanism can be established, the global impact of climate protection will be strengthened and, in the medium term, ambition will even increase, as other countries will have a double incentive to reduce emissions: to avoid reputational damage and to maintain ambitious European partnerships. Linking Germany's own targets in this unilateral manner could therefore create leverage for greater international climate protection without the need for multilateral agreements.

- **Risks:** International anchoring could lead to German climate targets being weakened in the event of a lack of international commitment. However, this would be a situation in which global climate protection would be fundamentally jeopardised, as individual countries such as Germany would not be able to have a sufficient global impact even if they went it alone. On the other hand, in such a situation, the threat of a loss of competitiveness for the "pioneering" countries would be reduced, so that the economic capacity to pursue a pioneering role – albeit at a slower pace – would remain intact. Ultimately, the risk described above leads back to the principle that a successful transformation is only possible with a strong economy.

If effective, such a mechanism would strengthen Germany's role as a role model and combine it with global effectiveness in a targeted manner – the concept explicitly does not envisage a weakening of climate targets, but rather a well-founded incentive and adjustment mechanism aimed at strengthening global climate protection.

Five complementary government pillars focus the tasks of government institutions on overcoming market barriers and market failures

In addition to the central market-based control mechanism for achieving climate targets, targeted, supportive government activities are planned where market failure exists or coordination tasks need to be performed. It is not the task of the government to define a variety of sub-targets and implement them through interventionist measures, but merely to ensure the framework for effective competition. The complementary state pillars relate in particular to the following five areas:

- **Ensuring technological competition and innovation**: The state creates the conditions for open technological competition by ensuring uniform and non-discriminatory framework conditions for all climate protection technologies. The aim is to establish a *level playing field* in which cost-effective and efficient solutions can prevail. Existing infrastructure should be maintained, made accessible and, where appropriate, opened up for alternative uses in order to keep transformation costs low and avoid path dependencies.

- The state will take on a coordinating role in the planning and further development of energy infrastructure:
  - Cross-sector network planning – particularly for electricity, gas, CO_2 and hydrogen – should ensure that synergies are exploited and inefficient parallel structures are avoided.
  - For the purpose of rapidly expanding new infrastructure, it may be advisable to temporarily allow vertical integration along the value chain, provided that this contributes to increased efficiency. This can, for example, help to promote the development of value chains for new energy sources and technologies in local or regional clusters before it is clear whether these energy sources will become widely established and require extensive infrastructure. This can improve investment security and accelerate the market ramp-up of new energy sources through cross-interface coordination. As with electricity and gas networks, the focus could then increasingly shift to liberalisation and non-discriminatory access in later phases after the establishment of a new energy source (*"speed before commodity competition")*.
  - New infrastructure – for hydrogen or CO_2, for example – often has to be built in advance and under a high degree of uncertainty before it is sufficiently utilised. This initially leads to low utilisation at high costs and carries a considerable risk of sunk investment. The state can play a supporting role here, e.g. by securing investments.
  - In addition, security of supply must be continuously monitored**.** If it becomes apparent that the market cannot reliably guarantee this (for example, in the event of critical bottlenecks or a lack of reserve capacity), the state should be able to intervene with the help of targeted security instruments. One reason for using security instruments may also be to achieve a desired level of resilience and independence from imports that goes beyond the level of market equilibrium. These measures should only be used when necessary and should complement market incentives, not replace them.

- **Risk addressing through targeted insurance instruments**: Investments in new climate-friendly technologies are often associated with considerable risks that can make financing difficult or delay it. A large proportion of today's technology-specific support programmes (e.g. the Renewable Energy Sources Act) were justified by such risks, among other things. While such risks and "first mover disadvantages"[60] can indeed constitute an obstacle to investment that can be overcome by socialising the risks, in practice the goal of risk hedging has often been coupled with the goal of subsidising specific technologies. In 'Plan B', future government intervention would be largely limited to risk hedging, and

[60] A "first mover disadvantage" arises, for example, when the "first mover" generates experience (e.g. with regard to the plant design of a new production facility) that then allows imitators to set up efficient production.

the competitiveness of energy transition technologies would be ensured by the central cap-and-trade system.

Government-supported risk hedging can be justified in particular when market-based insurance solutions, such as commodity swaps to hedge the market price risks of liquid tradable energy sources, cannot adequately reflect the corresponding risks. Reasons for this may include, for example, a lack of data, illiquid markets, incalculable risks, an unreliable legal framework, or a combination of high and difficult-to-quantify risks. If private insurability cannot be achieved through other measures, such as measures to promote liquid markets, the state (or semi-public actors such as KfW) could provide targeted insurance instruments in these cases. The focus here is on price volatility risks (not price level risks), technology risks and credit default risks. Hedging can be provided, for example, by government-backed financial derivatives (such as options or contracts for difference (CfD)[61]), government-coordinated default insurance, or credit guarantees. These are insurance mechanisms for the development of new technologies, not broad-based subsidies – in economic terms, there is no transfer payment, but rather a transfer of risk to improve investment conditions.

- **Research and education funding**: The energy transition requires sufficient technical and human resources for its implementation. Precisely because Germany has a competitive disadvantage in terms of renewable resources, these deficits must be compensated for through innovation and technological leadership. This applies both to the expansion and restructuring of infrastructure in Germany and to the development of new climate protection technologies that can contribute to reducing emissions internationally in the future. Research and education should therefore be promoted not only to "meet demand" but also as an important strategic investment in the national economy. Specifically:

  - **Qualification:** Strengthening the attractiveness of vocational and academic qualification programmes relevant to the energy transition in order to meet the demand for skilled workers along the entire value chain.

  - **Research**: Focusing public funds on technology-neutral projects along the entire value chain of climate-neutral energy sources and defossilisation options, especially where market players are reluctant to act. In addition, active participation in international research collaborations is essential in order to gain access to global innovation networks and ensure that Germany does not lose touch with future potential megatrends.

  - **Promotion of initial industrial scaling**: Support for pilot projects and projects for initial industrial scaling in order to test new technologies under real conditions and enable scaling (e.g. via investment grants). However, funding in these early market phases should always be subject to the condition that the knowledge gained is made

61 CfDs should be designed with a strike price (target price) at market price level in order to hedge price uncertainty, but avoid subsidising costs below market price level.

available to the entire industry and does not act as a barrier to competition for other players.

- **Addressing undesirable distribution effects**: In order for the central cap-and-trade system to be fully effective without causing undesirable economic or social side effects, targeted flanking measures are foreseeably necessary:
  - A cap-and-trade system can lead to energy-intensive companies losing competitiveness and relocating their production abroad when greenhouse gas emission prices rise (and are uniform across sectors). This so-called carbon leakage is a particular threat when companies in other countries are subject to lower or no costs for their greenhouse gas emissions. The result would be a decline in domestic value added without any actual reduction in global emissions. To prevent this, systematic monitoring is being introduced: if such a trend emerges, targeted border adjustment measures can be implemented, based on existing instruments such as the European Union's Carbon Border Adjustment Mechanism (CBAM). If climate targets are effectively anchored globally – for example, within the framework of the G20 – a border adjustment mechanism may become unnecessary in the future, as in this case companies abroad would also incur costs for greenhouse gas emissions – for example, through comparable cap-and-trade systems or other pricing mechanisms.
  - In addition, a mechanism for redistributing potential revenues from emissions trading could be established. This should primarily be used to correct undesirable distributional effects – especially those of a social nature – and to strengthen social acceptance of the energy transition. This is particularly relevant for (low-income) private households, which may incur high additional costs due to emission prices. Redistribution should take the form of a lump sum (e.g. via direct transfers) or tax relief (e.g. on income or corporation tax).

In the following section, we use our model-based analysis framework to illustrate the cost reduction potential that could be realised by implementing parts of the ‘Plan B’ concept. In Chapter 5, we specify how, based on the current political and regulatory framework, targeted adjustments can be made to move closer to the target concept.

4.2 Significant cost savings can be achieved by implementing the ‘Plan B’ concept

In Chapter 2, we used an analytical framework to estimate the cost burden of the energy transition under the status quo. In this subchapter, we use the same analytical framework to estimate the extent to which an energy transition in line with the presented ‘rethought’ target concept can lead to savings.

However, the fundamental limitations of the significance of the quantitative results must be taken into account, which we point out first. We will then present the results of the analysis and discuss the three key levers through which 'Plan B' leads to cost savings.

Modelled cost savings apply to exemplary framework conditions that develop dynamically in an uncertain future

In the following sections, we use model-based analyses to estimate the potential savings that implementing the 'Plan B' concept could bring for the German energy transition. One challenge here is that the current implementation of the energy transition follows a 'master plan', whereas the core of the proposed 'Plan B' is to take account of the defined principles of uncertainty about future developments through a flexible framework. In addition, a central component of 'Plan B' is the focus on innovation, entrepreneurial initiative and competition – meaning that the exact technological solutions for achieving the energy transition are therefore not predictable. Furthermore, the new concept is explicitly intended to provide new growth impulses. For this reason, key framework parameters such as energy demand cannot be planned, but can only be estimated in approximate orders of magnitude. If, for example, Germany were to establish itself as an attractive location for AI, the energy supply requirements would be different than if the focus were primarily on traditional industrial sectors. However, this means that potential savings can only be quantified on the basis of very restrictive, exemplary assumptions about future developments.

On the other hand, evidence must be provided that the proposals can also make a significant contribution to reducing costs. We have therefore modelled the savings that would result from 'Plan B', even if the framework conditions develop similarly to what is expected in the current planning for the energy transition.

For the modelling, we have therefore assumed a uniform final energy demand across all scenarios, which corresponds to the demand from the BMWK long-term scenario O-45 Electricity. This means that the same final energy consumption is anticipated in both the status quo and in 'Plan B'. Cost savings in 'Plan B' are therefore achieved exclusively through more efficient provision of final energy, not through a change in consumption structure or a 'fuel switch'. This means that this additional degree of freedom with potentially large savings is not yet considered in our scenario. In this respect, the results probably still significantly underestimate the potential savings. The results are mainly presented as ranges that reflect different assumptions about technological learning curves – from optimistic to reduced learning developments.

In line with the limitations and future uncertainties, all of the results presented below should be understood as illustrative estimates based on certain assumptions. It is expressly not the aim of 'Plan B' to pursue a specific technology scenario or to imply that the technology mix shown in the following analyses would be the optimal one. These exemplary results are based on the current state of knowledge and various parameters that are highly likely to change in the future.

However, by focusing on similar conditions to those in the status quo – in order to show potential savings in a direct comparison – many other potential advantages of the 'Plan B' concept are generally not taken into account in the following analyses. These include, among others:

- **Efficiency gains through a significantly changed end-energy carrier mix** – One approach of the new concept is to include the continued use of existing infrastructure, such as gas networks, as a possibility. This also results in options for end users to continue operating their end applications with the energy carriers offered and to make savings in this way. Potential cost reductions on the demand side exist, for example, through the retrofitting of existing natural gas applications in industry with CCS instead of a switch to hydrogen or complete electrification. Such advantages are not yet taken into account in the following analyses. Rather, the same final energy mix is assumed as in the current planning of the energy transition in the status quo.

- **Future technologies** – Plan B is characterised by the promotion of innovation and a high priority given to market-based technological competition. It can therefore be assumed that new technology options will also be developed in the future. These developments, which cannot be predicted today, are obviously not quantifiable. However, it is foreseeable that the significantly more innovation-friendly framework of the new approach, compared to the current dirigiste approach, will be able to realise significant additional potential in this area. Furthermore, further cost reductions are possible, for example in the context of sector coupling: for example, the generation of process heat at higher temperature levels could be defossilised in a cost-effective and system-friendly manner through a mixture of PV/wind surplus electricity and hydrogen.[62]

- **Halting deindustrialisation –** One of the central concerns of the 'Plan B' concept is to strengthen Germany's competitiveness as a business location. In line with the principle that "the energy transition can only succeed from a position of economic strength", maintaining and expanding industrial value creation in Germany is a clear goal. However, this will also lead to foreseeable additional energy requirements, which in turn will have repercussions on the costs of the energy transition. Such effects are also not taken into account in this modelling approach.

- **Bureaucracy and other indirect energy cost effects** – Any positive effects on other energy transition costs, e.g. through the reduction of bureaucracy, are also not included in the following analyses.

The actual macroeconomic benefits are therefore likely to be significantly higher than the following estimates. At the same time, however, such effects are not yet included in the exemplary technology mixes shown, so that these too serve only as a comparison with the analyses in Chapter 2 and do not claim to represent a prediction of the future.

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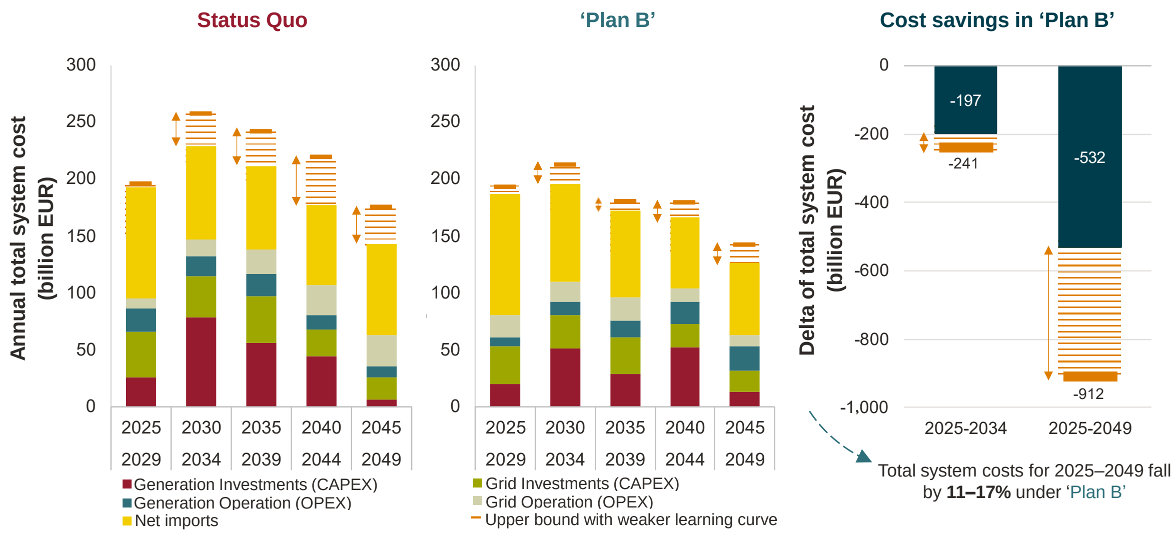
[62] See, for example, ZINQ and Fraunhofer UMSICHT (2025).

Despite restrictive assumptions, our model analysis shows considerable savings potential through 'Plan B'.

Given these important limitations, even the restrictive model approach shows that implementing key measures of the new approach could make the energy transition more effective and cost-efficient.

In total, simply by realigning the energy transition more efficiently – with identical total emissions in Germany – the overall system costs of the energy transition could be reduced by at least €530 to €910 billion by 2050 compared to continuing with the status quo.[63] This corresponds to a relative cost saving of 11% to 17% (see right-hand chart inFigure 25).

Figure 25 Reduction in system costs through 'Plan B' by 2050



Source: Frontier Economics.

Source: The energy system costs considered here include new investments in generation capacity (CAPEX), ongoing operating costs (OPEX), grid infrastructure costs (CAPEX & OPEX) and energy imports. Necessary demand-side investments in the building, transport and industry sectors are not taken into account.

The main drivers of these system cost savings are, on the one hand, the use of more cost-effective combinations of generation, storage and transport/distribution technologies as a result of competition between the technology options (see "Lever 1" below) and, on the other hand, the switch to a cross-sector emissions budget approach ("Lever 2").

It should be noted that the savings potential identified only relates to cost reductions in the supply side of the energy system (i.e. lower overall costs for domestic generation, transport, storage and import of energy). In reality, the cost reduction potential is likely to be significantly

63 The energy system costs considered here include new investments in generation capacity (CAPEX), ongoing operating costs (OPEX), grid infrastructure costs (CAPEX & OPEX) and energy imports. Necessary demand-side investments in the building, transport and industry sectors are not taken into account.

higher due to the above-mentioned savings in demand-sided end uses, which are not included in our modelling.

In addition to the possibility of choosing more efficient technologies, another component of 'Plan B' is the international integration of climate protection efforts – for example, to achieve greater global climate protection with the same investment expenditure through (implicit or explicit) international cooperation. This international integration could ultimately result in Germany having a larger emissions budget at its disposal than is currently planned. This would allow further cost savings to be achieved: for example, expanding the German budget by an amount corresponding to a two-year postponement of the net-zero target would save a further €80-220 billion – with corresponding scaling potential (see "Lever 3" below).

Overall, depending on the extent of international cooperation, 'Plan B' could potentially yield savings of well over €1 trillion by 2050. Since 'Plan B' envisages changes to the status quo in many areas, this will also result in comprehensive changes in the energy industry. In order to analyse the possible effects more precisely, we differentiate the analysis of cost savings below along three major levers:

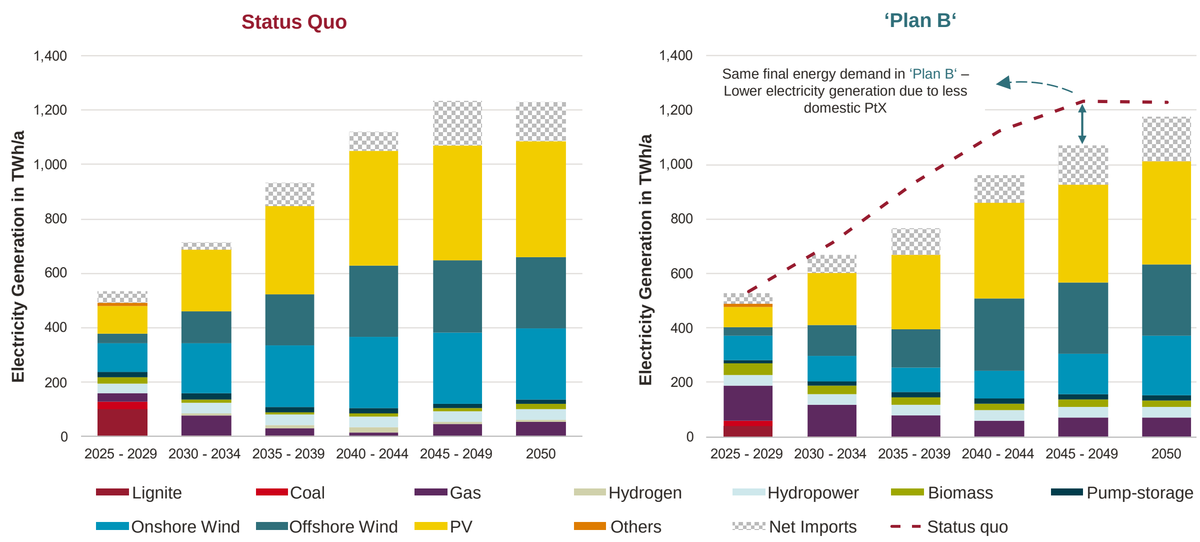
- Lever 1 – Creating a level playing field for all low-emission technologies
- Lever 2 – Realigning climate policy with a cross-sector emissions budget approach and abolishing annual climate targets
- Lever 3 – Further savings potential through more effective targets in an internationally coordinated climate protection goal

Lever 1 – Creating a level playing field for all low-emission technologies:

A key lever for cost reductions is the removal of political requirements for the choice of technologies to be used. In the interests of regulation that is as technology-neutral and competition-oriented as possible, 'Plan B' opens up the solution space for all available low-emission technology options – under the umbrella of a comprehensive cap-and-trade system. Fixed targets for the expansion of wind power (onshore and offshore) and PV are abolished. The expansion of electricity generation capacities will be achieved through free competition between all technologies on the market. Taking into account the available potential, greater use of biomass and low-emission technologies not based on renewable energies, such as blue hydrogen and CCS, will be permitted.Figure 26 compares the modelled electricity generation structure in the energy transition status quo with the electricity generation mix in 'Plan B'.

The technology-neutral, competitive regulatory approach can result in significant cost savings, e.g. by focusing on the most cost-effective domestic renewable energy generation options and, in the medium term, higher utilisation of the capacity that is necessary anyway to cover periods of low wind and low sunlight. In 'Plan B', the phase-out of coal (market-driven) takes place earlier, but gas is used more extensively. By replacing (expensive) domestic production of hydrogen (and its derivatives) with blue hydrogen and imports,[64] total electricity consumption in the 'Plan B' scenario is lower despite an assumed equal level of final energy consumption (see above). The focus on cost efficiency is also strengthened in grid expansion, among other things by removing the priority given to underground cables in transmission grid expansion. Electricity grid costs are further reduced by the overall more cost-efficient expansion of renewable energy generation capacities.

Figure 26 Modelled annual electricity generation in Germany

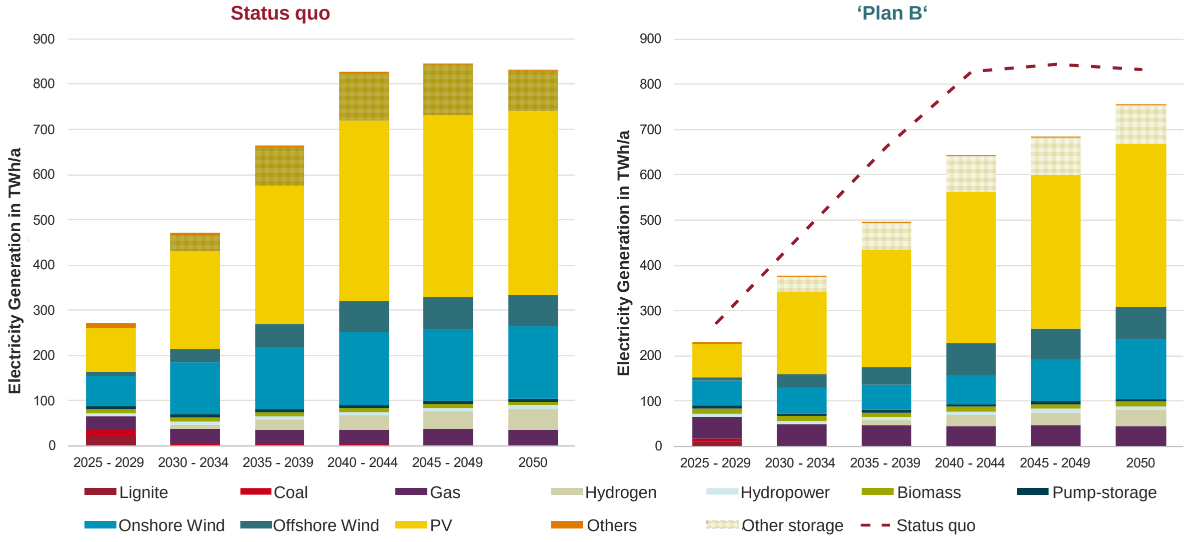


Source: Frontier Economics

Note: Electricity generation mix for scenarios with optimistic learning curves. Exemplary estimates based on certain assumptions and parameters that are highly likely to turn out differently in the future. 'Plan B' does not aim for a specific technology scenario.

64 Imports mainly from regions with favourable locations for renewable energies, e.g. the United Kingdom, and for the production of blue hydrogen.

Figure 27 Installed capacity for electricity generation in Germany



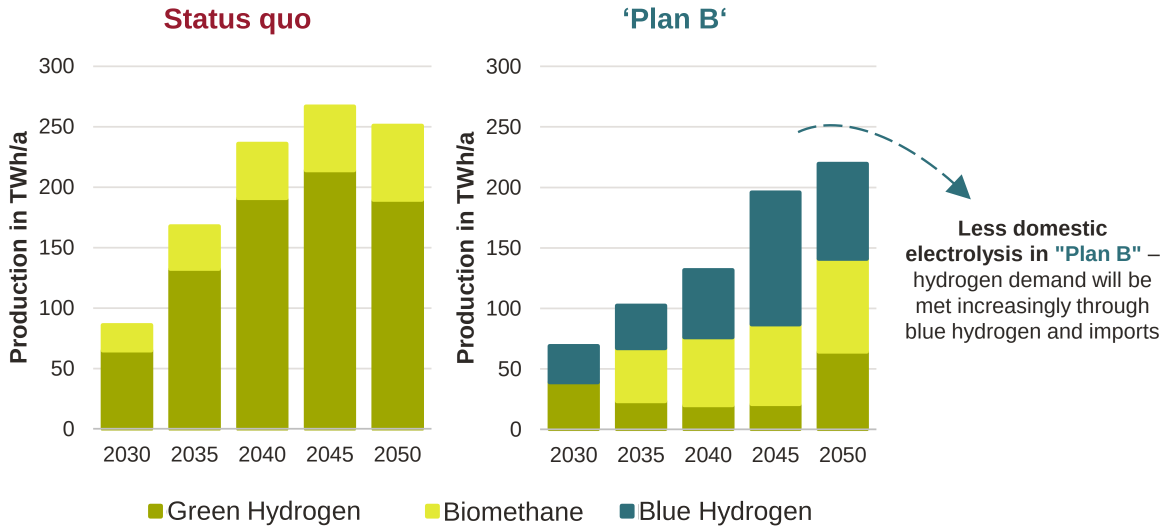
Source: *Frontier Economics*

Note: *Power generation mix for scenarios with optimistic learning curves. Exemplary estimates based on certain assumptions and parameters that are highly likely to turn out differently in the future. ‘Plan B’ does not aim for a specific technology scenario.*

Accordingly, investments in capacity can be more flexible in terms of timing and lower in amount, the latter particularly in the area of wind power and rooftop PV. Nevertheless, since the ‘Plan B’ modelling is based on the same exogenous final energy demand, large amounts of electricity must continue to be provided. This also requires a significant expansion of electricity generation, albeit less than in the status quo (seeFigure 27). As mentioned at the outset, Plan B would foresee further savings through a (avoided) fuel switch at the end-use level.

An important driver for cost reductions is the replacement of the construction of renewable capacities for domestic hydrogen production with cheaper imports. The technical advantages of gas/hydrogen being easier to transport and store are therefore used to reduce costs by resorting to cheaper renewable locations. In addition, the production of "green" hydrogen is replaced by domestically produced blue hydrogen from methane using CCS (seeFigure 28).

Figure 28 Production of climate-friendly gases in Germany

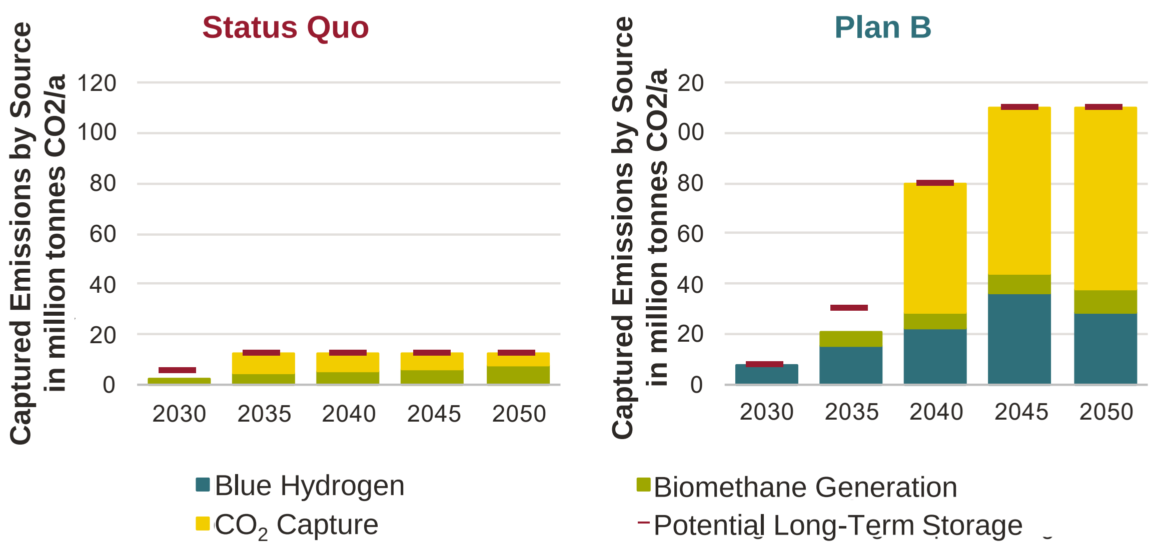


Source: Frontier Economics.
Note: Results for scenarios with optimistic learning curves.

Accordingly, CCS is becoming significantly more important as a technology for achieving climate targets, as shown by a comparison of the quantities inFigure 29 . In the 'Plan B' modelling, the potential limits of long-term CO_2 storage are fully exploited. Although CCS is also used in the energy transition status quo, it is only used to a comparatively small extent (as CCS is almost exclusively intended for hard-to-avoid emissions). The 'Plan B' modelling shows how expanding the potential limits would have an impact.[65] Here, significantly more emissions are captured and stored, including through the early use of blue hydrogen (from 2030) and a broader application of CO_2 capture.

65 By way of comparison, the technically feasible CO_2 capture potential in Germany is estimated at around 360 million tonnes per year (McKinsey, 2024), while the geologically available storage potential in Germany is around 20 billion tonnes of CO_2 (Luderer, Kost, & Sörgel, 2021). However, storage exclusively in Germany is not necessary – international projects open up additional options.

Figure 29 Emission capture and storage in Germany



Source: Frontier Economics.

Note: Results for scenarios with optimistic learning curves.

Digression: Possible role of nuclear power in the German energy transition

The phase-out of nuclear energy was completed in Germany in 2023 with the shutdown of the last three nuclear power plants and continues to be the subject of controversial debate. Within the framework of a technology-neutral policy approach, as envisaged in the ‘Plan B’ approach, nuclear energy from domestic production could once again become part of the electricity generation mix in Germany in the future – provided that investors and operators can be found. However, nuclear power is not currently part of the modelling of the ‘Plan B’ scenario:

- The construction of new nuclear power plants requires **long lead times**. The pure construction time for most projects is more than 10 years.[66] Added to this are planning and approval phases. Against this background, it does not appear feasible to commission new power plants in Germany well before 2045. These will therefore not be able to play a central role in achieving Germany's climate targets.

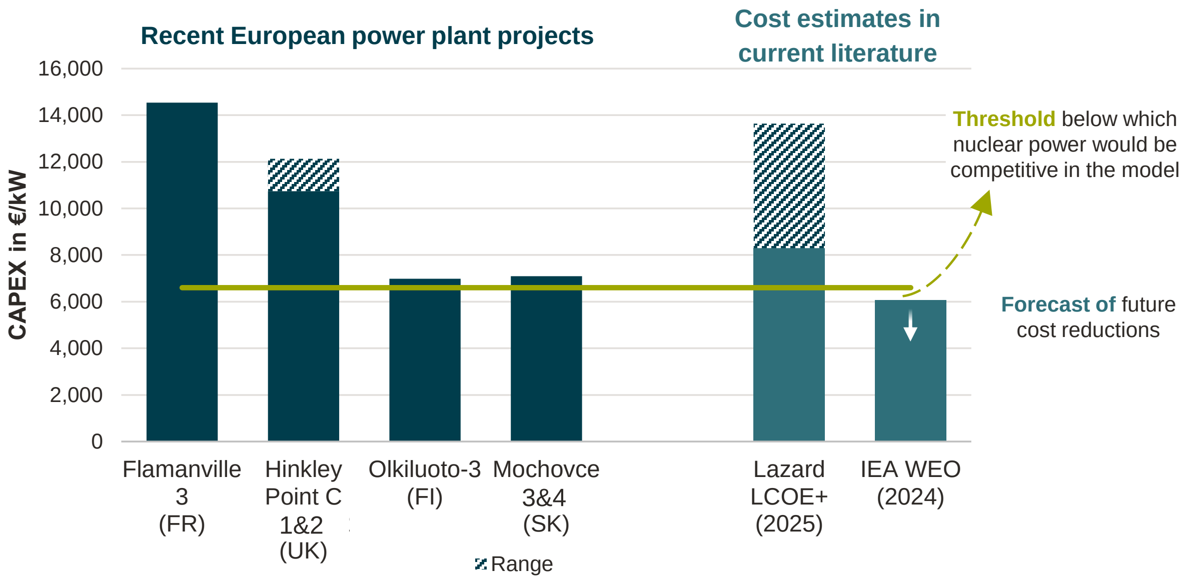
- The actual **costs of nuclear power are uncertain** and a recurring topic in the energy policy debate. Accordingly, there is a wide range of cost estimates: the most recent power plant projects in the EU and the UK have investment costs of €7,000–16,000/kW. The IEA puts the cost of nuclear power plants in the EU at just over €6,000/kW[67] and assumes that these costs will fall in the long term. Investment costs of less than €6,000/kW are difficult to achieve with individual projects in individual countries; this requires a serial production based on a standardised technical design (as is currently the case in South Korea/China, for example).

Taking into account the necessary lead times, we tested the competitiveness of nuclear power in the model as an option from 2045 onwards. In the ‘Plan B’ scenario, electricity generation from nuclear power would be competitive under the assumptions made for the modelling from a threshold investment cost of around €6,600/kW – whereby the exact extent of competitive capacity depends on the extent to which this cost threshold can be undercut. The cost estimates for recent projects in the EU and the UK are consistently above the threshold value mentioned above, while future cost forecasts and costs for serial projects outside Europe tend to be below it.

66 Construction times of significantly less than ten years have only been achieved by Chinese companies in China and Pakistan. For the latest nuclear power plants in Europe, the construction time was/is over 15 years. See Schneider and Frogatt (2024).

67 See IEA (2024), Annex B.4.

Overview of investment costs for nuclear power plants



Source: Frontier Economics based on published cost estimates

However, the threshold value determined is specific to the scenario modelled here as an example and is likely to differ under other conditions.[68] Whether nuclear energy could become a competitive part of the future electricity generation mix from a purely economic perspective therefore depends crucially on technological and commercial developments – for example in the field of small modular reactors (SMRs), serial power plant construction, etc. – and the associated cost reductions, which are subject to considerable uncertainty.

Against the backdrop of such uncertainties, the 'Plan B' approach deliberately does **not** set **a rigid target for a future technology mix**. Instead, it creates a regulatory framework in which market-based, efficient solutions can emerge.

However, an important element of the 'Plan B' approach is research and training (see pillar 4 in Chapter 4.1). Even though nuclear power is likely to play a relatively minor role overall, it makes sense to continue investing in research and training in the field of nuclear energy in order to maintain or create options that will enable Germany to benefit from potential future technological advances.

Lever 2 – Realignment of climate policy towards a cross-sectoral emissions budget approach with the abolition of annual climate targets

Similar to the removal of technological requirements, making the path more flexible over time can also lead to significant savings. Although the political discussion focuses on targets linked

68 For example, Fraunhofer ISI (2024) estimates the economic threshold for investment costs for base load power plants at €9,250/kW.

to specific years ("climate neutrality by 2045", "90% emission reduction in the EU by 2040") are at the forefront of the political debate, the decisive factor is the total amount of emissions accumulated over the years. The sum of greenhouse gas emissions over time is therefore relevant for the climate impact, not the point in time at which neutrality is achieved.

'Plan B' therefore dispenses with the existing annual emission reduction targets for 2030 and 2040. The same applies to the requirement that climate neutrality must be achieved in Germany in 2045 and in the rest of Europe in 2050. The annual climate targets are replaced by a cross-sector and cross-country residual emission budget. However, the budget is identical to the sum of emissions incurred in the status quo for the energy transition over the entire period under the assumed reduction path. The total emissions budget used in the status quo modelling is:

- 6 billion tonnes of CO_2 for Germany until climate neutrality is achieved,
- 37 billion tonnes of CO_2 for the entire EU to achieve climate neutrality.

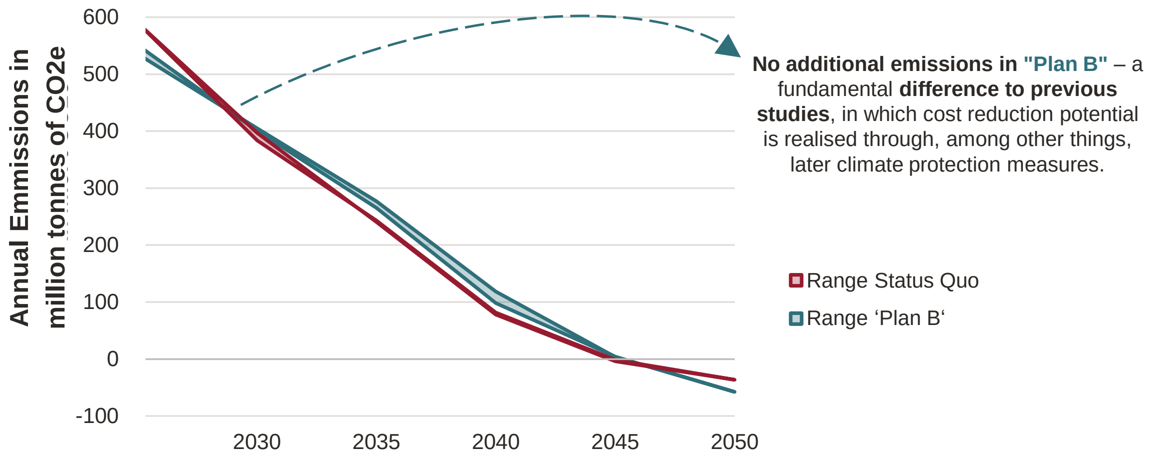
The identical budget approach ensures that the modelled 'Plan B' does not result in more CO_2 being emitted overall than the current targets for Germany and the EU. This guarantees the same level of climate protection as in the energy transition status quo (seeFigure 30). Only the timing of the actual emissions can be determined more freely.

Ultimately, focusing solely on a fixed target year for achieving climate neutrality, e.g. 2045 in Germany, without considering the overall budget, can lead to different total emissions depending on the path taken. For example, if emission reductions – with the same target year for climate neutrality – are implemented very late for cost reasons, overall emissions will be higher.[69]

The budget approach allows emitters a high degree of flexibility in determining the exact timing of investments in emission reductions. This reduces the overall costs of the energy transition, as expected cost developments and the availability of various technologies, as well as upcoming (re)investment cycles, can be better taken into account in investment decisions.

69 This is the case in various studies that analyse the cost reduction potential of achieving climate neutrality targets for Germany and the EU (e.g. Aurora (2025), BCG/IW/BDI (2025)). The costs of decarbonisation are reduced, among other things, by the fact that investments in climate protection are made later, which de facto means an expansion of the emissions budget.

Figure 30 Annual greenhouse gas emissions in Germany



Source: *Frontier Economics.*

Note: *The annual emissions shown include exogenous assumptions on LULUCF and waste management from the BMWK long-term scenarios (Fraunhofer ISI, 2025) . These account for only a small proportion of total emissions (-21 million tonnes of CO2e in 2030; -37 million tonnes of CO2e in 2045) and remain constant across all scenarios calculated. Ranges show scenarios with optimistic and flattened learning curves.*

In the results of an exemplary model run shown inFigure 30, this leads to the emission path initially being lower than in the status quo scenario, but with temporarily higher emission levels in later years (2035-2045). Overall, this allows system costs to be reduced while maintaining the same total emissions (e.g. through a rapid phase-out of coal-fired power generation,[70] the use of more gas in the transition phase and a slightly delayed ramp-up of renewable energies).

The exemplary modelling shows that simply by realigning the energy transition more efficiently in accordance with "leverage 1" and "leverage 2" – with the same total amount of greenhouse gas emissions in Germany – the total system costs of the energy transition can be reduced by at least €530 to €910 billion, or 11% to 17%, by 2050 compared to continuing with the status quo (see right-hand chart inFigure 25 and corresponding explanations).

Lever 3 – Use of international coordination opportunities as an additional lever for cost reduction

In previous models, total emissions were kept constant until climate neutrality was achieved in order to ensure comparability. However, an important additional component of our new approach is a significantly stronger international integration of climate protection efforts – in order to motivate other countries to make greater climate protection efforts and to achieve more global climate protection through skilful international cooperation with the same investment expenditure (see the explanations and excursus in Chapter 4.1).

[70] The use of carbon capture in coal-fired power plants would also be conceivable – however, there are currently only a few commercial coal-fired power plants worldwide that use CCS, and the technology does not yet appear to be sufficiently mature to be included in the modelling.

This international integration may ultimately result in Germany having a larger emissions budget at its disposal than currently planned, due to two mechanisms:

- Use and crediting of international climate protection measures.[71] Even moderate use of more cost-effective emission reduction measures outside Europe can enable more flexible implementation of climate targets – without increasing total global emissions compared to the status quo.
- Use of so-called "holding points" in the reduction path to ensure competitiveness if the international peer group (e.g. G20) does not progress at the same pace in climate protection.

This is another lever for efficiency gains. However, quantifying this poses a challenge, as the magnitude of these effects will only become apparent in the context of international coordination and will also be influenced in particular by the levels of climate protection pursued in other countries.

In order to nevertheless allow an estimate of the magnitude, we model below an example scenario "Plan B + 2-year budget", in which it is assumed that Germany (and the EU) will have an additional emissions budget available through international coordination, corresponding to the average of two additional future annual emissions until climate neutrality is achieved. In the current target path (the energy transition in the status quo), this budget expansion would correspond to a postponement of the achievement of climate neutrality by two years (2047 instead of 2045) for Germany.

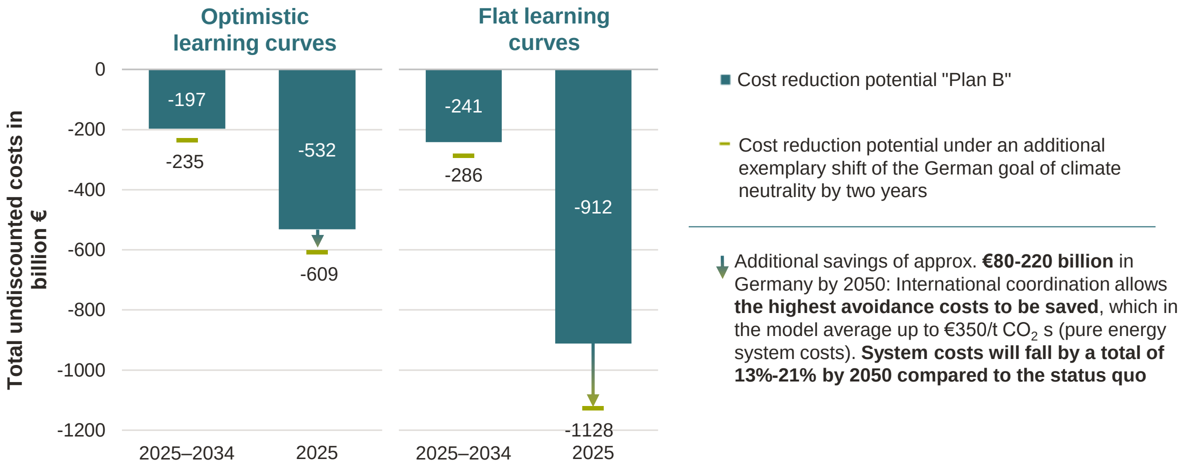
Modelling shows that even an exemplary postponement of Germany's net-zero target by two years could lead to additional cost savings of around €80 to €220 billion by 2050 (seeFigure 31).[72] Assuming optimistic technological learning curves, the total savings potential thus increases from around €530 billion to €610 billion, while with flattened learning curves it rises from around €910 billion to €1,130 billion. These additional savings result from the leverage of international cooperation, which makes it possible to avoid the highest avoidance costs in

[71] From an economic perspective, international certificates can significantly reduce avoidance costs, provided that their costs are lower than those of domestic measures. For example, the abatement costs of nature-based measures such as afforestation or peatland protection are typically €20 to €40/t CO_2, while technical processes such as direct air capture (DAC) are significantly more expensive, costing €300 to €60 € /t CO_2 in the future – and currently even far more than that. In practice, however, international offsets are controversial, particularly with regard to their quality and sustainability. An effective certificate system must therefore meet strict standards.

[72] According to a modelled budget approach, extending the German climate target by two years would correspond to an increase in the national emissions budget of around 10%. The underlying dynamics can be continued: an exemplary extension of six years – corresponding to a budget expansion of around 30% – would result in additional cost savings of around €150–310 billion compared to "Plan B". The average avoidance costs of the measures saved in each case decrease as the budget expansion increases: while measures costing an average of up to €300/t CO_2 are avoided with a two-year extension, this figure is only around €190 /t CO_2 with a seven-year extension. The reason: if the emissions budget is slightly expanded, the most expensive mitigation measure required last is eliminated first – the savings per tonne are high. With each further expansion, increasingly cheaper measures are eliminated. As a result, the average cost savings per "released" tonne systematically decrease.

the German energy system.[73] Taking into account the purely exemplary budget expansion of two annual budgets, system costs can thus be reduced by 13% to 21% by 2050 compared to the energy transition status quo scenario.

Figure 31 Additional cost reduction potential through international coordination



Source: *Frontier Economics.*

Source: *The energy system costs considered here include new investments in generation capacity (CAPEX), ongoing operating costs (OPEX), grid infrastructure costs (CAPEX & OPEX) and energy imports. Necessary demand-side investments in the building, transport and industry sectors are not taken into account.*

4.3 Companies and consumers benefit from lower energy costs in the ‘Plan B’ approach – even if the costs of the energy transition remain high

The macroeconomic savings potential outlined above, which can be leveraged by the ‘Plan B’ concept, would also result in immediate relief for end customers. In this section, we therefore conclude by focusing on the effect of the energy transition on energy prices for end customers and show the potential relief offered by ‘Plan B’.

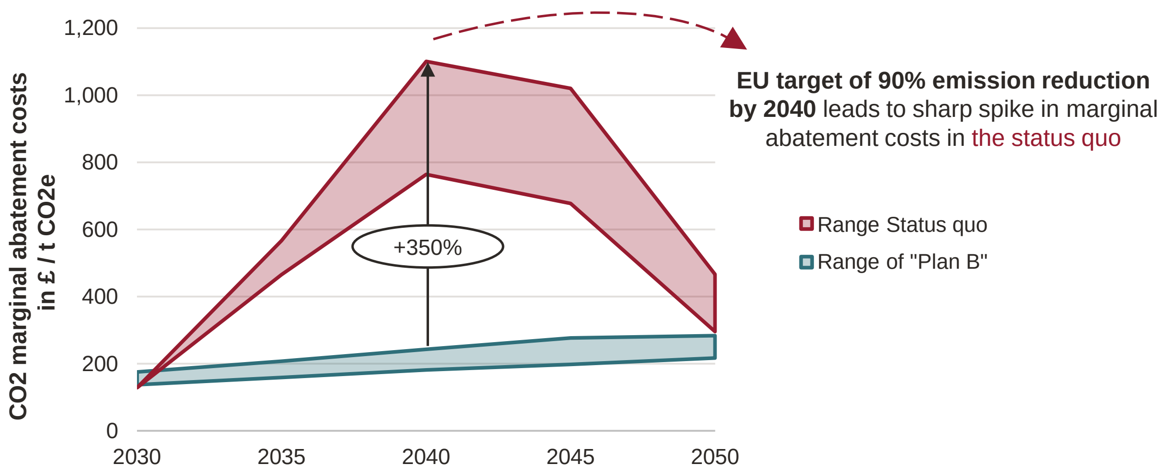
The economic costs of the energy transition under the status quo are reflected in rising electricity and gas prices for businesses and private households. Even today, energy prices in Germany – including procurement costs, grid fees, taxes, levies and surcharges – are at a

[73] With flattened learning curves, the overall system costs are higher, as slower technological progress and cost degression are assumed. Above all, the expansion of renewable energies specified in the status quo becomes more expensive as a result. Deviations from exogenous specifications, such as the two-year postponement of the German climate neutrality target considered here, enable correspondingly higher savings in this case.

peak level in international comparison for the majority of companies that do not benefit from temporary relief. [74]

Costs will continue to rise if the current energy transition plans are continued. A key driver of this development is the massive increase in marginal avoidance costs of CO_2 resulting from the status quo (see Figure 32): For example, in order to achieve the interim target proposed by the European Commission of a 90% reduction in CO_2 emissions by 2040, investments must be made early on in very expensive and currently largely untested avoidance options. For the capture of CO_2 from the air (DAC), for example, cost estimates of up to more than €1,000/tCO_2 exist.[75] Although the assumed exogenous final energy demand will be met entirely by CO_2-neutral alternatives after 2045, this will only lead to a reduction in avoidance costs in the long term.

Figure 32 Marginal abatement costs of CO_2 in Germany



Source: Frontier Economics

Note: The ranges show the cost spectrum of the scenarios with optimistic and flattened learning curves for the status quo, and for 'Plan B' the cost spectrum of the scenarios with optimistic and flattened learning curves, as well as an exemplary budget increase of 10%.

The removal of the strict, annual EU reduction target for 2040 in 'Plan B' (savings through lever 2, see Section 4.1) therefore allows this cost curve to be smoothed. Figure 32 shows that the use of a budget approach in 'Plan B' leads to a significant reduction and stabilisation of avoidance costs over time: with a flexible emissions budget, avoidance costs rise only slightly over time.

The marginal abatement costs of CO_2 shown in the figure are not directly comparable to CO_2 prices – such as those in the EU ETS – but must be interpreted for comparison purposes:

[74] This is illustrated by a comparison of international electricity prices for businesses inFigure 20 .

[75] See, for example, Fraunhofer ISI (2023).

- Firstly, the marginal abatement costs refer to the costs incurred to reduce the last unit of CO_2, which is necessary to achieve the corresponding CO_2 target (in the status quo, annual CO_2 targets; in 'Plan B', an overall emissions target). They therefore reflect the costs across all sectors, while the CO_2 prices of the EU ETS 1 mainly refer to the avoidance costs in the electricity generation and (energy-intensive) industry sectors.

- On the other hand, companies subject to the EU ETS also have the option in the status quo of carrying over allowances from one year to subsequent years ("banking"), whereas this option does not exist for the EU or Germany in achieving the annual targets in the status quo. As a result, even under the status quo, EU ETS prices would follow a smoother curve over time compared to the abatement cost curve, albeit at a significantly higher level than in 'Plan B'. Accordingly, the measures in 'Plan B' also reduce the burden of CO_2 prices on companies and households throughout the entire period.

The marginal abatement costs also have a direct impact on the marginal costs of the respective energy sources. This applies in particular to electricity and methane (gas), whose prices are significantly more stable in 'Plan B'. However, the price level remains high overall.

Figure 33 illustrates the future development of the marginal costs of electricity, hydrogen, and methane (gas) as they result from the model-based comparison of the status quo energy transition and 'Plan B' (bearing in mind the fundamental limitations in the significance of model-based quantifications discussed at the beginning of Chapter 4.2):

- Marginal costs[76] for **electricity**:
  - The **status quo** shows a sharp increase, with a decline only towards the end of the energy transition. In the later years, costs are dampened by a combination of falling emission costs, further declines in technology costs and increasing availability of low-cost import options for renewable energy sources for available electricity generation (e.g. green hydrogen).
  - Although costs also rise over time in **'Plan B'**, they do so at a much more moderate rate and at a lower level than in the status quo, and without a significant interim increase in costs.

- Marginal costs for **methane** (including CO_2 costs):
  - **The status quo** shows an even more significant increase in methane costs than for electricity. The high increase is largely determined by the scarcity of emission allowances and the resulting need for early deployment of emission-free natural gas alternatives. Falling costs in the later years are mainly due to declining demand for

76 Marginal costs are the additional costs incurred in the energy system model that arise from the provision of an additional unit of energy (e.g. an additional MWh of electricity). They differ from system costs, which represent the total amount of investment, maintenance and operating costs incurred. Marginal costs do not allow any direct conclusions to be drawn about system costs. However, system costs can be used as an indication of the development of procurement costs and thus ultimately of energy prices for end consumers.

methane as a result of ongoing electrification and substitution by alternative energy sources.

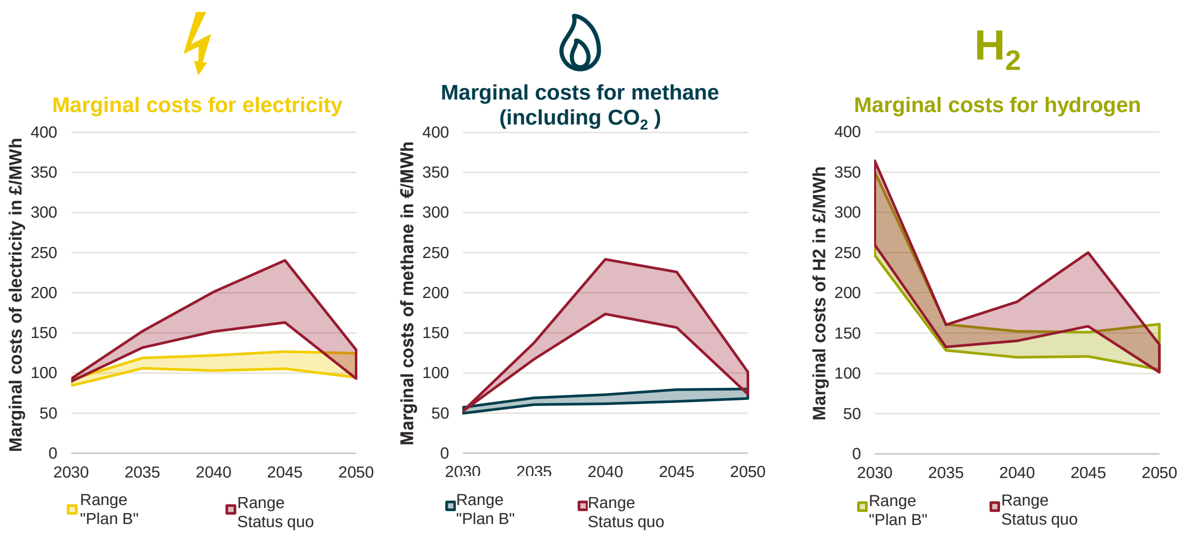
- As with electricity**, Plan B** also shows a significant moderation in the rise in costs for methane – mainly driven by the slower increase in CO_2 costs. As a result, costs will rise much less significantly over the next two decades.

- Marginal costs for **hydrogen:**

  - **The status quo** shows a strong fluctuation in hydrogen costs over time. Costs initially fall as a result of assumed techno-economic learning curves, rapid expansion of renewable energies and associated cost reductions in hydrogen production. However, costs rise again in the longer term. This is linked to rising consumption and rising marginal costs for electricity, which make the use of electrolysis for hydrogen production more expensive. Hydrogen costs then fall again to a level of around €100-130/MWh by 2050, thanks to falling electricity prices and assumed rising (and increasingly cheaper) import potential.

  - **Plan B** initially shows a similar trend. However, after initially high costs due to the hydrogen markets still being in the process of development, there will be significant cost reductions by 2035. From then on, these will remain at a relatively constant level until the end of the period under review: a further decline in technology costs and increasing import potential will be offset by rising demand – not least in the energy sector as a substitute for fossil fuels.

Figure 33 Comparing marginal energy costs in the status quo and 'Plan B'



Source: *Frontier Economics.*

Note: *The ranges show the cost spectrum of the scenarios with optimistic and flattened learning curves for the status quo, and for 'Plan B' the cost spectrum of the scenarios with optimistic and flattened learning curves, as well as an exemplary budget increase of 10%. Marginal costs for electricity in the status quo also include levies for the mandatory expansion of renewable energies.*

The results of the modelling show that 'Plan B' can achieve a significant stabilisation of energy costs throughout the entire transformation phase, thereby providing significant relief for consumers, especially in the next two decades, when a large part of the energy transition will be implemented. Although energy costs for both electricity and methane will rise over time, and hydrogen will also see a temporary end to cost reductions after initial learning curve effects, it is important to emphasise that marginal energy costs are not the same as total system costs or prices. In 'Plan B', overall system costs fall significantly, which is reflected in lower procurement costs for companies and a lower overall economic burden.

This development reflects one of the principles outlined in Chapter 3.2: Germany has a structural disadvantage in terms of natural resources. Even with the efficient implementation of the energy transition, it is therefore unlikely that Germany will have a competitive advantage due to low energy costs. Economic strength should therefore be based on other areas of relative strength, such as technological innovation.

5 The target concept in the new ‘Plan B’ approach could be achieved through targeted adjustments to the current policy framework

So far, we have developed ‘Plan B’ on the basis of the principles as a ‘reimagined’ energy transition. In reality, however, implementation would not take place on a clean drawing board, but would interfere with a mature, complex system of instruments and measures as well as numerous actors who have positioned themselves in reliance on the state and existing instruments.

Below, we show by way of example that this target concept could also be achieved within the current framework through targeted changes. We deliberately remain at a high level of analysis in order to demonstrate the fundamental feasibility of the concept. Detailed policy recommendations or proposals for the design of specific conversion measures are not the subject of this study. This should be left to the political actors to discuss.

Implementation of comprehensive cap-and-trade by expanding the EU ETS to become the central control instrument for achieving climate targets

A central element of the concept for a ‘Plan B’ for the energy transition outlined in the previous chapter is a comprehensive, ‘breathing’ cap-and-trade system. With the EU ETS, a similar instrument – albeit with significantly limited sectoral coverage – has been in place for around 20 years. In addition, EU ETS 2 (and national precursors) envisages such a system for the transport and heating sectors. It therefore makes sense to expand the existing EU ETS system into the proposed central and comprehensive control instrument.

In order to bring the EU ETS more into focus and expand it, an accelerated introduction of ETS 2 (for transport and heating) combined with a medium-term merger with ETS 1 (for electricity generation and industry) could be a sensible step. In the longer term, the system should also be extended to previously unregulated emission sources so that the annual ETS emission budget covers **all sectors** in future.[77]

For newly integrated areas, a transitional free allocation based on product-related benchmarks or a pro-rata allocation is conceivable (in order not to penalise reduction measures that have already been implemented). In the medium term, a standardised allocation of allowances through auctioning should be aimed for. In addition, certificates could be generated through recognised negative emissions.[78] Limited crediting of high-quality international emission

[77] As the EU ETS is a common instrument for all Member States, such a development requires a cooperative decision at European level.

[78] Negative emissions can be generated by various methods for the long-term removal of greenhouse gases from the atmosphere, e.g. reforestation or the use of direct air capture technologies for the capture and subsequent storage of CO_2 from the air.

reductions ("offsets") is also possible, for example based on established standards from earlier instruments such as the Clean Development Mechanism or Joint Implementation.[79]

The administrative implementation of the comprehensive ETS in the market should be straightforward, e.g. by ensuring that individual users of energy sources with GHG content do not have to purchase emission allowances. Instead, the distributors of these energy sources (e.g. (bio)gas suppliers) should make the purchases (similar to the approach taken in EU ETS 2).

An additional element of the ‘Plan B’ concept is the international integration of emission reduction targets. Such a mechanism could, for example, be incorporated into the EU ETS by continuing to follow a reduction path for the annual budget, but introducing "holding points". At these points, checks would be carried out to determine whether the reduction level is within the target corridor compared to the efforts of a peer group (e.g. in line with the example of a reduction equal to that of the G20 countries plus X% explained in Chapter 4.1). Otherwise, the current emission level would be frozen until the peer group has caught up accordingly. This creates a game-theoretical incentive for more climate protection, which could ultimately also increase the political credibility of the target. The latter is particularly important, as a look at current ETS market developments shows: the certificate price in the EU ETS in 2025 was around €70/tCO_2– well below the level that studies[80] consider necessary to achieve the emission target by 2030 (approx. €130/t). Since certificate prices in emissions trading also reflect expectations for the future, the observed price gap suggests that market participants assume that policymakers would intervene if prices rose too quickly – for example, by releasing additional certificates from the market stability reserve.

CBAM and redistribution of ETS revenues as accompanying measures

Full-scale emissions trading also has an impact on the distribution of costs among individual economic actors and on the competitiveness of export-oriented industries in particular. As shown in Chapter 4.3, achieving the current climate targets will also require higher CO_2 border avoidance costs than is reflected in the current EU ETS 1 certificate prices. Even if ‘Plan B’ is implemented on the basis of the current policy framework, undesirable negative competition and distribution effects should therefore be taken into account and offset:

- **Carbon leakage** could initially be offset by existing instruments: through free allocation and the planned CBAM on imported goods. With effective international target anchoring (peer group model), a CBAM could become dispensable in the long term if all relevant competitor countries also pursued ambitious climate protection targets coupled with CO_2 pricing, which would reduce the potential for carbon leakage. The first step would therefore be to monitor whether instruments for imports and exports are necessary to ensure

79 The *Clean Development Mechanism (CDM)* enabled industrialised countries under the Kyoto Protocol to finance emission reduction projects in developing and emerging countries and to have the savings achieved credited to them. *Joint Implementation (JI)* pursued a similar approach, but between industrialised countries, whereby emission reductions achieved through projects in other industrialised countries could be credited towards their own targets. Both instruments are considered precursors to today's international offset standards.

80 See, for example, Kopernikus Project Ariadne (2021).

a global *level playing field*. If necessary, a CBAM would have to be designed in an unbureaucratic and effective manner.

- Any government revenue from emissions trading should be distributed in a targeted manner via a **redistribution mechanism**. Redistribution and reallocation should take place at various levels:
  - **Households**, e.g. via flat-rate **per capita payments** or tax relief.
  - **Companies**, e.g. through targeted tax relief.
  - **Member States**, e.g. to **compensate for differences in relative burdens** (e.g. households in Eastern Europe would be more affected by rising prices for greenhouse gas emissions than households in Western Europe due to their currently more emission-intensive energy supply).

The exact scope and nature of redistribution requires comprehensive analysis and careful calibration.

Comprehensive ETS makes technology-specific subsidies and requirements superfluous

In an expanded ETS, the uniform emission price ensures compliance with the emission budget and creates a market-based incentive for emission avoidance. Climate protection is pursued where it is most cost-effective in economic terms. This makes today's technology- and sector-specific regulations and requirements superfluous and could lead to their abolition:

- The existing technology-specific subsidy framework (e.g. the EEG) could be scaled back in this system. Investment subsidies (CAPEX) or ongoing subsidies (OPEX, CfD) for individual technologies could be eliminated – with the exception of the targeted funding of pilot projects in the context of research and development described at the end of the chapter. In doing so, it must be ensured that the protection of trust and grandfathering for the subsidy measures currently in place is maintained.
- By ensuring compliance with climate targets through comprehensive emissions trading, any technology-specific regulatory requirements that currently have a significant cost-driving effect could also be eliminated without further ado, e.g. for the definition and use of green hydrogen, the energy efficiency of buildings or products, or the design of EU fleet regulations.

Such a radical restriction of instruments to what is really necessary would also significantly reduce implementation and bureaucratic costs for both businesses and the state.

The government has a role to play in providing insurance solutions to cover investment risks in the context of the energy transition.

As outlined in Chapter 4.1 , a large proportion of today's technology-specific support programmes (e.g. the EEG) not only serve to provide subsidies, but also play an important role in risk diversification, e.g. by reducing price volatility risks associated with investments.

As explained above, if the EU ETS were designed accordingly, the need for subsidies would largely disappear. If price volatility risk then still hinders investments, it could make sense to have instruments specifically for risk hedging. Subsidies and requirements would therefore be replaced by state-coordinated insurance solutions that do not include any subsidies in their expected value, but specifically hedge risks that are difficult or impossible to insure in the private sector. At the same time, the state's role can reduce costs – for example, through lower financing costs for hedged credit risks. (Semi-)governmental institutions such as KfW can make a particular contribution to implementation. Different approaches are conceivable depending on the risk category:

- **Price risks**: Price hedging instruments can be offered to hedge volatile prices for new energy sources and commodities such as CO_2, hydrogen or e-fuels. These instruments would only hedge the price level expected on the market and thus the volatility risk – but would not guarantee a price level set in advance. Financial instruments already in use today (e.g. oil swaps in the aviation sector) would be used for this purpose.

- **Technical risks**: New technologies are often associated with increased technical failure risks or unexpected cost increases during the development phase, which private insurers cover only to a limited extent or at very high premiums. KfW is already demonstrating how such a model can work in practice: in its offshore wind energy programme, it provides investors with a cost overrun framework in the form of a direct loan to , which cushions unexpected risks during the construction phase. Similar mechanisms could potentially be transferred to other energy sources.[81]

- **Credit default risks**: For climate protection projects with long payback periods, the government can hedge credit default risks through guarantees or sureties. The so-called Hermes cover, in which the federal government assumes export credit guarantees for international business risks, can serve as a proven model.[82] A similar model could be applied to climate protection-related domestic investments.

The state retains its role in coordinating network infrastructure and security of supply

There is a fundamental mandate for government intervention in the coordination of public goods such as ensuring security of supply or network infrastructure. However, in line with the new 'Plan B' approach, the processes surrounding these tasks should be streamlined and

81 See Federal Ministry for Economic Affairs and Energy (BMWE) (2025).

82 See Federal Ministry of Finance (BMF) (2024).

organised in a way that is as technology-neutral and competitive as possible. We summarise some initial thoughts on this below:

- **Cross-energy source network planning** is a sensible basis for transforming the energy system as efficiently as possible. Electricity, methane, hydrogen and other infrastructures, such as those for CO_2, would be systematically interlinked and expanded in a coordinated manner at European level – this could be achieved, for example, by expanding the integrated network planning for electricity, gas and hydrogen already envisaged by the EU Commission.[83]

- In order to reflect the investment costs of infrastructure expansion in a more cause-related manner, the **grid fee system** could be adjusted by increasing the share of the capacity price.

- **Approval processes** for infrastructure expansion should be streamlined and accelerated. Pragmatic guidelines are needed to accelerate priority projects (such as the rollout of smart meters or grid expansion projects that benefit the system), e.g. in the form of preferential approvals for grid connections for feeders that benefit the grid or system (e.g. large batteries), shorter deadlines, reduced participation requirements and uniform procedural standards.

- For new infrastructure – such as in the field of hydrogen or CCS – **strict vertical unbundling** could be waived during the market ramp-up phase in order to strengthen investment incentives and facilitate coordination. The focus in this phase is on rapid infrastructure development. Ex-post abuse supervision may be necessary to avoid market distortions. In addition, temporary regional concessions could be granted to increase investment security and streamline planning processes.

- To ensure that all defossilisation options for implementing 'Plan B' are available quickly, **a legal basis for CCUS and new energy sources** must be **created** rapidly to secure investments and advance approval procedures.

- To **offset the temporal effects of ramping up** new infrastructure, especially CO_2 networks, which must be dimensioned for long-term expected demand but only meet relatively low demand in the short term, a **temporal compensation mechanism** could be used – for example, in the form of an amortisation account, analogous to the hydrogen core network. This would allow revenues and costs to be decoupled and financing to be secured despite initially low utilisation.

- The state also continues to play a role in **ensuring security of supply** – for example, by monitoring guaranteed capacity in the electricity market or by ensuring sufficient reserves

83 See European Commission (2025).

for predominantly imported energy sources. Careful consideration is needed as to how explicitly the state should contribute to ensuring security of supply.

Strengthening the framework conditions for an innovation-friendly location

Not least because of the need for technical solutions for climate protection, as stated in the principles, and the fundamental disadvantages Germany has in terms of natural resources, innovation and the future (further) development of technologies are key to a successful energy transition. Accordingly, it is a central task of the state to create sensible and clear framework conditions for a competitive and innovation-friendly location.

First of all, a technology-neutral legal framework at both EU and federal level is a basic prerequisite for ensuring that all available defossilisation options can be utilised. However, the existing regulatory framework contains numerous technological restrictions that hinder innovation and potentially limit or even exclude economically viable options, e.g. the restrictions on the supply of synthetic fuels in the Federal Immission Control Ordinance (BImSchV) or the restriction of CCS to emissions that are difficult to avoid. Such regulations should be replaced by risk-based, technology-neutral standards in order to avoid distortions of competition.

Research and innovation form the basis for the development of new technologies. Broad government investment in basic research is needed. Targeted start-up funding for pilot projects is useful for transferring technologies from research to application. In the subsequent phase of industrial testing, operating costs (OPEX) can also be subsidised on a temporary basis, provided that the knowledge gained in the process is made publicly available. The government should establish clear eligibility criteria. The key criterion should be whether a technology has the potential to contribute to defossilisation or long-term emission reduction. In order to implement the energy transition in practice, it is necessary to build up a broad base of skilled workers and mobilise the labour potential.[84]

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84 A recent DIHK analysis (DIHK and Prognos, 2024) paints a clear picture:

- By 2030, around 550,000 additional skilled workers will be needed – in the key sectors of photovoltaics, wind energy and hydrogen alone, in addition to the approximately 200,000 employees currently working in these sectors.
- Around 250 different job profiles – from skilled workers and industrial foremen to engineers – are indispensable along the entire value chain.
- A particular risk factor is that bottlenecks are no longer limited to directly "green" professions: the shortage of lorry drivers, logisticians and planners could significantly delay the transformation.

6 Conclusion: ‘Plan B’ presents a true alternative course in energy transition policy towards more innovation, growth, and global climate protection.

This study shows that the energy transition strategy pursued to date will foreseeably lead to an economic impasse. With cumulative energy system costs of around €4.8 to €5.4 trillion by 2050, the current path appears not only unnecessarily expensive, but also structurally inefficient. The causes are manifold and lie in difficult-to-achieve, fragmented objectives, technological micromanagement with a one-sided focus on individual technologies and energy sources, and a multitude of regulatory interventions that hinder market mechanisms and innovation.

This strategy is already leading to a further increase in costs for businesses and households, which is likely to continue in the foreseeable future, posing a long-term threat to Germany's international competitiveness. Against this backdrop, there is a need for a fundamental change of course – new paths for the energy transition.

The concept of a ‘Plan B’ focuses on a fundamental streamlining of regulation and the establishment of genuine technological competition as a key driver of innovation and growth. Instead of a rigid target, climate protection is controlled via a uniform cap-and-trade system for all greenhouse gas emissions. This approach is complemented by increased international coordination of climate protection efforts in order to avoid structural disadvantages caused by national solo efforts and to strengthen incentives for globally coordinated action.

Successful climate protection is not characterised by adherence to rigid target years, but by the sensible use of the remaining CO_2 emissions budget in an economy until climate neutrality is achieved. This is precisely where the concept comes in, enabling the energy transition to be achieved at a lower overall cost to the economy, businesses and consumers, while maintaining the same level of ambition in climate protection.

An exemplary model, which assumes similar conditions to those in the current plans in the "energy transition status quo", already identifies significant cost savings in the energy system of €530 to €910 billion by 2050 for the implementation of the ‘Plan B’ concept. This corresponds to a reduction of around 11% to 17% of the estimated total costs of the energy transition. These savings result in particular from a more efficient technology mix and the use of all available avoidance technologies and low-emission energy sources such as biomass or CCUS. In the future, new technologies could also enable further savings, provided that they are available in a cost-effective manner in the long term – e.g. hydrogen production via pyrolysis, deep geothermal energy, monodirectional heat batteries, or small modular nuclear reactors.

Additional savings potential exists through greater global integration of climate protection efforts. If, purely as an example, this were to increase Germany's total emissions budget by a volume corresponding to a two-year postponement of the net-zero target, this would save a further €80-220 billion:[85] On the one hand, through the crediting of more cost-effective climate protection measures abroad while maintaining the same climate targets, and on the other hand, through flexible adjustment of the pace of transformation to the development of international peer groups. In this way, Germany's competitiveness can be largely maintained even within the framework of ambitious climate targets.

Furthermore, the concept is more robust in the face of future uncertainties, e.g. regarding technological change, costs, economic growth, and energy demand. Regardless of the exact development paths assumed, the advantages of a technology-neutral, competitively based and globally integrated system lead to consistently lower overall costs than continuing with the current energy and climate policy status quo.

Last but not least, it should be emphasised that the savings potential identified in this study is a conservative estimate. Further reductions in total costs have not yet been taken into account – for example, through the more efficient use of cost-effective avoidance options in the end-use sectors of industry, buildings and transport, as well as due to the greatly reduced bureaucratic burden on the state and businesses. The concept thus offers not only a more economically viable alternative to the current energy transition policy, but also one that is easier to implement.

Despite the potential savings identified compared to the status quo, it should nevertheless be noted that the energy transition will continue to involve considerable costs, even if the ‘Plan B’ concept is pursued. Climate protection and the restructuring of the energy system represent one of the greatest economic transformation tasks of the coming decades. This makes it all the more important to make the transformation as efficient and economically viable as possible, because successful climate protection can only be achieved with a strong economy. The energy transition challenges even the capacities of an economically powerful country like Germany, which makes it all the more necessary to mobilise all available resources in the economy, including new approaches to the energy transition.

85 Calculated in the model using an example of an expansion of the national (and EU-wide) emissions budget by around 10%, which corresponds to a two-year extension of the German climate target.

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