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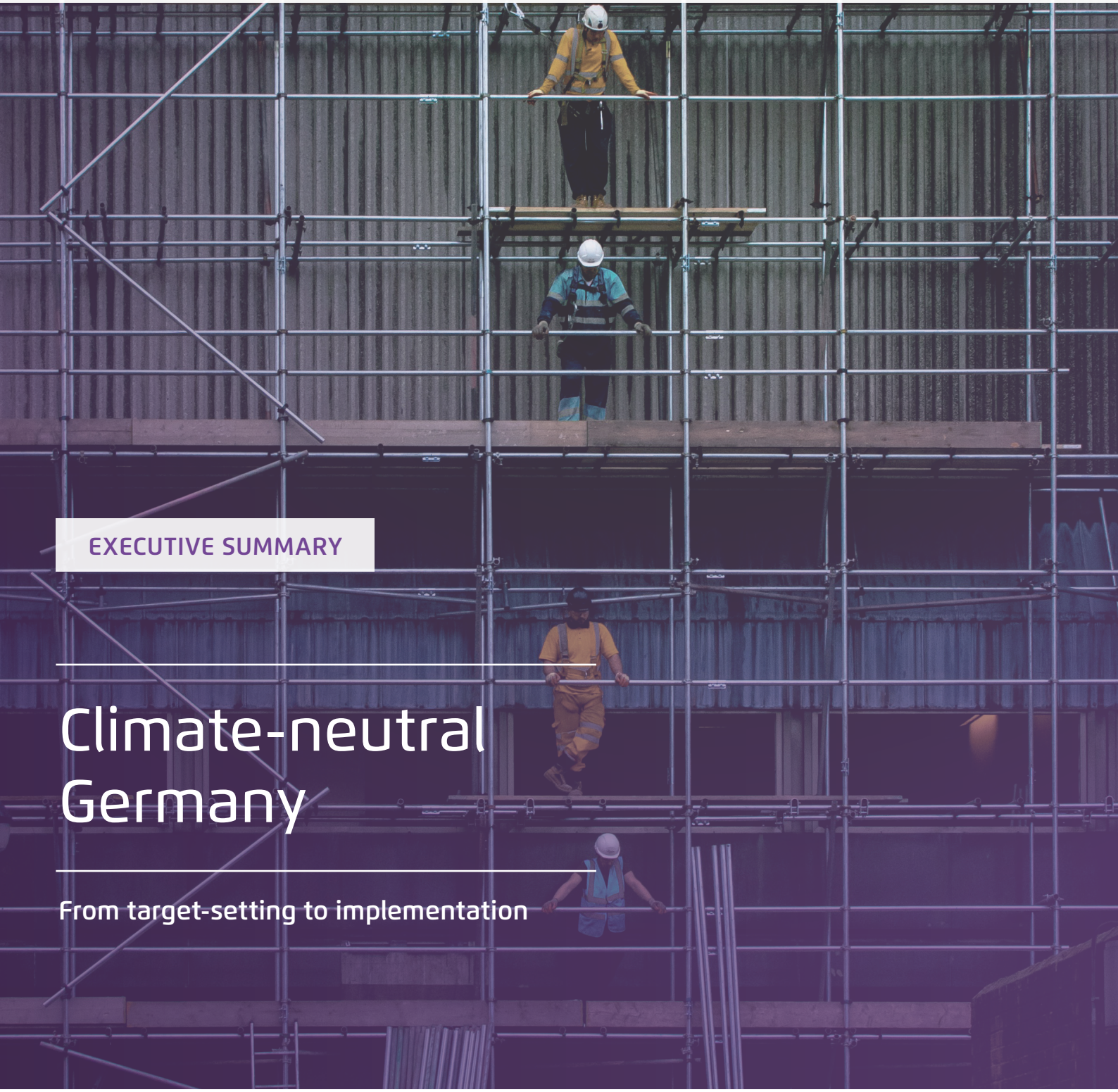

EXECUTIVE SUMMARY

Climate-neutral Germany

From target-setting to implementation

prognos

Wuppertal Institut

Öko-Institut e.V.
Institut für angewandte Ökologie
Institute for Applied Ecology

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Executive Summary
Climate-neutral Germany.
From target-setting to implementation.

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Prognos was responsible for the scenario design, overall management of the project and the calculation of investment requirements. Prognos was also responsible for the analysis of the buildings and energy sectors and parts of the non-energy-intensive industrial sector. Öko-Institut focused on transport, agriculture, waste and land use, land-use change and forestry (LULUCF). The Wuppertal Institute worked together with the University of Kassel on the industry sector.

Agora Think Tanks was responsible for the concrete design of the policy instruments and the calculation of the public financial requirements.

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Preface

Dear reader,

Germany has set out on the path to climate neutrality. Despite significant progress, such as the expansion of renewable energy, the current debate remains focused primarily on the challenges. It's true that the transition in transport and mobility and the climate-neutral modernisation of buildings are bringing about changes in citizens' daily lives. Meanwhile, a growing segment of the economy is facing significant structural challenges.

In updating our "climate-neutral Germany" scenario, we take these challenges into account and provide possible solutions. Our analysis demonstrates how a bold strategy can set the course for climate-neutral investments. It identifies key elements for socially equitable design and formulates a balanced policy mix to achieve this goal.

This pathway will certainly not unfold exactly the way we describe. However, the study presents a cohesive vision of the future and can thus form the basis for the solution-oriented discussions we need.

We hope you find it insightful.

Simon Müller
Director Germany, Agora Energiewende

Key findings at a glance

1 **The path to a climate-neutral Germany requires planning and investment certainty.** Climate policy is having an impact – emissions in the energy sector have fallen by around 40 percent since 2014. However, the transition in the transport sector, the climate-neutral modernisation of buildings and the necessary changes in the industry sector still pose challenges. To overcome these challenges effectively, reliable climate and economic policy frameworks are crucial.

2 **Climate investments boost innovation and improve structural competitiveness.** Three quarters of the investments in energy and transport infrastructure, industrial facilities and buildings required by 2045 are necessary regardless of the transition. Redirecting financial flows towards climate-neutral solutions through price incentives and market regulation is therefore crucial. Additional investments specifically for climate action account for about three percent of GDP, many of which are economically viable – renewables and electricity grids, for example, are 90 percent financed by market revenues and fees.

3 **Achieving climate-friendly housing and mobility for everyone requires extensive infrastructure expansion, targeted investment support and measures to correct social imbalances.** The scenario includes more targeted support for building retrofits, purchase incentives for electric vehicles that focus on small and used cars and the expansion of public transport infrastructure. These longer-term measures are bolstered by a temporary support mechanism, with ten billion euros per year from carbon pricing revenues allocated for compensation payments.

4 **A balanced policy mix ensures successful implementation.** Relying solely on carbon pricing, market regulation, subsidies or infrastructure expansion has its disadvantages. By contrast, a combined approach allows for cost efficiency, planning certainty and social equity. Regardless of the exact composition of the policy mix, the path to climate neutrality requires a collective societal effort – and paves the way for a future worth living for everyone.

Executive summary

Germany moves from setting climate targets to implementation

In spring 2021, the study "Climate-neutral Germany 2045" (Klimaneutrales Deutschland 2045) showed for the first time how Germany can achieve climate neutrality by 2045 and remain competitive at the same time. As a result, the grand coalition of the Christian Democratic Union (CDU), Christian Social Union of Bavaria (CSU) and the Social Democratic Party (SPD) enshrined this target alongside a 2030 target of reducing emissions by 65 percent (compared to 1990 levels) in the Federal Climate Protection Act (*Bundes-Klimaschutzgesetz*, or KSG). Now, Germany has moved from the target-setting phase to the implementation phase.

However, this implementation phase brings with it new challenges. How can Germany's industrial base become climate neutral while strengthening its competitiveness? What does it take to make sustainable mobility and the climate-neutral modernisation of buildings affordable and practical for everyone? And how can we fully leverage the potential of agriculture and forestry for climate protection, biodiversity and healthy nutrition?

To address these questions, "Climate-neutral Germany: From target-setting to implementation" (Klimaneutrales Deutschland – Von der Zielsetzung zur Umsetzung) outlines a pathway to climate neutrality from three central perspectives. First, the scenario modelling shows a coherent and optimised roadmap to climate neutrality across all sectors. Second, detailed calculations estimate the necessary private and public investments for the transition, and by extension the funding requirements. Third, the scenario proposes a comprehensive package of balanced policy measures that would enable these investments while ensuring social equity and broad participation.

Key results of the climate-neutral Germany scenario along five overarching goals

The key results of the scenario can be summarised along five central objectives as follows:

Affordable and reliable energy supply

In the climate-neutral Germany scenario, by 2045, renewable energy sources expand to 180 gigawatts (GW) of onshore wind, 73 GW of offshore wind and 470 GW of PV, making it the most cost-effective form of generation while also exploiting potential savings in grid expansion. Electricity demand increases from 553 terawatt hours (TWh) in 2023 to 1 280 TWh by 2045. However, incentives for electrification ensure that supply and demand develop synchronously and that the electricity system costs per kilowatt hour (kwh) remains largely constant at 16 cents until 2030 and then falls to less than 13 cents by 2045. Accelerated digitalisation combined with price-based incentives to make electricity demand more flexible alongside storage systems ensure a reliable and cost-efficient energy supply. Overall, energy import dependency decreases by approximately 85 percent by 2045.

Stimulating an innovative and competitive economy

Investments in climate-neutral processes and products stimulate economic recovery, supported by a mix of price-based incentives and funding as well as instruments to improve planning security. The use of industrial heat pumps in combination with waste heat leads to a significant increase in efficiency and thus enable a competitive heat supply for industry. Natural gas consumption falls to almost zero by 2040

to 2045, while electricity consumption doubles compared with 2025 to more than 400 TWh. New value chains are created, for example by replacing previously imported fossil raw materials in the chemicals industry with sustainable, domestically grown biomass. By 2045, net negative emissions of 19 million tonnes of carbon dioxide (CO_2) are sequestered in the industrial sector.

Inclusive social participation in housing

The scenario shows that the climate-neutral modernisation of buildings strengthens resilience to heat waves and simultaneously results in an increase in the value of the building stock. In the heating supply sector, the number of new buildings connected to district heating increases from 40 000 at present to 90 000 in 2030. From 2028, between 600 000 and 650 000 new heat pumps are installed every year, primarily in existing buildings. This is roughly equivalent to today's sales of gas boilers. A targeted and more demand-oriented funding framework ensures that homeowners and tenants are protected from excessive cost increases. Heat pumps and CO_2-free heating networks form the backbone of the heating supply – exceptions prove the rule. Demand-driven and affordable housing solutions are increasingly created in existing buildings.

Clean and accessible mobility for all

Expanded public transport in the scenario enhances mobility options and thus the attractiveness of rural areas to live in. Targeted subsidies help people on low incomes to purchase efficient electric cars, with mobility allowances providing short-term relief. Reduced pollution and noise levels, increased exercise associated with cycling and walking, and reduced soil surface sealing have a positive effect on health and quality of life. By 2045, final energy demand from transportation drops to approximately 280 TWh, less than half of the final energy demand in 2023.

Productive and resilient agriculture and forestry

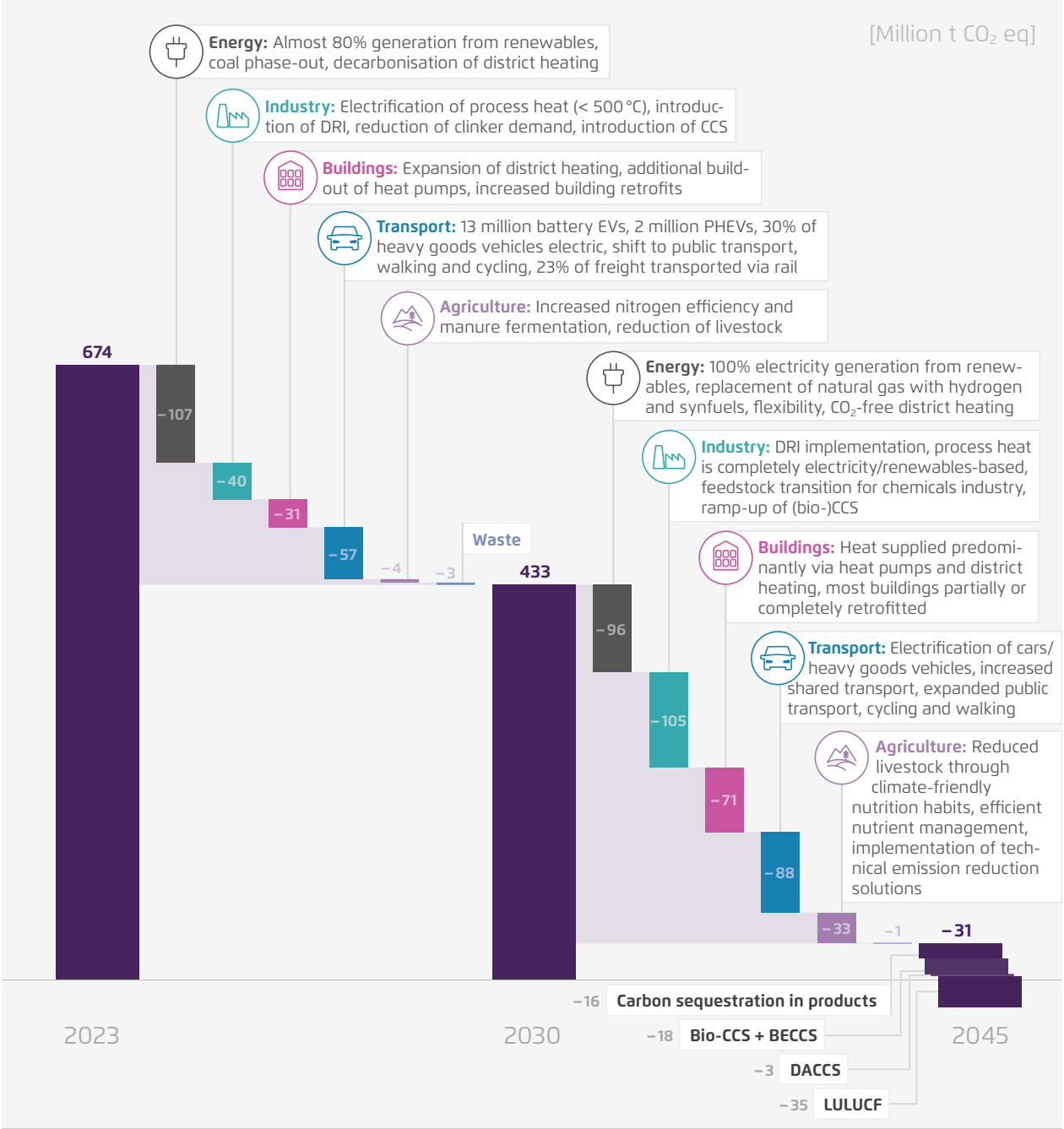
Greenhouse gas emissions from agriculture and peatlands used for agriculture falls substantially, while carbon storage on agricultural land and the carbon sink capacity of forests is stabilised. This is feasible if sustainability becomes economically advantageous for farmers through changes in the policy framework. Fair food environments that support easy, sustainable and healthy choices for consumers are also prioritised.

Biomass, hydrogen and carbon capture and storage (CCS)

In the scenario, biomass, hydrogen and CCS technologies have clearly prioritised, pivotal roles in achieving climate neutrality.

- By increasing the use of residual and waste materials, **biomass** is made available more sustainably than it is today, with supply increasing slightly from 286 TWh in 2020 to 301 TWh by 2045. Use of biomass as a raw material, especially as a sustainable source of carbon for plastics production in industry is significantly more important at 74 TWh in 2045. The use of biogenic gas for energy decreases from 87 TWh in 2020 to 41 TWh in 2045, while the use of solid biomass for energy increases from 201 to 245 TWh.
- For cost and efficiency reasons, **hydrogen** is primarily used as a seasonal energy storage medium in the electricity sector and in certain industrial processes in the steel and chemicals industries. The demand for hydrogen increases to just under 270 TWh by 2045 and is covered mainly by imports. In addition, 155 TWh of liquid hydrogen-based fuels (power-to-liquid) is used primarily in aviation and to a much lesser extent in the energy industry.
- CCS used at the few **fossil point sources that remain unabated in the industrial and waste sectors**. In the scenario, CCS is used at fossil point sources that remain unabated in the industrial and waste sectors. These include process emissions, particularly

Measures in the climate-neutral Germany 2024 scenario → Fig. A



Agora Energiewende, Prognos, Wuppertal Institute, Öko-Institut and University of Kassel (2024). EV = electric vehicle; CO_2 = carbon dioxide, CCS = carbon capture and storage; DACCS = direct air carbon capture and storage; DRI = direct reduction of iron ore (in steel production) through hydrogen and natural gas; LULUCF = land use, land use change and forestry; PHEV = plugin hybrid electric vehicle

in cement and lime production, the non-biogenic share of waste incineration and CO_2 generated during the chemical recycling of plastic waste. **CCS is also used in combination with biogenic CO_2** to offset residual emissions, particularly from agriculture. In addition, a small amount of CO_2 is captured directly from the ambient air. The total amount of CO_2 stored in 2045 is 45 million tonnes.

Resilient transition pathways

Recent years have made it clear that supply-chain problems and unexpected hurdles in implementation can delay the transition to climate neutrality. To account for these, resilient pathways are part of the climate-neutral Germany scenario. The scenario contains various sensitivities, including expanded CCS applications for industrial plants located in proximity to a CO_2 transport network, increased imports of intermediate products in industry, reduced building retrofits, and forest carbon sink vulnerabilities due to extreme weather such as storms or droughts.

In the scenario, the emission targets set by the Climate Protection Act for 2021 to 2030 have been met, with greenhouse gas emissions dropping by more than 65 percent by 2030 compared to 1990. Germany achieves negative emissions of 30.7 million tonnes CO_2eq by 2045, with most emission reductions in the energy and industrial sectors completed by 2040, driven by developments in the European Union Emissions Trading System (ETS 1). By 2040, both sectors are almost completely climate neutral.

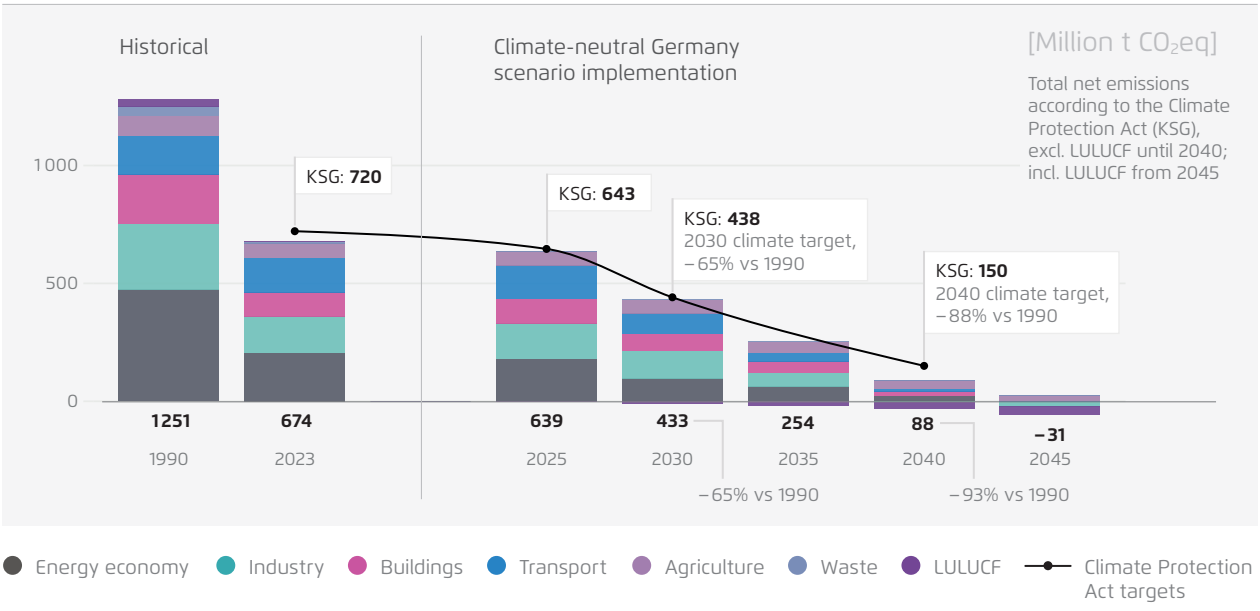
Three quarters of the investments in Germany up to 2045 would be required even without the transition to climate neutrality. All additional climate-specific investments from 2025 to 2045 amount to approximately 3 percent of gross domestic product (GDP).

Total investments during this period are projected to average EUR 540 billion (2023 values) per year – this corresponds to around 11 percent of Germany's economic product (GDP) in this period (Figure C). After an initial period of high investment, the overall need for investment is expected to decline significantly from 2030.

Total investments can be divided into **two categories**:

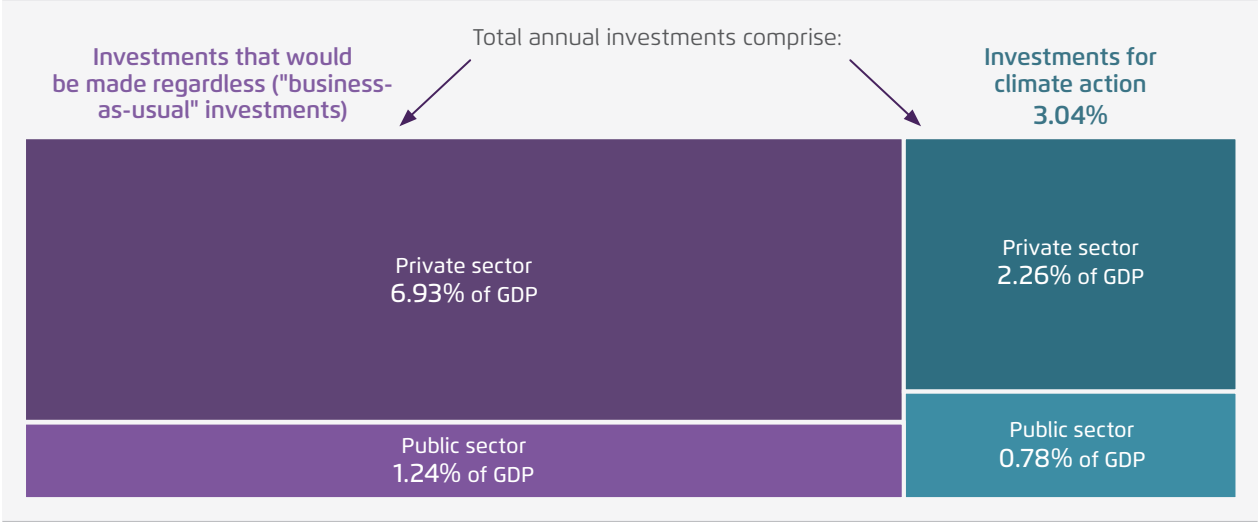
→ **Investments that would be made regardless of climate-neutrality objectives ("business-as-usual" investments): Around three quarters of the total would occur even without the transition to climate neutrality.** In other words, this would be a redirection of investments from fossil-based technologies to climate-neutral alternatives. This would total an

Greenhouse gas emission reduction pathways by sector, until 2045 → Fig. B



Agora Energiewende, Prognos, Wuppertal Institut, Öko-Institut and University of Kassel (2024), historical data: Umweltbundesamt (2024).
KSG = *Klimaschutzgesetz* (German Climate Protection Act).

The average annual investment volume is 11.2 percent of the gross domestic product (GDP) → Fig. C



Agora Energiewende, Prognos, Öko-Institut, Wuppertal Institut and University of Kassel (2024)

average of EUR 394 billion per year or 8.1 percent of GDP from 2025 to 2045 across all sectors. Private investments account for 85 percent of this, while public investments account for the remaining 15 percent.

→ **Investments for climate action: Only a quarter of total investments consist of targeted investments for climate action.** These are additional investments required for climate-neutral technologies as alternatives to fossil-based technologies. However, these investments do not always translate to higher lifecycle costs. For example, despite a higher initial purchase price, many electric cars are already more economical than gasoline and diesel vehicles due to lower operating costs over their entire lifecycle. From 2025 to 2045, targeted climate investments across all sectors are set to average EUR 147 billion per year, or about 3 percent of GDP. Private investments contribute 74 percent, with public investments covering the remaining 26 percent. In the scenario, around 90 percent of investments in renewable energy and grid infrastructure are financed by market revenues and fees.

Public funding helps bridge economic efficiency gaps and mitigate excessive cost burdens on citizens and companies.

While the majority of investments by companies and citizens is self-financing, the amount of investment required indicates that funds from the state budget will be needed to bridge cost gaps or ease the cost burden on households and companies. Until 2030, the annual requirement for public funding is expected to

→ Public funding requirements: From the state budget

Subsidies for investment and operating costs
→ Objective: Enable investments and close profitability gaps

Compensation payments for citizens and companies
→ Objective: Avoid excessive cost burdens

average EUR 58 billion. In contrast to other sectors, the largest cost in the energy sector results from existing renewable energy power generation plants, which will incur a total cost of EUR 95 billion by 2045. All new renewable energy plants that are added from 2025 onwards will require only EUR 45 billion by 2045 – even as electricity production increases fivefold.

A mix of policy tools can ensure these investments are made efficiently and equitably.

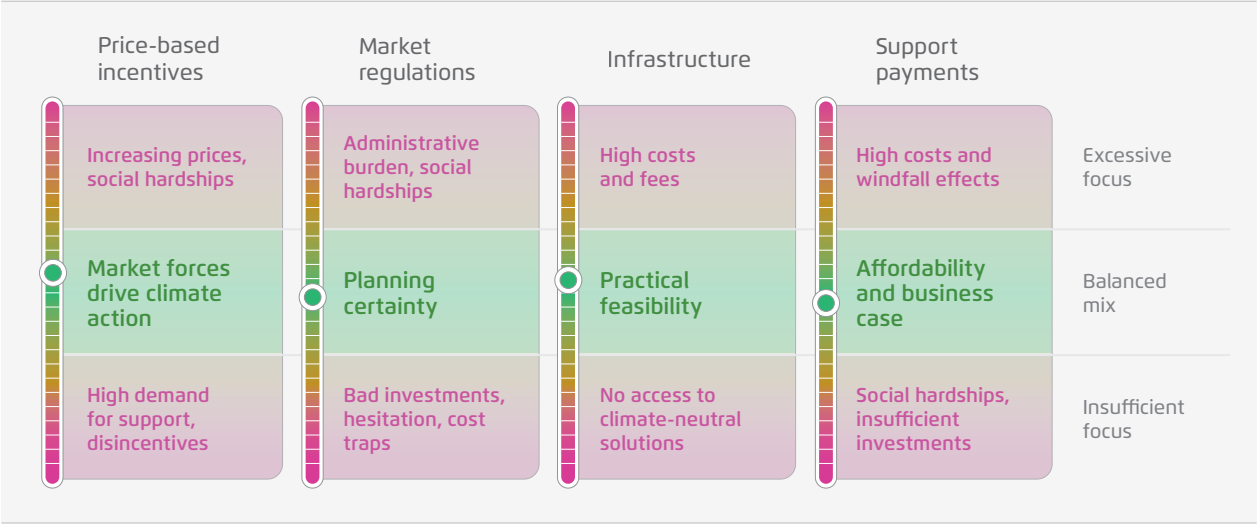
Four main policy instruments are available to facilitate the necessary change. Each of these make an important contribution, but also have their disadvantages:

→ **Price-based incentives:** Carbon pricing makes the use of fossil fuels more expensive, making climate-friendly technologies more competitive. However, upfront investment costs for climate-neutral alternatives remain unchanged. Putting a cost on emissions increases energy prices for both industry and consumers, potentially straining those with limited financial or infrastructural options to switch to climate-neutral technologies.

→ **Market regulation:** Restricting access to fossil technologies and regulating the distribution of costs can create investment security. Although such measures create demand for climate-friendly technologies, they do not guarantee affordability. For this reason, these measures should primarily be used where the cost gap between fossil-based and climate-neutral solutions is minimal or non-existent, but where there are other barriers to investment. Where cost gaps are larger – for example in the buildings sector – it is essential to combine them with financial support measures. Excessive regulation can complicate legislation and may stifle innovation if it becomes too detailed.

→ **Funding:** Financial incentives, such as grants or loans, can lower the initial investment barriers to climate-friendly technologies. These instruments are particularly useful when technologies are cost-effective over their lifecycle, but high upfront costs remain a hurdle. Targeted financial support can reduce additional costs and offset burdens for households and companies. However, excessive focus on state support can strain state coffers, while untargeted subsidies risk benefiting consumers who would have made these investments

A balanced policy mix is the key to climate neutrality → Fig. D



Agora Energiewende (2024)

without assistance, driving up costs for the state and inhibiting a cost-efficient transition to climate neutrality.

→ **Infrastructure development:** Well-developed energy and transport infrastructure is essential for widespread adoption of climate-friendly technologies. Clear rules and strategic planning can ensure smooth and efficient development and make capital access easier for companies, facilitating their investments in climate-neutral technologies. However, overemphasis on infrastructure can result in additional economic costs and, depending on the financing model, higher state expenses of increased user fees.

A balanced combination of these elements reduces these drawbacks and maximises their strengths: market regulation offers planning security, price-based incentives activate market forces for climate action, and financial support ensures social equity.

The climate-neutral Germany scenario developed in this study draws on this balanced approach, outlining each sector's central policy levers and their impact and interaction.

This future vision may not play out exactly as described. However, it provides an illustrative view forward of the transition to a climate-neutral Germany and thus provides a cohesive basis for discussing how to get there. The core elements of the scenario reinforce the roadmap already outlined in our 2021 study[1]. Regardless of where the political emphasis will be placed on the specific design of this transition pathway, one thing is clear: realising a socially equitable and prosperous climate-neutral Germany will require societal commitment, rapid technological advancements and ambitious policies.

1 Agora Energiewende and Agora Verkehrswende (2021): Climate-neutral Germany 2045.

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Publication details

About Agora Think Tanks
Agora Energiewende, Agora Industry, Agora Agriculture and Agora Verkehrswende develop scientifically sound and politically feasible strategies for a successful transformation to climate neutrality – in Germany, Europe and internationally. The organisations which are part of the Agora Think Tanks work independently of economic and partisan interests.

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