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The economic benefits of climate action

How decarbonization can enhance competitiveness and growth

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Executive summary

Climate action is no longer a distant matter, it has become an increasingly important imperative for economies and businesses worldwide. The consequences of climate inaction are already evident, with climate-related disasters causing trillions of dollars in economic damage over the past decades. Over the past five years only, climate-related damages sum up to more than $ 1 trillion, not even counting indirect effects such as longer-term health consequences and natural resource depletion. The social cost of carbon in the latter half of the century would exceed $ 1,000 per ton of carbon dioxide emissions—far more than any carbon price applied in the foreseeable future. Damages often materialize through disrupted supply chains, damaged infrastructure, or productivity losses. Mitigating these threats opens up scope for economic activity. At the same time, geopolitical tensions and resource dependencies have intensified systemic risks, further underscoring the urgent need for a transition to a resilient, low-carbon economy.

This study presents a comprehensive economic case for climate action with a particular focus on how decarbonization can enhance competitiveness and growth. It describes chances for companies both supplying and employing green technologies—especially at a time when many traditional industries are facing disruption, declining demand, and shifting consumer preferences. The study argues that competitiveness can be strengthened by offering innovative products in growing markets, as well as through cost reductions—whether by increasing resilience, improving efficiency, or securing better financing options. Moreover, it examines the main obstacles for climate action during the transition phase and describes policy measures that are needed to enable a successful transformation.

Growing green markets are coming within reach. Despite the withdrawal of the US from the Paris Climate Agreement, countries responsible for more than three-quarters of global economic output have now committed to achieving greenhouse gas neutrality goals. For businesses, this translates into significant opportunities to access rapidly growing markets through manufacturing, exporting, or innovating sustainable solutions. Technology is pivotal to linking climate action to business opportunities. The global market for green technologies has already been growing rapidly in the past. Both the demand for green technologies and capital inflows into the sector have recently increased at a dynamic pace, averaging around 7,3% and 9,6% per year, respectively. If these observed trends continue, the overall market volume could double in less than ten years. Looking further ahead, growth prospects for the green tech sector also remain strong: With the continued pursuit of ambitious climate policy plans, the global market for green technologies could triple or even quadruple by the middle of the century. However, political decisions will be crucial in shaping this growth potential.

Firms moving towards sustainable business models can gain competitive advantages in three fields.

- **Enhanced resilience.** Climate action can shield businesses from risks related to volatile prices for fossil fuels or carbon, as well as from tightening regulatory requirements. As the world is heading towards a net-zero economy in order to evade detrimental climate change, the demand for emission intensive products will come to an end—it is just a question of when. Carbon pricing schemes have expanded with respect to coverage and price levels—raising over $ 100 billion around the globe in 2024. In the European ETS, the allocation of certificates is scheduled to stop around 2040, leading to a sharp increase in allowance scarcity and an unpredictable surge in carbon prices.

- **Efficiency gains.** For many businesses, reducing energy costs is one of the main drivers for climate-related investments. Putting more focus on measuring and optimizing energy use and carbon emissions helps to identify efficiency improvements and to reduce energy costs. Moreover, with upfront costs of renewable energy generation and battery falling sharply, the payback period of onsite green power generation are significantly shortened allowing companies to achieve cost efficiencies more quickly. Finally, the electrification of previously fossil-based processes offers significant potential to reduce final energy consumption, as electric technologies typically operate with much higher efficiency compared to fossil fuel-based options providing similar energy services.

- **Improved access to financing.** Clean energy solutions, especially renewable energy and energy efficiency, are globally considered top investment priorities. 88% of investors worldwide show interest in sustainable investing. In the German venture capital market, investment in green technology start-ups more than doubled between 2019 and 2024. Regulation in the Euro area increasingly requires financial institutions to take sustainability and climate-related risks into account in their lending processes. Consequently, lending standards for firms with higher climate risks have tightened disproportionately over the past twelve months.

In the transition phase towards seizing the prospects of climate action, a number of challenges has to be overcome, such as:

- **Technological immaturity of infant green innovations.** One-third of the emission reductions needed by 2050 will depend on technologies that are currently still in the demonstration or prototype phase.

- **Price volatilities in energy and critical raw material markets.** Future electricity prices will depend on the efficiency of the power systems and on the speed of investments in the current power grids in particular. Supply of raw materials like copper, lithium, or rare earths is vital to new technologies. Political and regulatory uncertainty hampers investment in new technologies.

- **Uncertainties regarding future policy regulations.** Carbon pricing involves significant price uncertainties and considerable international variations, negatively impacting the risk-return profiles of green investments.

To address these challenges and help businesses realize the returns of climate action, targeted policy measures in five key areas are essential.

- **De-risking green investment projects** in order to improve risk-return profiles. Targeted support schemes such as contracts for difference, guarantees or promotional financing can help mobilizing private capital.

- **Accelerating market penetration of green products.** Activated demand for green products and new technologies can enable businesses to enter emerging markets early on. Harmonized standards—such as in the European Industrial Decarbonization Accelerator framework—enable economies of scale for market ramp-up. States themselves can serve as role models through their procurement policies and regulatory mandates.

- **Implementing incentive-compatible carbon pricing mechanisms** is the silver bullet of climate policy. In lack of reliable global collaboration ensuring sufficient carbon prices, pricing schemes such as the EU ETS must be supplemented with accompanying instruments such as carbon border adjustment mechanisms.

- **Strengthening research and development, and empowering start-ups** as engines of innovation and rapid technology deployment. Appropriate policy instruments include direct research and development funding or tax incentives for innovative activities. It is equally important to address the capital needs of fast-growing new businesses (such as, the Zukunftsfonds and WIN Initiative in Germany) as well as to create large and liquid capital markets, also for start-up financing.

- **An enabling market environment** complements the above specific instruments. Modernizing infrastructure, accelerating digital transformation, securing competitive energy prices, reducing bureaucracy, and streamlining approval procedures for investment supports economic growth in general—and is also vital for a successful transformation.

1. Motivation

Climate risks have transitioned from being distant threats to immediate challenges, with their effects materializing across regions and industries. Societies and businesses must face the new reality that the world we operate in today will undergo significant changes in the future—and adjust activities accordingly. The long-term economic costs of inaction on climate change are significantly higher than the costs associated with proactive climate action, thereby hindering long-term economic growth.[1] Climate inaction could lead to substantial financial losses for businesses, and a potential shrinkage of national economies and global GDP.

Climate action, on the other hand, is not only about avoiding risks—it is about building resilience for societies and businesses and unlocking value in a transforming world. As businesses encounter escalating physical and transition risks that redefine industries, these challenges also present prospects for innovation, participation in future markets, and competitive advantage, paving the way for an expanding climate mitigation and adaptation market.

Technology plays a pivotal role in linking climate action to business opportunities. Green technologies are advancing rapidly, with significant investments driving their development. The green technology sector exhibits significant future growth potential, the size of which depends on political path decisions. If ambitious climate policy plans continue to be pursued, the global market for green technologies could triple or even quadruple by the middle of the century.[2] Market expansion could be lower if further efforts are not undertaken, or substantially higher if current political pledges are accelerated.

Germany, for example, has specialized strengths in several lead markets of the green technology sector such as energy efficiency or circular economy.[3] Additionally, Germany is recognized for its expertise in manufacturing clean technology products, including (intelligent) power-grid technology, which are highly specialized and technologically advanced. These technologies not only have the potential to generate value domestically but also to position Germany as a leader in sustainable finance and related services, offering export opportunities and contributing to regional economic growth.

This study presents a comprehensive economic case for climate action. In particular, the study argues that competitiveness can be strengthened by participating in growing and innovative markets, as well as through cost reductions—whether by increasing resilience, improving efficiency, or securing better financing options. Moreover, it examines the main obstacles for climate action during the transition phase and describes policy measures that are needed to enable a successful transformation. We argue that beyond participation in future markets, climate action presents opportunities for businesses to mitigate substantial operational, financial, and reputational risks, increase efficiency and lower operational costs. However, there is a number of significant challenges on the path towards sizing the prospects of climate action. Key obstacles include the technological immaturity of infant green innovations, price volatilities in energy and critical raw material markets, uncertainties regarding future policy regulations, as well as bureaucracy and complex approval processes delaying implementation. We propose targeted policy measures in five key areas to address these challenges, with a focus on derisking green investment projects, accelerating market penetration of green products, implementing incentive-compatible carbon pricing mechanisms, strengthening research and development and start-up activities, and an enabling economic market environment.

Our study thus sheds light on the intersection of environmental sustainability and economic strategy, offering valuable insights for policymakers, businesses, and researchers aiming to leverage the opportunities for sustainable development. It is organized as follows: Chapter 2 presents economic rationales for climate action from a macroeconomic perspective, focuses on the development of green future markets, and identifies additional competitive advantages. Chapter 3 summarizes challenges associated with climate action. A risk-return view on climate investment projects is introduced in chapter 4. Chapter 5 details policy measures that allow businesses and economies to size the prospects of climate action. Chapter 6 concludes.

2. Economic rationales for climate action

2.1 Advancing climate change from a macroeconomic perspective.
Climate change will cause significant economic costs. Intensifying climate events are likely to be far costlier than previously thought.[4] The "social cost of carbon" in the latter half of the century would exceed $ 1,000 per metric ton of carbon dioxide emissions, far more than any carbon price applied.[5]

These costs not only appear in abstract estimates, but also materialize. According to EM-DAT's international disaster database, climate-related disasters have caused more than $ 3.6 trillion in economic damage in the years 2000 to 2024, only reflecting direct damages such as infrastructure destruction, insured losses and immediate economic impacts. Indirect effects such as longer-term health consequences, loss of productivity and natural resource depletion are not included. The costs of climate-related damage increased from around $ 450 billion in the 5-year period 2000–2004 to more than $ 1 trillion in 2020–2024. This trend reflects the expected increased probability as indicated in the last IPCC climate report. The damages are expected to further increase in the next years due to a rising number of extreme weather events.

The costs will rise even further as climate change moves on. Last year's global greenhouse gas emissions represented a new historical peak. The world is now on track to a 3° C temperature rise by the end of this century due to the ongoing burning of fossil fuels.[6] Various studies and publications have analyzed the economic effects of limiting temperature rise to under 2° C compared to a scenario that is following the current 3° C pathway (table 1). There is a consistent picture showing that short-term investments are clearly overcompensated by avoided climate damages in the long run. The numbers differ, but all studies find substantial economic benefits of ambitious climate policies by the year 2100. Put differently, in the long run, climate action clearly pays off at a global level.

Tab. 1 – Projected economic benefits of limiting climate change

Study	Projected relative GDP gains by 2100 under a 2° C szenario compared with a szenario based on current policy/3° C warming
Bilal and Känzig (2024)[7]	up to 12% of global GDP
WEF and BCG (2024)[8]	10–15% of global GDP
Benayad et al. (2025)[9]	11–24% of global GDP
OECD/UNDP (2025)[10]	1–13% of global GDP

Source: Own representation based on the cited studies.

2.2 Competitive advantages associated with climate action.

Climate action is increasingly recognized and leveraged in practice, as many firms are taking concrete steps to integrate climate considerations into their operations. Technologies that have already crossed the threshold of economic sensemaking, such as renewables, are broadly invested in also by companies themselves—in Germany and across the globe. Industry leaders already use a range of clean technologies, the most widely adopted being solar power generation (60%) and heat pumps (50%).[11]

This trend is also reflected in investment behavior which has significantly risen for larger corporates in recent years: In 2024, 61% of larger firms in the EU reported having made investments to address climate change, up from 56% in 2023 and 53% in 2022.[12] We argue that competitiveness can be strengthened by offering innovative products in growing markets, as well as through cost reductions—whether by increasing resilience, improving efficiency, or securing better financing options (see figure 1). The four different channels are outlined in the following paragraphs.

Fig. 1 – Areas of competitive advantage through climate action

Participation in future markets
- Market opportunities due to international climate targets and growing willingness to pay for sustainable goods
- Technological leadership through innovation

Enhanced resilience
- Reduced dependence on volatile raw material and fossil energy prices, and lower vulnerability to supply chain disruption
- Better preparedness for stricter regulations and carbon pricing
- Improved reputation and stakeholder trust

Efficiency gains & cost reduction
- Lower energy and resource consumption through efficiency measures
- Cost savings from renewable energy usage
- Economic benefits from circular economy principles

Improved access to financing
- Access to green financial and capital market instruments
- Increased interest from new investor groups
- Favorable lending conditions

Source: Own representation.

Climate action enables participation in future growth markets.
Despite the withdrawal of the USA from the Paris Climate Agreement, 138 countries have set targets for greenhouse gas neutrality. These "net-zero" states represent 77% of global economic output and 74% of global emissions.[13] Meeting ambitious emission goals is fueling worldwide demand for climate protection technologies and low-emission products—driven not only by policy, but also by market forces such as rapid cost reductions in renewables, rising innovation, and increasing consumer willingness to pay for sustainable solutions. For businesses, this translates into significant opportunities to access rapidly growing markets through manufacturing, exporting, or innovating sustainable solutions. Technology progress seems therefore pivotal to linking climate action to business opportunities.

The green tech industry is highly diverse, bringing together a wide range of businesses that offer environmentally and climate-friendly technologies and services. Prominent market segments in this cross-sector industry are, for instance, providers of renewable energy generation facilities, technologies to increase energy efficiency, recycling and waste management solutions, or sustainable mobility concepts. In addition, the industry encompasses many other actors whose products contribute directly or indirectly to a cleaner environment. Further examples therefore also include green digital solutions—such as smart energy systems and digital platforms for resource management—or producers of advanced materials like decarbonized versions of metals, chemicals, and plastics, which are essential for low-carbon industrial processes.

A look at past developments already underscores the green and clean[14] tech sector's dynamic growth potential. Both the demand for clean technologies and capital inflows into the sector have recently increased at a rapid pace, averaging around 7.3% and 9.6% per year, respectively. Specifically, in the last five years, between 2019 and 2024, clean energy investments grew by 9.6% annually. In 2025, expected investment levels amount to $ 2.2 trillion, twice as much as the $ 1.1 trillion going to oil, natural gas and coal.[15] Likewise, global trade volumes have increased significantly. According to the German Environment Agency, global trade in green tech was valued at € 1.02 trillion in 2022, representing a worldwide increase of 7,3% p.a. compared to 2010. If these observed trends continue, the overall market volume could double in less than ten years.[16]

This dynamic development is also reflected in selected subsectors of the clean tech industry. Table 2 illustrates past market developments across several prominent segments of the green tech sector. Over the past decade, global trade in renewable energy & energy systems, energy efficiency, environmentally friendly mobility, and circular economy has achieved compound annual growth rates between 5% and 11%. Even more dynamic growth can be observed when looking at individual key technologies: For example, total renewable capacity additions (solar and wind) increased by 30.4% per year between 2019 and 2024, and electric vehicle sales surged by 50% per year in the same period.

Besides global trade, innovation activity targeted at green technologies has also increased significantly. As highlighted in table 2, patent applications in selected green tech subcategories have grown steadily in recent years, with annual growth rates between 3% and 8% over the period 2008 to 2020. In a relatively young industry such as the green tech sector that is continually confronted with evolving regulatory requirements and rapid technological change, innovation is essential for unlocking further growth potential. The development and deployment of new technologies enable businesses to stay ahead, adapt to shifting market demands, and deliver more efficient, cost-effective, and sustainable solutions.

Tab. 2 – Recent market developments across selected green tech segments

Selected market segments	Subcategories/key technology fields[1]	Current market size (as measured by global trade volume in 2022)[1]	Growth in selected individual technologies (p.a.)	Innovation activity (as measured by growth in selected transnational green patent applications, p.a., 2008–2020)[5]	Innovation activity (as measured by growth in selected transnational green patent applications, p.a., 2008–2020)[5]
Renewable energy & energy systems	Renewable energy (solar, wind, etc.), energy systems and grids, storage technologies, electrification in industry	€ 137.5 billion	+ 5.4%	Total renewable capacity additions (solar + wind): + 30.4% (2019-2024)[2]	Energy: + 4.9%
Energy efficiency	Energy-efficient and resilient buildings, energy-efficient production processes and technologies	€ 157.8 billion	+ 10.1%	Heat pumps: + 6.7% (2019–2023)[3]	Buildings: + 3%
Environmentally friendly mobility	Mobility and propulsion technologies, logistics and mobility services, traffic management systems and infrastructure, bicycle economy	€ 245.5 billion	+ 11.0%	Electric vehicles: + 50% (2019–2024)[4]	Transportation: + 4.9%
Circular economy, waste management and renewable raw materials	Waste treatment and recycling, waste management technologies, waste collection and transport, circular processes, wenewable raw materials and environmentally friendly materials	€ 252.6 billion	+ 4.8%	–	Waste: + 8.0%

Sources: [1] Bechhaus, P., Bichlmeier, T., Dietzsch, N., Draeger-Gebhard, J., Hutzenthaler, P. (2025), GreenTech made in Germany 2025: Umwelttechnik-Atlas für Deutschland, Umweltbundesamt; [2] IEA (2025), Total renewable capacity additions by technology, 2019–2024, IEA, Paris, https://www.iea.org/data-and-statistics/charts/total-renewable-capacity-additions-by-technology-2019-2024, Licence: CC BY 4.0; [3] IEA (2024), Heat pump sales by country or region, 2019–2023, IEA, Paris, https://www.iea.org/data-and-statistics/charts/heat-pump-sales-by-country-or-region-2019-2023, Licence: CC BY 4.0; [4] IEA (2025); 4 Global electric car sales, 2014–2024, IEA, Paris, https://www.iea.org/data-and-statistics/charts/global-electric-car-sales-2014-2024, Licence: CC BY 4.0; [5] Based on own calculations using Patstat data. The analysis covers transnational patent applications, defined as applications filed at the European Patent Office for European countries or as Patent Cooperation Treaty (PCT) applications for non-European countries. Green tech-relevant patents were identified according to the Y02/Y04 classification.

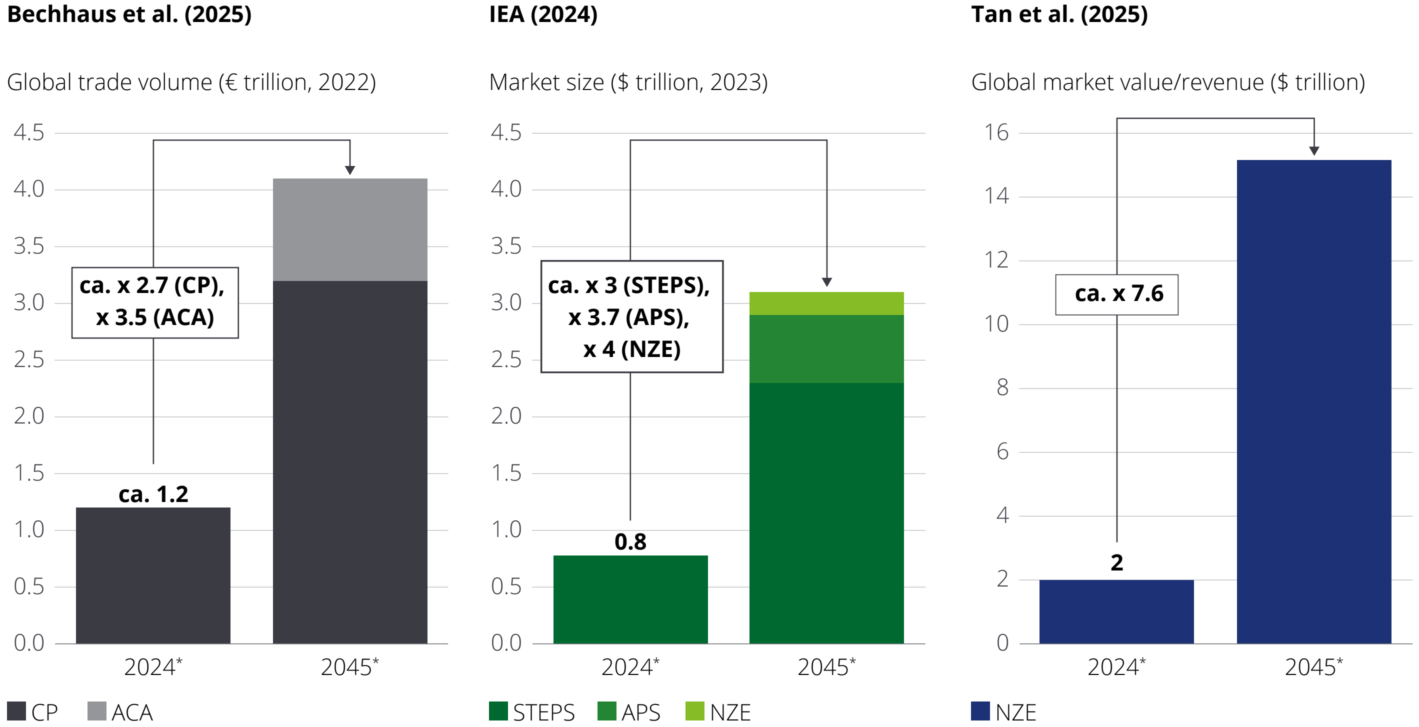
Looking ahead to 2045, future growth prospects for the green tech sector remain strong. Figure 2 summarizes three recent studies that have assessed future green growth opportunities. Depending on the study, different types of technologies are considered (see lower part of the exhibit for details), which leads to differences in the estimated absolute market volume for 2024. Nevertheless, when examining the projected growth paths into 2045, all studies consistently point to substantial future potential. In scenarios where ambitious climate policy plans are pursued—such as the ambitious climate action or the announced pledges scenarios—estimates suggest that the global market for green technologies could triple up to quadruple by mid-century.

Growth projections in further selected market segments are even more striking. For example, market for green ICT solutions is expected to grow from $ 17.21 billion in 2023 to $ 105.26 billion in 2032, a CAGR of 22.4%. This market comprises solutions such as carbon footprint management and reporting systems, a growing adoption of cloud-based deployment models for better scalability and reduced energy consumption, and IoT and analytics integration in sustainability platforms to enhance real-time monitoring and reporting.[17]

In addition, there are smaller, complementary markets, like carbon removals, which are growing even faster:[18] Within four years, the market for carbon removals has risen to $ 6 billion. Estimates of the future volume, measured by total revenues by 2030, range between $ 30 billion and 100 billion per year. By 2050, based on net-zero climate needs, the size of the CDR market could even be in the range of $ 0.3 to 1.2 trillion. The latter figure roughly corresponds to the current market size of the global pharmaceutical industry—and is at the same time 400 times the current market size.

At the same time, the scale of market expansion will depend heavily on the ambition and consistency of climate policy. While some clean technologies are more than cost-competitive already, accelerating their diffusion rapidly, others require political intervention to scale in time.[19] A comparison of the different growth paths depicted in figure 2 shows that in scenarios where political efforts to implement and strengthen climate action stall—such as the current pathway or stated policies scenarios—projected growth rates fall shorter, though estimates still remain positive. The global market for green technologies could then increase two- to threefold by mid-century. Conversely, if net zero by 2050 is rigorously pursued—such as in the net zero emissions scenario—green growth opportunities could expand even more rapidly and extensively (up to 7.5 times the market size of today). These figures highlight the interconnection of green tech growth opportunities and transformation paths: There are significant opportunities that a strong global transformation policy can offer for the green tech industry. Yet the size of opportunities hinges on the strength and speed of global transformation activities. The drawback of the US as a major economic player from climate policy may thus be expected to have an impact. In fact, recent survey evidence suggests that current US policy has negative spillover effects on climate action in other countries—but the global growth prospects remain positive.[20]

Fig. 2 – Green growth opportunities, projections 2024–2045



Technologies considered: energy efficiency, renewables, green mobility, circular economy, mitigation & protection technologies, water management, sustainable agriculture

Current pathway (CP): describes the continuation of the current transformation path, which has already led to significant global market growth between 2018 and 2023.; **Ambitious climate action (ACA):** simulates further development that can be expected if the international community fully pursues the transformation goals set out in international climate agreements and additional commitments

Technologies considered: six key clean energy technologies: solar PV, wind, electric vehicles (EVs), batteries, electrolyzers, heat pumps

Stated policies (STEPS): projects the future based on current policies and measures that are already in place or officially announced, excluding aspirational targets; **Announced pledges scenario (APS):** assumes all announced climate pledges and net-zero targets are fully achieved on time, regardless of whether concrete policies are in place to support them; **Net-zero emissions by 2050 (NZE):** outlines a pathway to global net-zero energy sector emissions by 2050, limiting warming to 1.5° C and meeting key UN sustainability goals

Technologies considered: critical materials, green manufacturing, green industrial materials, green services

Net-zero emissions by 2050 (NZE): outlines a pathway to global net-zero energy sector emissions by 2050, limiting warming to 1.5° C and meeting key UN sustainability goals

Notes: * To ensure a consistent time span (2024 to 2045), the values for the green tech sectors were extrapolated from the respective base and end years reported in each study. In cases where no annual data were available, growth was assumed to be evenly distributed across the intervening years by applying a constant compound annual growth rate (CAGR).

Sources: Bechhaus, P., Bichlmeier, T., Dietzsch, N., Draeger-Gebhard, J., Hutzenthaler, P. (2025), GreenTech made in Germany 2025: Umwelttechnik-Atlas für Deutschland, Umweltbundesamt; International Energy Agency (IEA) (2024), Energy Technology Perspectives 2024, International Energy Agency, Paris, https://www.iea.org/reports/energy-technology-perspectives-2024, License: CC BY 4.0 international: Tan, S., Minifie, J., Jones, E. R., Daniel, C., Bharadwaj, A. (2025), Economic Growth Opportunities in a Greening World, Boston Consulting Group.

Deep Dive: Green growth markets for Germany

Germany has long been recognized for its manufacturing and engineering excellence, particularly in the mechanical engineering, automotive, chemical, and electrical sectors. In the field of environmental and climate technologies, Germany has also managed to establish a strong starting position. The green tech sector includes technologies, products, and services. Over the past few decades, it has become a significant economic force in Germany, accounting for around 7.5% of the national workforce, 9% of gross value added, and over 8% of exports.[21] Much of this success can be attributed to close synergies with Germany's traditional industrial sectors, such as automotive and mechanical engineering. The share of German green tech exports in global trading volume currently amounts to about 13%—a share significantly higher than Germany's general share in global exports of about 7%.[22]

However, the competitive landscape is changing rapidly. Germany now faces increasing international competition in the green tech sector and is at risk of falling behind, especially compared to China. With regard to green technologies, China has already become the leading manufacturer and exporter of crucial clean technologies such as solar panels, wind turbines, electric cars, and battery technologies. The growing competitive pressure means that German companies must act early and decisively. To secure their current position and remain competitive in the future, they need to build on their existing strengths, quickly address relative weaknesses, and develop forward-looking strategies that respond to the evolving global market for new green technologies.

A closer look at six selected green growth market segments reveals a nuanced picture, with both strengths and challenges of the German economy.

Renewable energy technologies: Germany has traditionally enjoyed strong competitive advantages in the development and production of renewable energy systems. However, its role in manufacturing these systems has declined over the past decade: In 2010, German exports accounted for about 13% of global demand, but by 2022, this share had dropped to less than 8%.[23] China has now become the leading exporter of solar, wind, and battery technologies, dominating global supply chains.[24] In terms of innovation, Germany still holds a respectable position, ranking among the top nations for patent activity in this field: 13% of worldwide patent applications originate in Germany—with China rapidly closing the gap.[25] Notably, most recently, German patent filings in renewable energy generation technologies surged significantly, in particular in solar and wind power with increases of 57.3 percent and 14.2, respectively—marking by far the largest growth among the countries with the highest number of applications.[26] To maintain and strengthen its position in this market segment, Germany must therefore continue to build on its existing innovation strengths. Manufacturing of electrolyzers is a positive example: German companies remain among the global market leaders in this technology.[27]

Environmentally friendly mobility: Germany has traditionally enjoyed strong international competitive advantages in providing mobility solutions. In 2010, exports from this sector totaled € 11 billion, and until 2023 the market had grown at an average annual rate of nearly 13%, reaching an export volume of over € 54 billion.[28] However, German companies are now facing increasing competition, especially from China, which has become the world's largest exporter of electric cars.[29] In particular, Chinese manufacturers have established a dominant position in battery technology, the heart of electric vehicles. A similar trend can be observed in innovation: While China is rapidly catching up, Germany still holds a leading position, accounting for 22% of all transnational patents for environmentally friendly mobility.[30] Germany can benefit from well-established clusters bringing together suppliers and manufacturers and fostering innovation and from its strong market position, especially in Europe. Encouragingly, the share of EVs in German car exports has increased recently. In the first quarter of 2025, on average 82,000 battery-electric vehicles (BEVs) worth € 3.4 billion were exported each month. Germany now generates a higher export surplus with BEVs than with conventional cars.[31] There is also further potential for expansion, for example, in next-generation battery technologies,[32] autonomous driving, and other advanced mobility solutions.

Energy-efficient production technologies: In the face of climate change and volatile or rising energy costs, energy efficiency is becoming increasingly important. For Germany as an industrial location, energy-efficient production is a particularly important technology field, closely linked to the country's traditional strengths in mechanical engineering. Overall, Germany maintains a strong market position: In the market segment for energy-efficient optimization of production processes Germany ranks second worldwide, with a 14% share of global patents, just behind the USA.[33] However, there is still room for improvement in certain areas, such as connected production and smart factory technologies. [34]

Circular economy: The circular economy is becoming an increasingly important element in transforming the economic system and offers a means to rewire the entrenched linear practices.[35] The aim of this green tech segment is to keep products and materials in closed loops throughout their entire lifecycle, thereby reducing dependence on raw material imports. Germany holds a solid position in this technology area, with exports reaching nearly € 23 billion in 2023, though the annual growth rate of 2.7% lags behind other green tech areas.[36] In innovation, Germany ranks third worldwide in recycling technologies, accounting for 14% of global patents—behind the USA and Japan.[37] In some market segments, Germany even leads the field: For example, in metal and mineral recycling, Germany holds the top position globally with an 18% share of patents. For the future, it will thus be important to continue building on existing strengths to maintain and expand Germany's competitive edge in the circular economy.

ICT technologies with climate relevance: Digital innovations play an increasingly important role in climate action, with technologies like the internet of things and artificial intelligence offering significant potential to reduce energy consumption, manage resources more efficiently, and monitor emissions. However, Germany lags behind other leading nations regarding digitization. This is evident both in the trade balance—Germany consistently imports more goods based on digital technologies than it exports—as well as in patent activity.[38] This relative weakness is also apparent in climate-related digital technologies. Here Germany's share of global patents remains low in international comparison.[39] Nevertheless, there are positive starting points in areas that intersect with Germany's traditional manufacturing strengths, particularly in technologies for connected mobility and energy efficiency.[40] To play a more significant role in this technology segment, substantial improvements will be necessary. Germany should build on existing avenues and gradually work towards closing the gap with the world's leading markets.

New advanced materials: Advanced materials are the building block of the green transformation and enable the production of lighter and more stable components that help simplifying and accelerating production processes.[41] These include coatings, paints, and varnishes, catalysts for efficient and sustainable production processes, high-performance materials for efficient energy supply and storage, and diagnostic procedures to the recycling and reuse of these substances. Accordingly, the areas of application for these new materials range from the construction industry and the automotive sector to the ICT and energy sectors. Germany is well positioned in this context due to its pioneering technologies, advanced infrastructures, and track record of strong R&D spending.[42] However, consistent and reliable standards are necessary to accelerate scaling from lab to market and improve investor confidence.

Climate action enhances resilience.
The Russian invasion of Ukraine and the resulting threats to Europe's fossil fuel supply have clearly demonstrated that a high dependence on fossil fuel imports increases vulnerability to price fluctuations on global energy markets and poses risks to energy supply security, especially when energy resources are used as leverage in geopolitical conflicts. Thus, the expansion of renewable energy is not only essential for achieving climate goals but is also a critical strategic pillar for long-term energy security—at both the corporate and the national level. Spain and Portugal, for instance, benefited from lower electricity prices compared to much of Europe during the energy crisis, thanks to their strong reliance on solar and wind power.[43] Likewise business investments in generation and storage of electricity from renewable energies (e.g. solar, wind, batteries) have accelerated markedly in recent years. In Germany, for example, corporate spending on renewable energy generation and storage nearly doubled in 2022—at the onset of the energy price crisis—and has remained a consistently higher level ever since.[44]

Moreover, companies that fail to decarbonize, or make only minimal progress, are increasingly exposed to transition risks. Tightening climate regulations or further evolving incentive schemes—such as expanding carbon pricing mechanisms—can lead to significant regulatory risks for laggards. As the world is heading towards a net-zero economy in order to evade detrimental climate change, the demand for fossil-based products will come to an end—it is just a question of when. Carbon pricing schemes have expanded with respect to coverage and price levels—raising over $ 100 billion around the globe in 2024. In the European ETS, the allocation of certificates is scheduled to stop around 2040, leading to a sharp increase in allowance scarcity and an unpredictable surge in carbon prices. Thus, firms that do not act may face higher costs or even risk exclusion from certain markets, particularly in carbon-intensive sectors. Furthermore, reputational risks are becoming increasingly important: Stakeholders, including customers, investors, and employees, are paying more attention to corporate climate action, and negative perceptions can result in lost business opportunities, difficulties in talent acquisition, and declining investor confidence.

Circular economy insight
A transition towards a circular economy does not only represent a green growth market (see table 2). It also mitigates risk exposure, in particular against resources scarcities and price variabilities, as a Deloitte survey of 128 supply chain managers from German companies shows: Two-thirds of respondents believe that circular approaches mitigate supply risks for critical raw materials and create new business opportunities.[45] That is also why circularity is a key element of the EU's Clean Industrial Deal, too[46].

Climate action improves efficiency and reduces costs.
On a global scale, the adoption of renewable energy has already led to significant reductions in energy cost. For example, in 2022, global fuel costs decreased by at least $ 520 billion due to the adoption of renewable energy sources.[47] In Europe, the additional expansion of wind and photovoltaic systems from 2021 to 2023 led to a reduction in electricity supply costs of approximately € 100 billion.[48]

These benefits are not limited to the macro level; individual companies also stand to gain. By adopting green technologies and practices businesses can realize substantial competitive gains. First of all, systematically measuring and analyzing energy and material consumption can help companies identify potentials for cost savings and efficiency improvements.[49] Once these areas are identified, measures such as energy efficiency upgrades, recycling and waste reduction, or the use of renewable energy sources help companies to lower their energy consumption and resource use. In fact, cost savings are among the most frequently cited reasons for climate action by businesses themselves. In Germany, 66% of businesses reported that reducing energy costs is a key motive for making climate-related investments.[50]

As upfront costs for green technologies keep falling over time, e.g. due to increased economies of scale, the payback periods shorten, enabling businesses to realize individual cost savings and efficiency gains more quickly. This trend is already evident: Over the last decade, the unit costs, of several green energy technologies have dropped considerably. From 2010 to 2019, levelized cost for solar energy fell by 85%, for wind energy by 55%, and for lithium-ion batteries by 85%, accompanied by substantial increases in their deployment.[51]

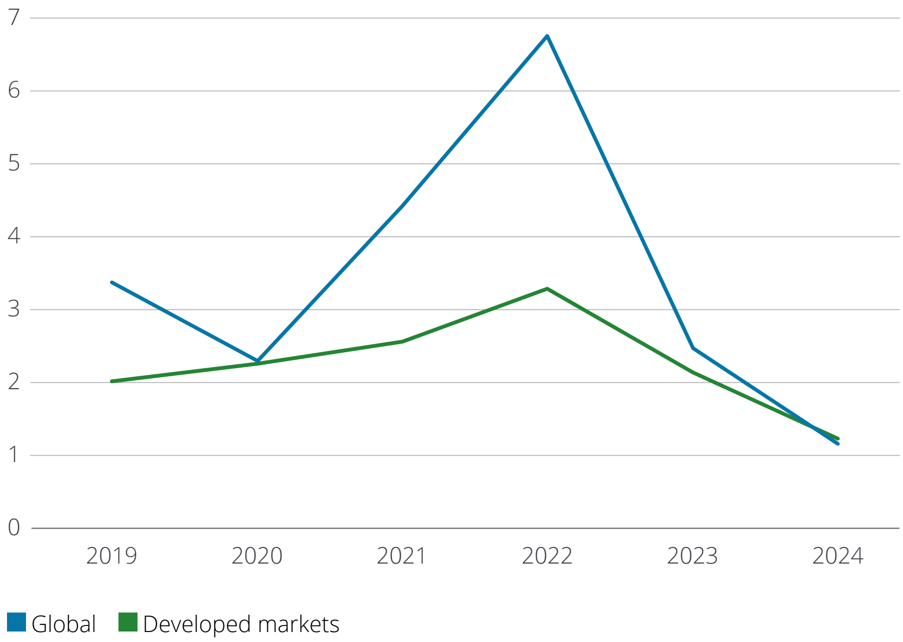
Moreover, the electrification of previously fossil-based processes offers significant potential to reduce final energy consumption, as electric technologies typically operate with much higher efficiency compared to fossil fuel-based options providing similar energy services.[52]

Adopting circular economy practices helps businesses reduce material and waste disposal costs. In 2020, the direct global cost of waste management was estimated at $ 252 billion. Including the hidden costs of pollution, health issues, and climate change caused by poor waste disposal practices, the total rises to $ 361 billion.[53]

Climate action also affects profitability by reducing the costs associated with climate change. 66% of firms in the EU have already been impacted by the physical risks of climate change (with either a major or a minor impact).[54] These physical risks can translate into material costs within the next two decades. A study quantifies the costs of unchecked climate change (more than 3° C pathways) for selected sectors at 5 to 25% of firms' EBITDA by 2050. Under a Paris-aligned scenario, these costs would be materially lower.[55]

Climate action provides access to attractive financing options and investors.
Given the current demand for sustainable investments among capital providers, businesses with credible climate strategies can access attractive financing instruments: A significant 88% of investors worldwide have shown interest in sustainable investing.[56] More than half of these investors plan to increase their allocations towards sustainable investments in the coming year. This decision is largely driven by the belief that sustainable investments can yield competitive returns similar to traditional investment options, with only 3% of investors globally intending to decrease their allocations. Additionally, a substantial majority of investors, over 80%, do not view sustainability and financial performance as mutually exclusive. They believe it is possible to achieve financial gains while also supporting sustainability efforts.

Fig. 3 – Development of the green social and sustainability bonds premium (basis points)



Source: Amundi/IFC (2025).[57]

Against this backdrop, it is not surprising that explicitly designated green financial instruments are high on investors' agendas. They now account for a substantial share of the capital market. Last year, 2024, was strong for Green Bonds, achieving record issuance of $ 447 billion globally. While the market premium for Green, Social, and Sustainability (GSS) bonds has decreased in the last two years, it still remains present in the market. Empirical analysis has identified a so-called green premium or "greenium", representing a yield discount for issuers of GSS bonds compared to regular bonds. In developed markets, the value of the "greenium" has essentially ranged between one and three basis points over the past five years reflecting high investor demand for sustainable assets as opposed to conventional bonds.

The growing importance of green finance is also reflected in the venture capital market. In 2024, the climate-tech sector became the leading technology segment in the German VC market, with deal volumes reaching around € 2.3 billion—more than doubling since 2019.[58]

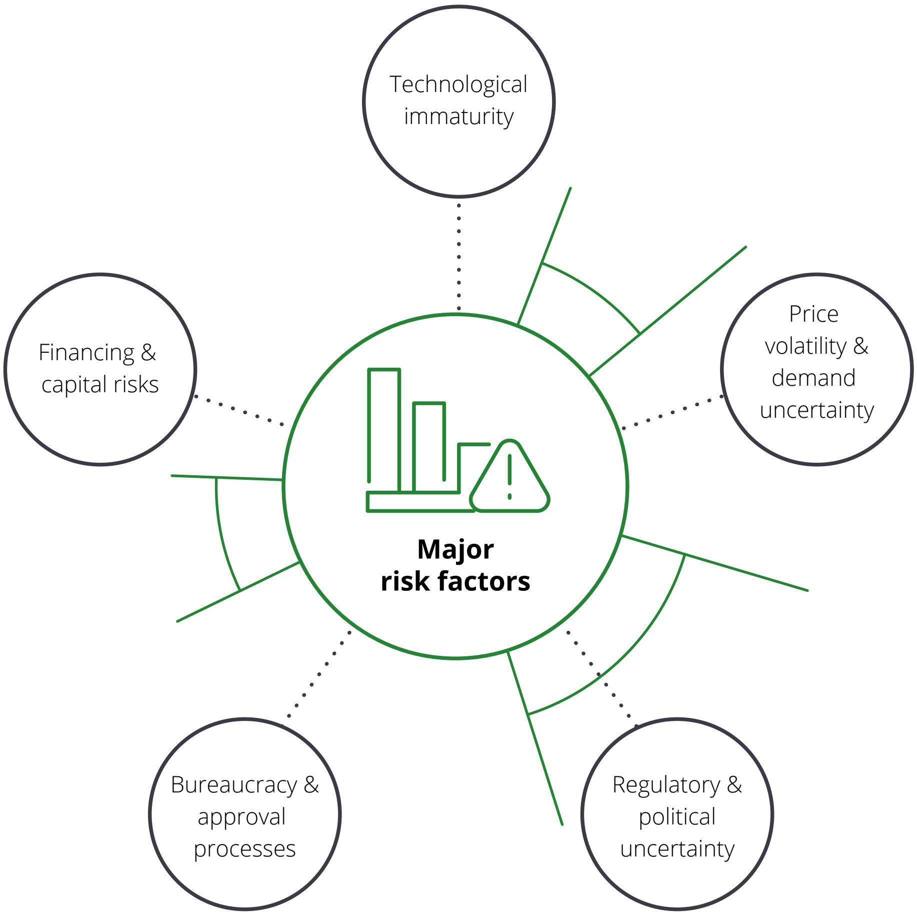
Besides mounting investor interest, new regulations are increasingly requiring financial institutions to take sustainability and climate-related risks into account in their lending processes. As a consequence, lending conditions are shifting in the Euro area. Climate-related risks and the measures businesses take to address them have already had a restrictive effect on lending standards over the past twelve months, particularly for firms with higher negative climate impacts ("brown" companies).[59] In contrast, lending terms for climate-friendly ("green") companies have become more expansive and supportive.

3. Current challenges and obstacles for climate action

Though climate action clearly shows benefits in the long run, the transition phase towards fully realizing its potential can be cumbersome. Economies face substantial investment needs to achieve their green transition goals, requiring significant contributions from both the public and private sectors. The annual climate financing needs range between $3 trillion and $ 8 trillion until 2050 if the 1.5° C target is to be met by mid-century – with an expected financing gap of $ 27 trillion by the end of the decade.[60] This figure is vastly higher than the current level of public and private investment, which amount to approximately $ 2 trillion.[61] Even when focusing solely on businesses in specific regions, the current pace and volume of investment remains insufficient to meet climate objectives.

During the transition phase, the initiation and financing of green projects itself often face significant challenges and investment barriers, which often fall into five key categories (fig. 4).

Fig. 4 – Major risk factors and investment barriers for green investments



Technological immaturity: Roughly one-third of the emission reductions needed by 2050 will depend on technologies that are currently still in the demonstration or prototype phase.[62] These technologies may prove less reliable or less efficient than expected. In addition, integration issues can arise if new technologies cannot seamlessly be integrated into existing systems, leading to unexpected costs and delays.

Immature technologies often lack a proven track record, making it difficult for investors to assess their viability and potential returns. Additionally, the limited ability of capital markets to manage long-term risks associated with immature technologies can lead to insufficient investment, as these markets may fail to provide adequate risk management instruments due to a lack of historical data.

Furthermore, immature technologies in green projects face significant challenges due to competition with established technologies. These have benefited from tailored institutions and infrastructures, creating path dependencies that can inhibit the adoption of promising newer, greener alternatives.

A related risk is the potential for higher costs of capital, which can exacerbate the climate investment trap in developing economies. These regions often face higher weighted average costs of capital due to perceived investment risks, making the transition to low-carbon technologies more expensive and less attractive compared to those in developed economies.

Price volatility and demand uncertainty: Initiating and financing green projects can be fraught with risks due to market factors related to price and demand. One significant risk is the volatility in market prices for green technologies and renewable energy sources, which can create uncertainty in revenue projections and impact the financial stability of projects. Additionally, fluctuating demand for green products and services poses a risk, as it may not align with supply, potentially leading to situations of oversupply or undersupply.

Moreover, the transition to renewable energy and low-carbon technologies requires significant changes in market dynamics, which can introduce financial and reputational risks for organizations if they fail to adapt quickly enough. These market risks can impact the willingness of investors to finance green projects, as they may perceive these investment projects as less stable compared to traditional investments.

The volatility in the prices of energy sources, raw materials, or CO_2 certificates can lead to economic uncertainty, complicating project planning and execution. This price volatility can significantly impact the financial aspects of green investments. For instance, if there is a sudden increase in the price of rare-earth minerals or metals, the cost of manufacturing and installing technologies such as wind turbines or solar panels can rise. This increase in costs can directly affect the profitability of these projects, making them less attractive to investors.

With respect to carbon pricing, international heterogeneity is a further source of uncertainty. Around the world, 55 countries have implemented carbon prices as an instrument of climate policy. The instrument has gained importance, mainly in advanced economies, but also—and increasingly—in emerging economies. The World Bank currently counts 80 direct carbon pricing initiatives around the world, 37 emission trading schemes (ETS) and 43 carbon taxes, covering 28% of global emissions. There is great heterogeneity in the price levels set per ton of carbon, the inclusion and exemption of individual economic sectors and, not least, the share of greenhouse gas emissions captured by a carbon price.[63]

Regulatory and political uncertainty: Political and regulatory uncertainty can significantly impact green investments by increasing volatility and risk perceptions, potentially deterring investment in green

technologies and renewable energy projects. For instance, the rollback of green regulations and climate action strategies could hinder growth in renewable energy sectors, affecting the risk-return profiles of green investments negatively, as we currently witness in the global context, where US policies have led to a downturn in IPR's Policy Sentiment index.[64]

Accordingly, for many businesses, planning certainty is one of the most important framework conditions for climate-related investments. In a representative survey of around 10,000 businesses in Germany, more than half of the firms expressed a desire for greater planning certainty regarding the CO_2 price.[65] This broad support is noteworthy, as carbon pricing initially represents a cost factor for firms, and highlights the importance of predictability as a key element of an effective and incentive-compatible investment environment. This is especially true when it comes to dealing with heterogeneous carbon prices around the globe: Nearly as many businesses also called for international harmonization of CO_2 pricing, which would help reduce competitive disadvantages.

Financing and capital risks: Climate-linked projects frequently require substantial, long-term capital commitments that may not align with the yield expectations of short-term private investors or the risk tolerance of longer-term investors. Changes in credit terms or interest rates or difficulties in raising capital can increase costs and reduce profitability, the risk of defaults or access to sufficient capital.

These risks are especially relevant for longer-term investment projects, such as the provision of infrastructure for electrical power supply or hydrogen, and their mitigation requires an embedding in a plausible and credible regulatory outlook.

In addition to the availability of debt financing, sufficient equity ratios play a crucial role for firms' ability to finance long-term projects. Yet capital investors may be reluctant to provide venture or equity capital. This burden is particularly high for start-ups and growing technology-oriented firms.

Lack of affordable and comprehensive insurance is a related risk. Insurance is important for qualifying projects as investment-grade and attracting private sector capital. Technological uncertainty, for example, can lead to costly, restrictive, and limited insurance options, thereby slowing the deployment of cost-effective energy solutions.

Another potential challenge is the need to harmonize regulatory frameworks and standards to effectively promote green financing. This entails aligning public sector financing decisions with environmental objectives and boosting investment in clean and green technologies.

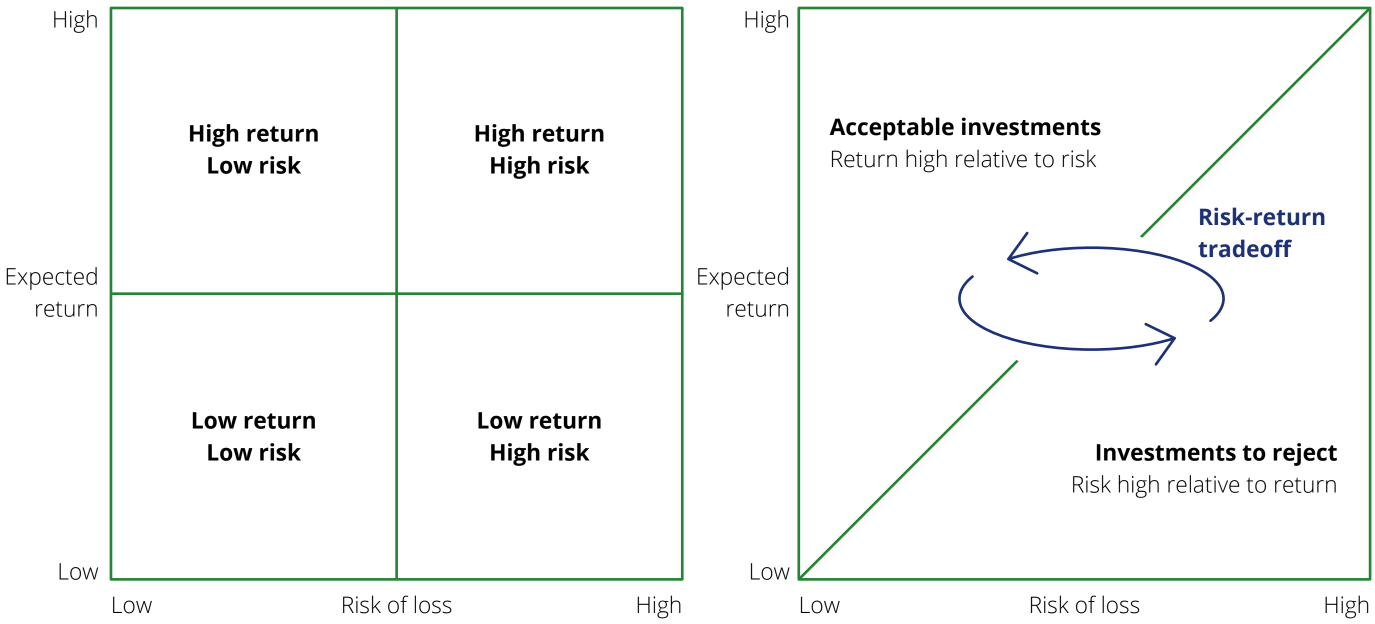
Bureaucracy and approval processes: Bureaucracy and approval processes for green projects can be quite extensive, often taking several years. These processes involve multiple layers of regulation and paperwork that can slow down the initiation and completion of projects and increase costs for project developers. The need for various permits and compliance with environmental regulations can lead to delays, making it difficult for projects to start on time. Also, the complexity of navigating these bureaucratic systems can increase costs, as projects may require additional resources to manage the administrative burden. Furthermore, lengthy approval processes can discourage investors who are looking for quick returns on their investments. From a business perspective, lengthy planning and approval procedures represent one of the most significant hurdles to climate-related investments. In a representative survey of around 10,000 businesses in Germany, more than one-third of firms identified this challenge as a frequently experienced obstacle.[66]

4. Balancing rewards and risks of green business models

To fully capitalize on the competitive advantages associated with climate action, businesses must actively invest in climate-oriented measures. The nature of these investments can vary depending on the sector, region, and individual business model. Common examples include capital expenditures for new or upgraded technologies—such as advanced renewable energy systems, energy-efficient equipment or the electrification of production processes and mobility. At the same time, investments in research and development are necessary for businesses to refine existing processes and develop innovative, climate-friendly products and solutions.

When financing climate projects, the actual cost of capital is strongly shaped by the risks investors associate with these investments. Investors generally seek to maximize returns relative to risk—that is, they strive to achieve the highest possible financial benefit for a given level of risk, carefully weighing whether expected rewards justify any uncertainties or potential losses. This approach is known as the risk-return tradeoff (fig. 5).

Fig. 5 – Risk-return tradeoff principle in investing



Source: Own representation.

While the competitive advantages of climate action can offer attractive rewards for investors, some green investments are still perceived as riskier than conventional ones. Factors—such as high upfront capital requirements, technical immaturities, regulatory uncertainties, or unclear pricing mechanisms—can lead investors to view the risk-return profile of certain green investments less favorably.[67] In line with risk-return logic, external financiers may then demand higher returns to compensate for these higher risks—which drives up the cost of capital. Alternatively, if the anticipated rewards do not sufficiently outweigh the uncertainties, financiers may simply decide not to invest in climate-related projects at all.

It is crucial to recognize that there is not one single risk-return profile that fits for all measures and projects associated with decarbonization. Future markets and clean technologies encompass various asset classes, including power plants, electricity grids, infrastructure for hydrogen, and facilities for carbon capture and storage, each possessing distinct risk-return profiles. These asset classes vary in aspects such as the stability of their cash flows, their resilience to economic fluctuations, the maturity of the technologies used, and opportunities for capital appreciation and recovery rates. Consequently, they cater to diverse investor preferences and risk tolerances.

The flow of additional capital and investments into a specific green asset class is influenced by how its risk-return profile compares to other asset classes, including conventional ones. Measures to improve the risk-return profile, such as stabilizing cash flows or reducing default risks, must be specifically considered for each asset class, making them a competitive alternative for investors seeking strong performance with lower risk or volatility.

Risk-return profiles of clean technologies vs. conventional fossil-based technologies

Fossil-fuel technologies, such as combustion engines and conventional aviation fuel, currently benefit from substantial subsidies and due to a managed low carbon price. In a first-best future market set-up with carbon pricing adequately reflecting the actual costs of carbon, the risk-return profile will significantly favor clean technologies, like renewables, heat pumps and electric vehicles, given the high economic damage caused by CO_2 emissions. However, given that a global solution with fair carbon prices is way out of reach, a second-best policy set-up might accompany an ambitious (regional) carbon price with additional cost-reducing or risk-reducing measures for green technologies. The European Emission Trading System (EU ETS) in combination with border adjustment mechanisms or climate clubs may serve as an example.

Spotlight: In Germany, the national emission trading system (nETS) for the heating and the mobility sector was introduced at a fixed price of € 25 per ton of CO2 in the year 2021. The price increased steadily to € 55 by 2025, leading to a rise in the cost of fossil fuels such as gas and oil. The price is scheduled to increase up to € 65 in 2026. From 2027 onwards, the German nETS will be integrated as a second-market segment. The future price in the EU ETS II is subject to significant political uncertainty, with price projections in the literature ranging from € 50 to more than € 300 by the year 2030.[68] Some investors are already using internal carbon prices for their investment decisions that are significantly higher than the current market prices. This business approach is due to the underestimation of climate costs and risks in market prices, prompting them to factor in internal carbon prices that reflect a more realistic assessment of future carbon costs.

Renewables risk-return profile

Renewable energy technologies offer moderate to high long-term returns and are increasingly competitive due to falling technology costs and strong policy support. Globally, they were the most cost-competitive option for new electricity generation in 2024, with 91% of newly commissioned utility-scale capacity delivering power at a lower cost than the cheapest, newly installed fossil fuel-based alternative.[69] The global weighted-average levelized cost of electricity (LCOE) for new utility-scale solar PV, for instance, was over four times higher than the LCOE of the least-expensive fossil fuel-fired generation in 2010. By 2024, solar PV had become 41% cheaper.

Accordingly, technologies like wind and solar are already mature and widely deployed, with renewables supplying nearly half of the EU's electricity in 2024.[70] Renewable energies benefit from established supply chains and regulatory frameworks, making them more bankable than more newly emerging solutions like hydrogen.

However, the return profile is characterized by a long-term horizon, as projects require high upfront capital and have extended payback periods. Commercial-level onshore wind projects, for example, have a typical payback period of around eight to twelve years, which corresponds to an internal rate of return of 5–10%.[71] The cost of capital remains a critical factor, especially in a high-interest environment. While Germany, for instance, has made significant progress in scaling up renewables, challenges persist. Grid bottlenecks, slow approval procedures, and rising costs for materials and labor can delay returns.[72]

On the risk side, policy and regulatory stability is essential. The IEA emphasizes that long-term clarity in market design and funding mechanisms are crucial to maintaining investor confidence. Moreover, while renewables reduce exposure to fossil fuel price volatility, they introduce new risks related to intermittency and infrastructure adequacy. In terms of scaling, grid stability and political stability are risk factors.

Outlook
Hydrogen risk-return profile

Hydrogen technologies hold strong strategic value for decarbonizing industry and for enhancing energy security. However, the returns for green hydrogen are largely realized over the long-term, making them less attractive for investors seeking near-term gains. The breakeven point can be reached by 2030 at the earliest (for ammonia).[73] The levelized production costs of grey hydrogen (generated through steam methane reforming) averaged approximately € 3.76/kg H_2, while the average cost of production of green hydrogen (by water electrolysis, using grid electricity) averaged € 7.94/kg H_2.[74]

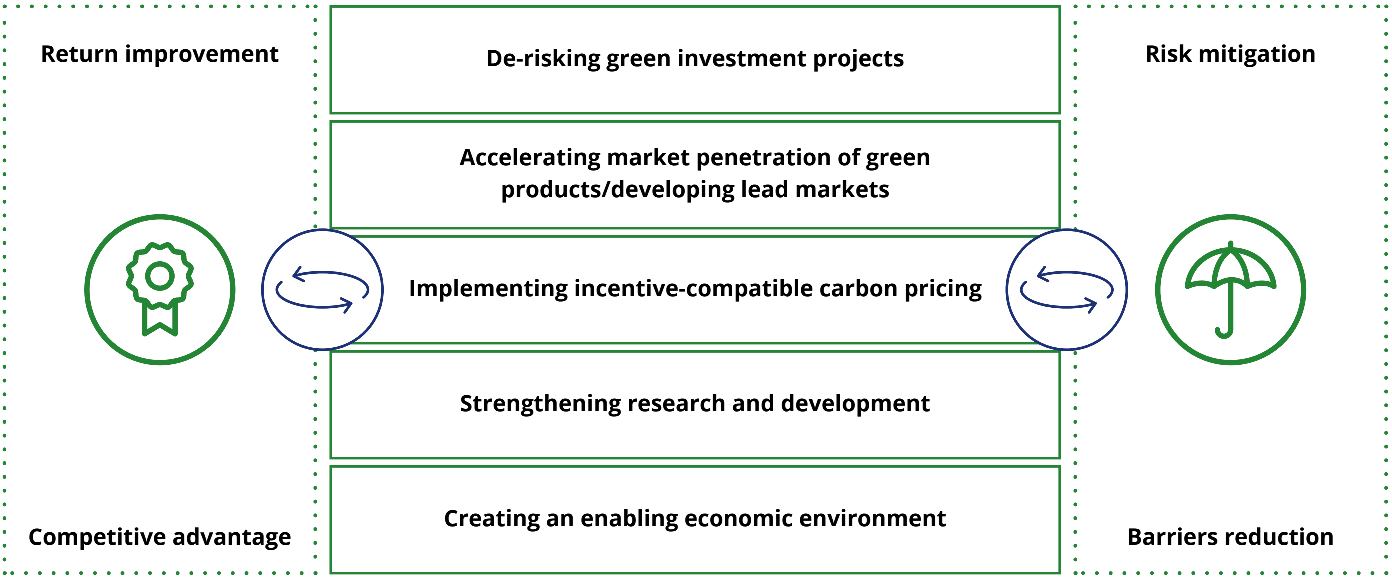
This delayed payoff is compounded by regulatory uncertainty, underdeveloped infrastructure, and financing hurdles. In Europe, only 4% of announced clean hydrogen volumes were under construction in 2024 and less than 10% of planned hydrogen pipeline corridors had reached permitting stage.[75] Many projects struggle to reach final investment decisions due to the lack of stable offtake agreements and high upfront costs. What is more, many projects have used overly optimistic assumptions in their investment plans, including fallbacks that are not economically feasible.

While public support is increasing (albeit inconsistencies in, for example, transparency of support programs) and the market is expected to mature, the current risk-return profile remains skewed toward high risk and deferred reward. A clear policy framework coordinating a joint ramp-up of supply, transportation infrastructure, and demand is a key ingredient for facilitating investments in and the financing of the H_2 sector.

5. Policy instruments to enhance competitiveness and growth

Climate action can offer significant competitive advantages for businesses—from cost savings and access to new markets to improved risk mitigation and better financing opportunities. However, when it comes to financing the necessary climate investments, complex risk profiles remain a major hurdle for both investors and businesses. To unlock the potential of climate action, it is therefore essential to support businesses in leveraging these competitive advantages while simultaneously reducing existing risks and barriers. We identify five key areas for supportive action: de-risking green investments projects, accelerating market penetration of green products, implementing incentive-compatible carbon pricing, strengthening research and development, and—more broadly—creating a plausible and credible, enabling economic environment.

Fig. 6 – Impact of policy instruments on risk and return



5.1 De-risking green investments projects.

Public support instruments play a pivotal role in mobilizing private capital for the green transition by sharing the risks inherent in green investment projects. Several risk categories of green investments need to be mitigated—such as high upfront capital requirements, technical or regulatory uncertainties, or unclear pricing mechanisms—to make climate-related investments bankable. This is where public support instruments can make a decisive difference. By absorbing part of the project risks or accepting lower returns, they can help to close financing gaps and thereby create more attractive conditions for private investors. Such risk-sharing instruments can take various forms, including subsidized loans, state guarantees, equity(-like) instruments or public-private partnerships. It is crucial that these instruments are designed to achieve a "crowding in," meaning they are intended to mobilize new private investment rather than merely substituting for it. In this way, public support acts as a catalyst, leveraging additional private funds and accelerating the pace of the green transition.

Mobilizing private investments also requires having the right resources available in the appropriate form at the right time. From a financing perspective, it is important to distinguish between the early stages of the technology lifecycle (research and development) and the later stages (market introduction and diffusion). Due to different risk-return profiles across these phases, the same sources of finance are not always available and equally supportive at every point in time. Early-stage R&D projects are for instance characterized by high technological and commercial uncertainty; here, internal financing, grants, and tax incentives play a crucial role. As technologies progress toward market introduction, risks decrease and external (equity) financing, including venture capital, become more appropriate. Government support for equity providers and demonstration projects can further accelerate market development. In the diffusion phase, when technologies are widely established and technological risk is low, investment loans become suitable, though certain risks—such as regulatory uncertainty—may still persist. In this context, subsidized loans and grants can help bridge remaining financing gaps and incentivize further investment.

Public support instruments are crucial in reducing the risks of green investments, making them more attractive to private investors and bridging the climate investment gap.

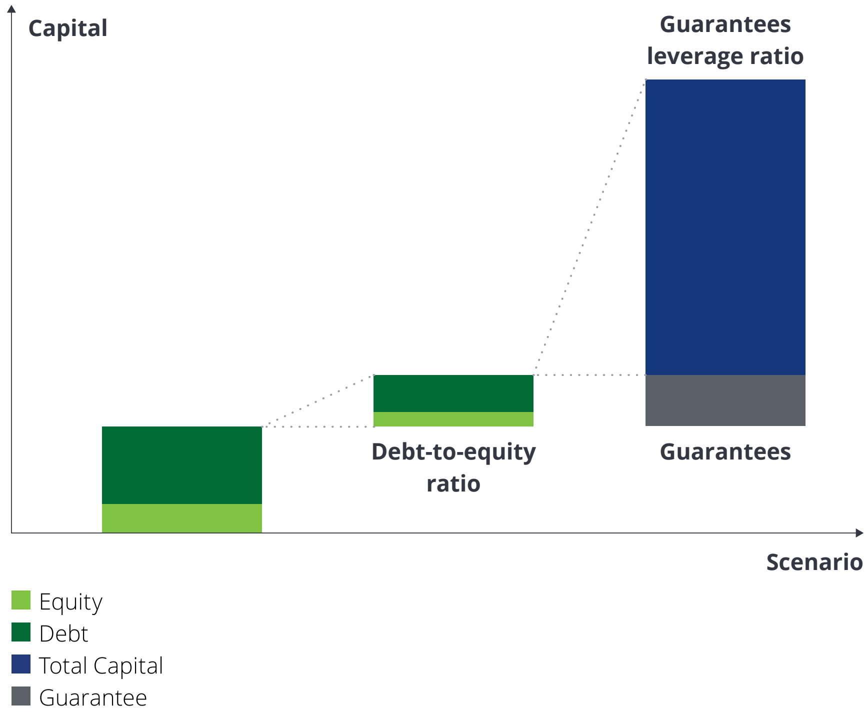
Use case
Energy Transition Fund

The concept of the Energy Transition Fund (ETF) is based on equity-strengthening capital investments and accompanying state guarantees to exploit the existing leverage effects in terms of debt capital and the mobilization of private capital.

The purpose of the ETF is to improve the equity ratio in order to use the leverage effect based on the targeted debt-to-equity ratio, as well as to leverage private investments through state guarantees.

Spotlight: With an assumed debt-to-equity ratio of 2:1 and a leverage ratio of 1:5, government guarantees of around € 25 billion would be required to close an investment gap of € 440 billion by 2030.[76]

Fig. 7 – Leverage effects of an equity strengthening Energy Transition Fund with state guarantees



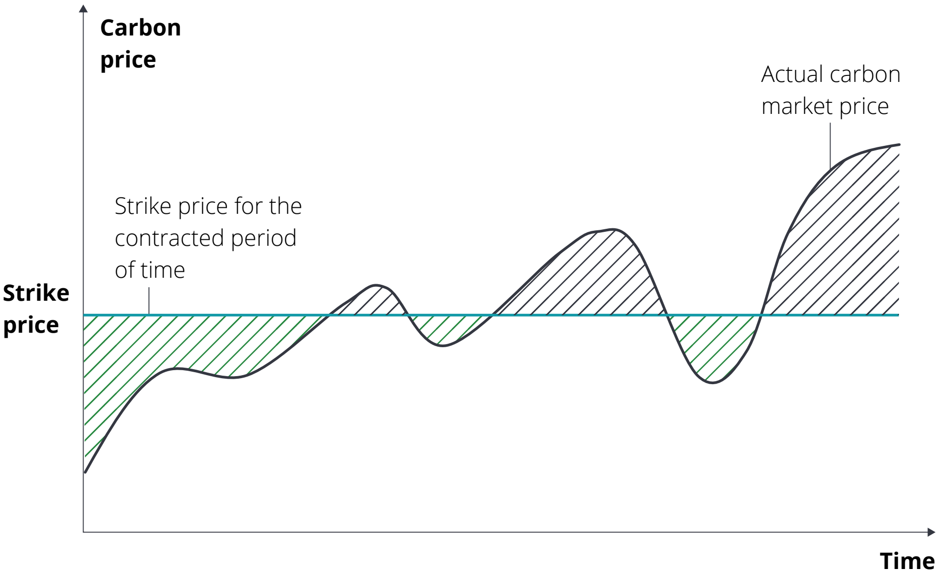
Source: Own representation.

Carbon Contracts for Difference (CCfDs)

CCfDs are a policy tool designed to provide financial certainty and incentives for investments in low-carbon technologies. They work by setting a fixed carbon price over a specified period, which helps reduce investment risks for companies and shares the CO2 costs between public and private entities.

The basic mechanism involves a contract between a public administration and a company, where the government agrees to pay the difference between the current carbon price and the actual CO_2 abatement cost. If the market price of carbon exceeds the agreed strike price, the company pays back the difference to the government.

Fig. 8 – Carbon Contracts for Difference (CCfDs) to ensure a stable carbon price to attract investors



High-price scenario:
Investor pays the difference between strike price and actual market price back to the government (subject to CCfD design).

Low-price scenario:
Investor receives for each ton of CO_2 avoided through the low-carbon project the difference between the strike price and the actual market price from the government.

Source: Own representation.

CCfDs are particularly useful for industries that are hard to decarbonize and require substantial investments with long investment horizon, such as steel, cement, and chemicals. They provide a stable revenue stream from carbon savings achieved from climate-beneficial production technology, and cover the risk of low carbon prices in the future.

These contracts can be tailored to different sectors and projects, allowing governments to strategically support the transition to low-carbon technologies while sharing the financial risks involved.

The deployment of CCfDs faces multiple challenges that must be addressed during implementation. They can limit competition by discouraging new market entrants, leading to market concentration. The transfer of investment risks to taxpayers can strain public finances, as the government covers price differences when market carbon prices fall. Additionally, CCfDs may reduce incentives for companies to lower costs or innovate, as their revenue is secured through state support. CCfDs are not a cure-all and cannot replace consistent carbon pricing. However, targeted use of CCfDs can offer economic benefits. This is especially true when new replacement investments are to be made which can cause lock-in effects—while economic incentives from current carbon price levels are insufficiently low. Challenges in applying CCfDs include selecting the technologies to be supported and determining an adequate level of the strike price. The economic viability of CCfDs only exists if the risk of artificially sustaining inefficient technologies in the market is low. However, this risk can be reduced through appropriate contract design.

5.2 Accelerating market penetration of green products and developing lead markets.

Activating and strengthening (private) demand for green products can enable businesses to enter emerging markets early on. The development and market introduction of new, climate-friendly products are often associated with significant learning and scaling effects. To ensure that the market potential of such products is realized swiftly, measures aimed at increasing their demand can be useful: They enhance planning security regarding market opportunities and provide businesses with the necessary incentives to invest in the development and launch of green products at an early stage. When green products subsequently reach broader market adoption, businesses are already well-positioned and able to quickly scale up production. In this context, states themselves can serve as models through their procurement policies and regulatory mandates, thereby strengthening or even creating stable sales markets with guaranteed purchase volumes for climate-friendly products or methods of production.

Efforts to certify green products are pivotal in ensuring they are easily identifiable, and demand is directed towards them. Climate-friendly products, like green steel or renewable electricity, are often physically identical to their fossil-based counterparts. For a distinct market for green products to emerge, it is therefore essential that customers can adequately identify the differences. In this regard, unified standards are crucial as they establish the necessary transparency and trust. Labels and certification serve as accessible tools for consumers to make informed product choices, further encouraging the adoption of sustainable options. Through their efforts to establish so-called green lead markets, the European Union has recognized the importance of a holistic approach. Within the Industrial Decarbonization Accelerator framework, the EU aims to integrate various efforts to establish comprehensive standards and systems that support the transition to a sustainable future for industry.[77] Harmonized standards and quotas would not only facilitate trade in climate-friendly products but also enable economies of scale that support market ramp-up. The same applies to alternative materials, where consistent standards would accelerate market attention.

5.3 Implementing incentive-compatible carbon pricing.

Incentive-compatible carbon pricing enables businesses to effectively capitalize on the competitive advantages of a green economy. By attributing a monetary cost to carbon emissions, it aims to internalize the social cost of carbon output, rendering carbon-intensive (production) processes more expensive compared to greener alternatives. The approach incentivizes emission cuts wherever they are most cost-efficient to achieve. At the same time, as the usage of green products becomes more economically attractive, their demand further increases, enhancing business opportunities in the growing green market. The European Emissions Trading System (EU ETS) and Germany's national emission trading system (nETS), for instance, are carbon pricing tools in place. Since current carbon prices do not yet fully reflect the true social costs of emissions, carbon pricing should be continuously and systematically strengthened and further developed. A reliable and steadily increasing carbon price signal can help to enhance planning security for businesses and prevent risks associated with volatile price fluctuations. This creates a more predictable environment for climate investments and supports long-term business decisions in favor of sustainable solutions.

However, international collaboration plays a vital role in maintaining competitive neutrality of carbon pricing across domestic and international markets. Region-specific carbon pricing, such as the EU ETS, can elevate production costs for businesses in those regions, decreasing the competitiveness of their products compared to those from regions without such measures. This situation can lead to carbon leakage, where businesses move operations to regions with lower costs, distorting market competition and diminishing export competitiveness. To prevent competitive disadvantages for domestic industries and effectively reduce global emissions, supporting measures are essential. Multilateral trade agreements with unified standards and carbon pricing strategies are a crucial policy tool in this regard.[78] A noteworthy example in this context is the EU Carbon Border Adjustment Mechanism (CBAM), which seeks to combat carbon leakage and ensure competitive neutrality by aligning the carbon costs of imported goods.

5.4 Strengthening research and development.

Unlocking further upsides of climate action will require continuous technological progress and sustained innovation activities along the transitional path. Roughly one-third of the emission reductions needed by 2050 will depend on technologies that are currently still in the demonstration or prototype phase.[79] At the same time, ongoing improvements to existing technologies are essential to achieve greater cost efficiency and overall effectiveness. This means that comprehensive efforts must be undertaken to accelerate both breakthrough innovations and incremental advances. Alongside the previously mentioned instruments—carbon pricing, demand stimulation, and targeted financing solutions—broad-based innovation policies are also needed to foster green innovation.[80] These include direct research and development funding, tax incentives for innovative activities, initiatives to address the shortage of high-skilled workers, strengthening companies' innovation competencies, or programs that facilitate knowledge exchange between science, industry, and policy. According to an assessment of 4,163 companies across all sectors and company sizes, 83% of companies report R&D investments in low-carbon products, and sustainable products can provide a revenue increase of 6% to 25% over traditional products.[81]

Technology- and growth-oriented start-ups play a central role in driving innovation and deploying technology within economies, including in the field of green technologies. As newly established organizations, they can often operate faster and more flexibly than established companies, allowing them to bring new technologies to the market more quickly. The German start-up ecosystem, for instance, has grown considerably over the past decade. However, access to suitable financing through venture capital remains stronger in key international markets, especially for firms in capital-intensive growth phases. Recent initiatives such as the Zukunftsfonds and the WIN Initiative are steps to address these challenges. Further potential for the German venture capital market lies in mobilizing institutional investors, such as insurance companies and pension funds, to engage more actively in venture capital investments. In addition, progress towards a European Capital Markets Union is essential for creating a larger and more liquid market, also for attracting private venture capital.

5.5 Creating a plausible and credible enabling economic environment.

A credible and enabling economic environment builds on coherent and forward-looking policy frameworks. Effective policy plays a catalytic role in unlocking private capital by providing confidence in the underlying business case for green investments—whether in hydrogen, alternative materials, or energy-efficient building refurbishments. Strategic policy interventions must modernize infrastructure, accelerate digital transformation, and ensure access to competitively priced clean energy. Crucially, policies should reduce bureaucratic hurdles and streamline approval processes to shorten investment cycles. Targeted financial support for energy-intensive sectors, such as chemicals, is essential to mitigate transition risks and maintain industrial competitiveness. By embracing a broad mix of decarbonization technologies and embedding them in long-term policy planning, governments can lower systemic costs, foster innovation, and ensure that climate ambition translates into economic opportunity.

6. Conclusion

This study highlights the dual nature of decarbonization, emphasizing the balance between economic growth potential and the need to navigate complex interdependencies and risks. It underscores the importance of a coordinated approach across various sectors, including industry, finance, politics, and levels of governance, to ensure the benefits of climate action are fully realized. By working together, these entities can create a supportive environment that fosters innovation, investment, and sustainable development, ultimately leading to enhanced competitiveness and growth in a low-carbon economy.

In conclusion, effective climate action and the establishment of a level playing field for all market participants necessitate international collaboration among industry, finance, and political entities. Within this framework, the standardization and harmonization of global policies are critically important. Achieving this requires coordinated efforts and the active involvement of all pertinent stakeholders on a global scale.

Ultimately, it is important to note that the transformation induced by climate change will persist despite evolving political narratives and priorities. Businesses, economies, and political entities alike must contemplate how they can harness this development for value creation and growth.

7. Endnotes

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8. Glossary

APS	Announced Pledges Scenario
BEVs	Battery-Electric Vehicles
CAGR	Compound Annual Growth Rate
CBAM	EU Carbon Border Adjustment Mechanism
CCfDs	Carbon Contracts for Difference
CDR	Carbon Dioxide Removal
EBITDA	Earnings Before Interest, Taxes, Depreciation, and Amortization
EM-DAT	Emergency Events Database
ETF	Energy Transition Fund
ETS	Emission Trading Schemes
EU	European Union
EU ETS	European Emissions Trading System
EVs	Electric Vehicles
EWI	Energiewirtschaftliches Institut
GSS	Green, Social, and Sustainability
GSS bonds	Green, Social, and Sustainability bonds
$\mathbf{H_2}$	Hydrogen
ICT	Information and Communication Technology
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPR	Inevitable Policy Response
IoT	Internet of Things
LCOE	Levelized Cost of Electricity
NDCs	Nationally Determined Contributions
NZE	Net-Zero Emissions by 2050
OECD	Organisation for Economic Co-operation and Development
PV	Photovoltaic
R&D	Research and Development
SDGs	Sustainable Development Goals
SMEs	Small and Medium-sized Enterprises
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
VC	Venture Capital
WEF	World Economic Forum
nETS	Germany’s national emission trading system

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The opinions expressed within this paper are the authors' alone and do not necessarily represent the position of KfW and/or Deloitte.

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