McKinsey & Company

Net-Zero Germany

Opportunities and challenges on the pathway to climate neutrality by 2045

Net-Zero Germany

Opportunities and challenges on the pathway to climate neutrality by 2045

Contents

Foreword

To preserve a livable planet for ourselves, for our children, and for future generations, we need to successfully navigate the transformation to a climate-neutral world within the next 25 years. This transformation to a sustainable society is a joint, global challenge, and an imperative for policymakers, the business community, and each and every one of us.

Climate change has finally made it to the top of the agenda – for policymakers, businesses, and citizens. We have no time to lose in completing the transition to climate neutrality.[1] Our calculations show that we can do it in a socially balanced way and – viewed over the full period and across all sectors – at net-zero cost, provided we take decisive action now. The stakes are high: failure to reach the climate targets would mean exposure to significantly higher climate risks. The next ten years will prove crucial. So, with this study, we want to show how Germany can successfully advance down the path to climate neutrality.

Before it broke for the summer, the German Bundestag – following a watershed ruling by the Federal Constitutional Court – passed a new edition of the Climate Protection Act. This sets out the national goal of reaching climate neutrality by 2045. As a milestone on the way to the final goal, greenhouse gas emissions are to be reduced by at least 65% by 2030 compared with 1990 levels.

The preconditions for the initiative's success have never been better. Other countries and international communities have likewise agreed ambitious climate goals. Take, for instance, the EU Commission, which has adopted its climate plan for Europe, the European Green Deal. This envisages the EU becoming climate-neutral by 2050 at the latest. With "Fit for 55," the EU Commission proposed in July a first major package of measures for implementation. At the same time, companies are driving the decarbonization of value chains and consumers are increasingly choosing to buy sustainable products and services.

Nevertheless, for Germany as a core European economy, reaching climate neutrality is a daunting endeavor. Achieving the net-zero goal involves a complex technological and societal transformation that has to be accomplished in the shortest possible time frame: value chains have to be restructured, the energy transition has to be further accelerated, we need emissions-free mobility, and we need to build and adapt the critical infrastructure before the end of the decade. In practice, the path to climate neutrality is unlikely to be linear. At times, it will be necessary to backtrack and return to the drawing board. But we should not let that discourage us. Far from it, quick and decisive action is of the essence – the longer we delay, the greater the cost and severity of the additional measures that will then be necessary to still hit the net-zero target.

Back in December 2020, McKinsey published "Net-Zero Europe," a report that provides impetus for Europe's rigorous decarbonization by 2050. One of the key findings: Europe's business case for transformation toward climate neutrality can be favorable, provided the cost-optimal path is taken by adopting the necessary package of measures on time. Specifically, that means that the investments and additional costs necessary to reach climate neutrality can be offset through the reallocation of replacement investments needed anyway together with improvements in future operating costs. At the same time, jobs lost in some areas can be more than compensated for by growth in high-potential "green" areas, such as building renovations and expansion of EV charging infrastructure.

1 That is, the additional investments required are offset by savings in operating costs in subsequent years – when aggregated across all sectors.

Against this backdrop, it is time to back up Germany's net-zero goal with concrete actions. Our report identifies the key challenges and actions through to 2045 in the five most emissions-intensive sectors: power, industry, transportation, buildings, and agriculture, together with the banking sector as a key enabler. But it also underscores the opportunities that Germany can capture thanks to its innovation power.

The report is intended to serve as guidance for businesses and policymakers. For, while it is the task of policymakers to shape a regulatory framework that enables the transformation to climate neutrality, it is the task of the private sector to develop, test, and scale green technologies. There is no shortage of examples that illustrate the effectiveness of this approach.

As an economy and as a society, we are facing one of the most important and complex transformations we have ever known. Compared with other countries, Germany's starting conditions are excellent, and it can make a contribution to decarbonization that will have an impact far beyond its borders. We must embark on this journey now – together, we can stay the course. Even if Germany cannot accomplish the global transformation to a climate-neutral world on its own, it must do its part and set a good example as one of the leading export-oriented economies.

With "Net-Zero Germany," McKinsey wants to make a contribution to ensuring the success of Germany's decarbonization. We are proud of the support we have already been able to lend many companies worldwide – including in Germany – as they take on the challenges they face on the road to climate neutrality. It is our declared aim to factor in decarbonization and climate neutrality as key decision-making parameters in all our consulting projects in future.

We are convinced that the transformation to a net-zero world can and must succeed so we can preserve a livable planet for our children and future generations.

Ruth Heuss

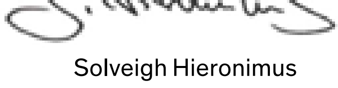
Senior Partner, Berlin

Stefan Helmcke

Senior Partner, Vienna

Hauke Engel

Partner, Frankfurt



Solveigh Hieronimus

Senior Partner, Munich

Summary

On the road to climate neutrality by 2045, policymakers, the business community, and society are confronted with the most far-reaching and complex transformation of our time. It requires determined and concerted action by policymakers, businesses, and the scientific community, as well as a rethinking of our consumption decisions. Studies show that if the transformation to net-zero emissions proceeds optimally, it can mean a positive transition at net-zero cost for society as a whole (on aggregate over the entire period and across all sectors) – enabling a socially acceptable means of dealing with climate change, a favorable business case for Germany, and a leap to a new technological age. A concerted effort is needed to mitigate the effects of climate change already taking hold, while ensuring Germany can maintain a socially balanced quality of life without major setbacks.

Substantial investments in tangible assets are needed to achieve climate neutrality in Germany by 2045. The total investment in replacement tangible assets required for the transition to climate neutrality comprises additional investments of EUR 1 trillion and replacement investments of EUR 5 trillion. The latter are investments that have to be made in any event to replace aging infrastructure, equipment, and buildings. To achieve climate neutrality, this EUR 5 trillion must be invested in green or more climate-friendly goods when the time comes for the scheduled replacement of assets, for instance, favoring vehicles with electric drive rather than a combustion engine. The total investment volume of EUR 6 trillion equates to an average annual investment of roughly EUR 240 billion through 2045 or about 7% of Germany's gross domestic product (GDP)[2] – of which EUR 40 billion per year concerns additional investment (or about 1% of GDP).

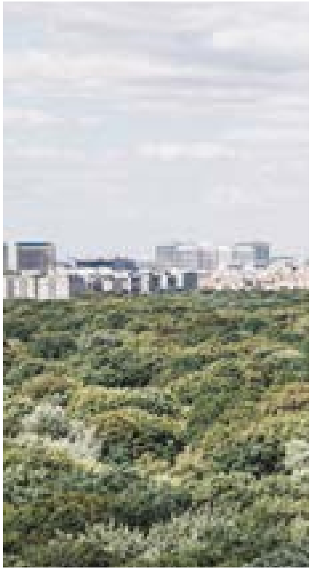
If we stay on the optimal path, cumulative cost savings and revenue over the period through 2045 can offset the cost of decarbonization. Investments in new technologies can lead to an array of improvements in operating costs, among them the energy cost of buildings or the fuel and maintenance costs of vehicles. In this way, Germany can benefit from a strengthened position as an industrial hub as well as from the creation of new jobs. If the transformation is successfully undertaken on time, Germany will be able to hold on to its technological leadership in critical export-oriented sectors and safeguard their contribution to employment and prosperity. This concerns as much as 20% of jobs in Germany and up to 25% of GDP. At the same time, the transition will trigger structural shifts in employment, for example, from thermal power generation to hydrogen production or from combustion engine manufacturing to battery production. Overall, employment is expected to increase, for instance, driven by greater renovation activity and the installation of heat pumps in the building sector or the manufacture and installation of solar and wind power capacity.

Should Germany fail to create the framework conditions for the transformation soon, its private sector stands to lose market share and, in turn, jobs and prosperity. Moreover, in such an event, a significant increase in costs can be expected, especially for basic needs such as energy, housing, and mobility. For instance, an insufficient expansion of solar and wind power could lead to a shortfall in clean electricity for the production of green hydrogen or the electrification of industrial processes, leading in turn to the last-resort adoption of more costly countermeasures such as carbon capture and storage. So, the longer Germany needs to reach climate neutrality, the costlier and less socially balanced the transition will be.

---

[2] Statista, GDP 2019

The next ten years will determine whether Germany is able to achieve the transition to climate neutrality and capture the economic opportunities. Consistent implementation at speed of the required actions has to be the top priority. The preconditions have never been better – countries and international communities are agreeing on climate goals, investors are shifting their capital into climate-conscious portfolios, companies are voluntarily committing to reducing their emissions, the majority of citizens are in favor of the move toward sustainability and are increasingly choosing to buy sustainable products. It is now time to follow up declared intentions with actions. Renewable energy and infrastructure must be expanded faster, production and sales of electric cars massively ramped up, and industrial processes electrified or converted to zero-carbon gases. There is plenty of green capital available. The main barrier is rather the complex realignment that is required of entire industries and supply chains.



The rate of change so far must be boosted threefold over the next 10 years compared with the last 30 – with a tenfold increase in some sectors – in order to transform the system as a whole. A look at the energy and transportation sectors – just two examples – illustrates the scale of the task at hand; challenges of a similar magnitude also arise in all of the other sectors, as explained in the full report:

— In the energy sector, which currently accounts for 32% of all emissions in Germany,[3] the annual expansion of renewable energies has to exceed the figure for 2020 roughly threefold over the next ten years – between 15 and 20 GW of capacity have to be added annually. This is partly because the electrification of industrial processes and mobility must be powered by electricity from renewable sources to ensure their climate neutrality. The grid infrastructure has to be expanded massively and at a far faster pace than is the case at present. And we need a "smarter" grid that enables, for example, charging of electric cars whenever renewable energy is in ample supply. At the same time, the establishment of cost-effective production and import of green hydrogen and the corresponding infrastructure are essential to decarbonize industrial processes and grow storage capacity for green energy.

— In transportation, which accounts for 20% of total emissions in Germany,[4] the transition to e-mobility is in full swing. However, the share of electric vehicles in Germany has to increase from 6.7% of new registrations in 2020 (in addition to 6.9% plug-in hybrids)[5] to roughly 60% of new registrations in 2030 to meet the new targets set by the EU. That said, achieving climate neutrality by 2045 will require even more ambitious targets – models show that, by 2030, more than three-quarters of new vehicles registered annually will have to be electric – roughly a tenfold increase on registration numbers in 2020.[6] The industry is making good inroads: in June 2021, it had already achieved a significant year-on-year increase, with electric cars making up 12.2% of new registrations[7] (in addition to 11.4% plug-in hybrids). Key enablers and drivers for the massive shift needed include the climate-neutral construction of battery plants and a huge expansion of charging infrastructure.

[3] In addition to emissions from the energy, industry, transportation, buildings, and agriculture sectors, the figure also includes a negligible share of emissions from waste management and other sectors of around 1% in 2019 (see Exhibit 3); German Federal Environment Agency
[4] German Federal Environment Agency
[5] German Federal Motor Transport Authority (KBA), passenger car sector for 2020
[6] McKinsey Center for Future Mobility (MCFM)
[7] KBA, passenger car sector for 2021

To master the transformation, ten core elements will be decisive.

Massively accelerate the expansion of renewable energy capacity

Expand (about 25% expansion in the power transmission grid) and increase flexibility of the energy grid

Decarbonize the basic materials industry (green materials) through innovations in processes and plant technology, driven by requirements and innovations from the manufacturing industry

Pursue accelerated build-up of cleantech enablers: hydrogen production and transportation, battery plants, charging infrastructure, recycling

Transition to 100% zero-emissions mobility

Improve resource productivity by establishing smart and shared mobility

Modernize heating systems of building stock, especially with sustainable heating systems (> 50% heat pumps)

Develop future-proof key technologies for resilient and sustainable agriculture

Accelerate the trend toward healthy eating and sustainable consumer behavior

Finance and support the net-zero transformation by developing a green portfolio

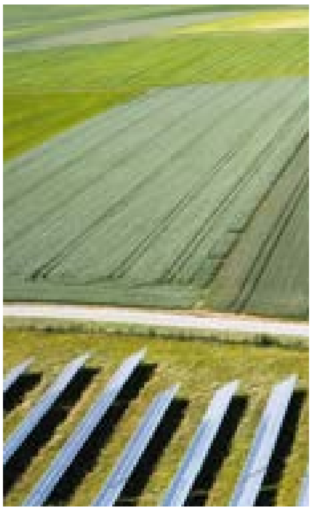
In addition to these core initiatives, a number of important preconditions and framework conditions (enablers) will be required, such as the acceleration of permitting procedures, especially for the expansion of solar and wind power, the designation of areas for urgently needed additional infrastructure, as well as the accelerated education and training of experts on the topic of decarbonization in the various sectors. This is imperative to drive implementation across the board and at all levels, from entrepreneurs and decision-makers to skilled workers and trainees, all of whom have a contribution to make. All these measures are dependent on bold and committed decision-makers, and they need the broad support of society.

As drivers of innovation and industrialization, companies in Germany have a pivotal role to play in developing, testing, and scaling green technologies. Many German companies have already set out on the path, defined sustainability strategies, identified ways to decarbonize, and examined their portfolios, production operations, and supply chains to identify opportunities to rigorously decarbonize. Many companies are deep in the transformation process – but it is a complex endeavor: they need to invest in transforming their facilities and their value chains end to end, identify the demands on their workforce, and prepare for the transformation – a task of enormous proportions. Germany's automotive industry is a role model in this respect. All OEMs have set themselves ambitious targets, with some manufacturers aiming to build net-zero electric vehicles as early as 2030. In doing so, they have set in motion the transformation of entire value chains toward the adoption of sustainable technologies.

At the same time, the green transformation offers companies the opportunity to tap into the markets of the future. A sustainable product portfolio and technological innovations offer new growth opportunities. This is true in both the consumer goods industry, where sustainable products deliver both significantly higher growth and significantly wider margins, and in the capital goods sector, where players are looking ahead to a period of growth fueled by the pressing expansion of infrastructure and the restructuring of value chains. Leading, sustainably oriented companies often benefit from attractive valuations that are otherwise only reached by technology companies (with some reaching EBITDA multiples of between 15 and 30). This makes it easier for them to raise capital to invest in further growth and to scale faster. Government stimulus packages and a growing "green capital market" are providing additional tailwind. The key to business success lies in quickly recognizing the opportunities inherent in the transformation process and capturing the value and growth potential. In the following, we discuss numerous examples.

Legislators need to establish the preconditions for a transformation that is 3 times faster than in the past 30 years.

In parallel, legislators have to establish the preconditions for rapid transformation. Germany is currently on a reasonably good path: many of the fundamental political, technological, and financial parameters are already in place. Further concrete actions now have to be initiated in the individual sectors, and the conditions have to be created that will catalyze the requisite changes to infrastructure. To this end, a reliable planning basis is critical (how much renewable energy is available, when, and at what cost?) so that Germany's industrial sector can invest now in sustainable production processes. Significantly accelerating the pace of change is no small challenge for policymakers and businesses. Nevertheless, it is a challenge that must be mastered already within this decade.



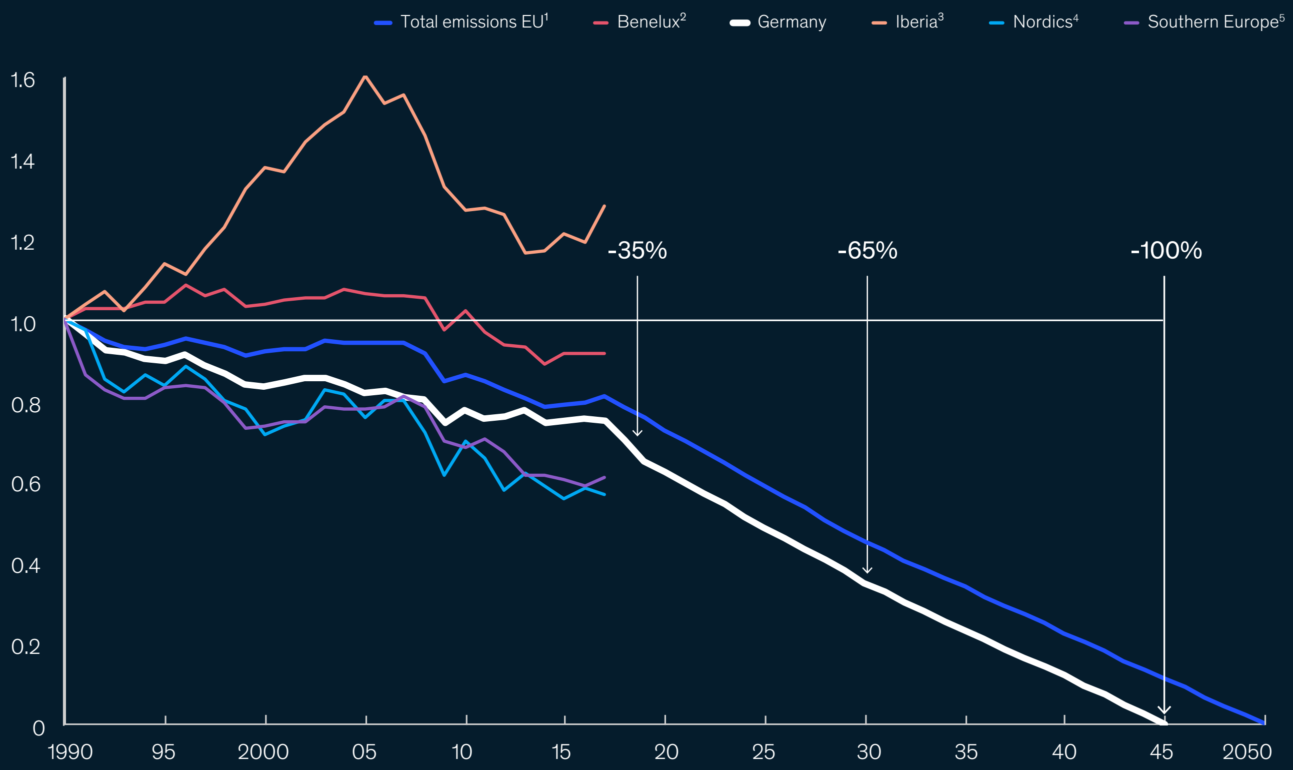
I. Climate neutrality is picking up momentum

There is more **power behind climate protection efforts** than ever before: countries and international communities are agreeing on climate targets, investors are shifting to climate-conscious portfolios, companies are voluntarily committing to reduce their emissions, and consumers are increasingly choosing to buy sustainable products (Exhibit 1).

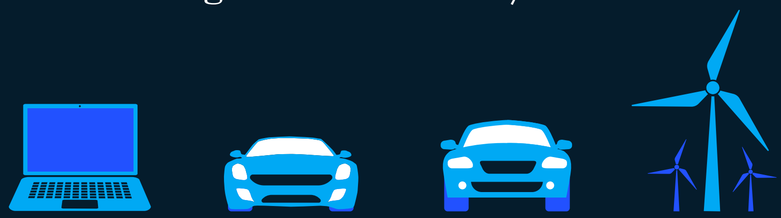
Exhibit 1

Climate neutrality is picking up momentum

Development of emissions, indexed (1 = 1990 level)



German companies are setting specific deadlines for achieving climate neutrality[6]



SAP	Porsche	Daimler	RWE
by 2023	by 2030	by 2039	by 2040

Population in favor of action against climate change

83%

of the German population believe that industrialized countries such as Germany have a duty to take the lead in climate action

Total volume of sustainable financial investments in Germany is growing

19% p.a. since 2010, most recently by as much as 25% from 2019 to 2020 (to EUR 335 bn)

Consumers attach more importance to sustainability

81% now pay greater attention to sustainability in consumption decisions than before and 69% are even willing to pay a higher price for products that are sustainable

1. Emission trends from land use, land use change, and forestry (LULUCF), waste and other sectors are included in total emissions but not shown separately in the graph; these sectors also show a decrease in emissions (and an increase in CO_2 sequestration through LULUCF) between 1990 and 2017
2. Belgium, Luxembourg, Netherlands
3. Spain, Portugal
4. Denmark, Estonia, Finland, Latvia, Lithuania, Sweden
5. Bulgaria, Greece, Romania
6. Nominal climate neutrality (i.e., including offsetting)

Source: BMU, Eurostat; EEA; FNG; KPMG; SAP; Porsche; Daimler; RWE; IFH Cologne; McKinsey

65%

emissions reduction by 2030 compared to 1990

Specifically, by 2030, greenhouse gas emissions in the EU are to be reduced by at least 55% below 1990 levels. That figure is a milestone on the pathway to a climate-neutral EU by 2050. Since 1990, Germany has successfully reduced its emissions by around 35% and is now planning to approve a new climate protection law with an even more ambitious target. Climate-neutral by 2045 is the goal[8] and by 2030, emissions should be reduced by 65% compared to 1990. Now, the task is to substantiate these legal provisions with concrete actions and speed up the restructuring process to make roughly the same reductions this decade as in the past 30 years.

Sustainability is also increasingly rewarded on the capital market. Sustainable businesses are not just more profitable with stronger growth, they also enjoy higher valuations (EBITDA multiples) and significantly higher TRS (total return to shareholders). In the chemicals industry, for example, firms that lead on sustainability have seen valuations two to five times that of their peers.[9]

As the world's largest asset manager, BlackRock has established clear guidelines to build sustainability into its investment decisions. As a result, on the one hand, some industries and companies are ruled out regardless of profitability expectations. On the other hand, BlackRock takes ESG (environmental social governance) criteria into account in its evaluation of potential investees. In an open letter to the world's CEOs, BlackRock CEO Larry Fink called for a clear plan to establish a sustainable business model compatible with a net-zero world.[10]

Investors and companies increasingly use ESG criteria as key metrics – though these are currently often inconsistent and lack transparency. More efficient, more objective allocation and pricing of capital requires the standardization and consolidation of ratings.

We are seeing the growing relevance of sustainability reflected in the global debt and equities market: green debt instruments grew at a rate of 72% a year from 2015 through 2020, reaching over USD 700 billion.[11] In the equities market, over 70% of net inflows in the EU in Q1 2021 were tied to ESG criteria (to put that into perspective: in 2014 it was 2%).[12]

8 Germany's federal government adjusted its climate targets under pressure from the Federal Constitutional Court. The judges appealed for an interim target in addition to the targets for 2030 and 2045: 88% less GHGs should be produced in 2040 than in 1990.
9 26 European chemicals firms; CPA; Refinitiv; McKinsey
10 BlackRock
11 Climate Bonds Initiative, J.P. Morgan Asset Management
12 Morningstar Direct; McKinsey

Many companies are preparing to undergo a "green transformation." Several major German firms have already announced their intention to take a leading role, aiming to be climate neutral within the next two decades (for instance, SAP by 2023, Porsche by 2030, Daimler by 2039, RWE by 2040). In the course of this, they plan to restructure their product portfolios, business models, and value chains.

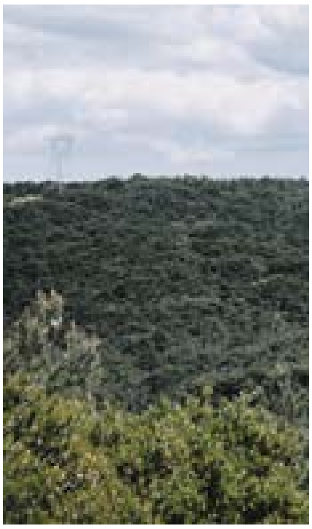
Ørsted is the global market leader in offshore wind energy and was named the world's most sustainable company in 2020. The conversion of its portfolio to renewable energies was accompanied by a realignment of internal processes (including extensive retraining, performance-based pay – 60% of which is linked to ESG criteria – and newly installed sustainability management) and has been extremely successful to date (ROCE up 39 percentage points since the portfolio was converted).[13]

Alongside investors and regulators, consumers are the motivating force behind this push for sustainability. Younger adults, Generation Z, and millennials in particular are passionate about sustainable consumption. Today, three-quarters of Germans say that they seek out green products while shopping.[14] Despite the often significant differences between the consumer preference for sustainability as expressed in surveys and their actual decisions in store (the attitude-behavior gap), growth rates for ecofriendly products have risen significantly. This is a hugely positive step since the food sector, as an example, produces around 25% of global greenhouse gas emissions.[15] Animal proteins make up a significant proportion of those emissions – vegetarian and vegan alternatives are greener.

Vegan food is more sustainable, an aspect that a growing number of consumers value. In 2018, the global market for vegan food was already worth around USD 14 billion; it is projected to pass the USD 31 billion mark by 2026, equivalent to an annual growth rate of roughly 10.5%.[16]

13 Ørsted, Corporate Knights Top 100 Sustainable Corporations
14 McKinsey
15 McKinsey
16 Allied Market Research

A commitment to sustainability makes companies more attractive employers.



Companies that make a commitment to sustainability also make themselves more attractive as employers – to existing staff and to potential new recruits.[17]

Patagonia, a manufacturer of sustainable outdoor clothing, is known not only for its apparel, but also its popularity as an employer. It has an employee turnover of only 4%; the industry average is 13%.[18] A recent analysis showed that its employees particularly appreciate the company's focus on them and on sustainability.[19] For example, Patagonia actively requires that employees be committed to climate action, be aware of environmental activism, bring experience in nonprofit organizations, and have an understanding of political processes.

[17] Talent Transfer, Peakon Post, Personalwirtschaft
[18] LinkedIn Talent Blog Patagonia Employee Turnover, LinkedIn Talent Blog Industries Talent Turnover Rates
[19] Great place to work

What does climate neutrality mean?

Climate neutrality refers to the balance of anthropogenic greenhouse gas emissions and their absorption or reduction in greenhouse gas sinks. When most people talk about reaching climate neutrality, they are referring to the need to reduce emissions. And yet, emissions caused by humans are almost impossible to prevent completely, which is why any residual emissions need to be offset by being stored in greenhouse gas sinks (for example, forests). Which is why climate neutrality means the same as net-zero emissions and net-zero.

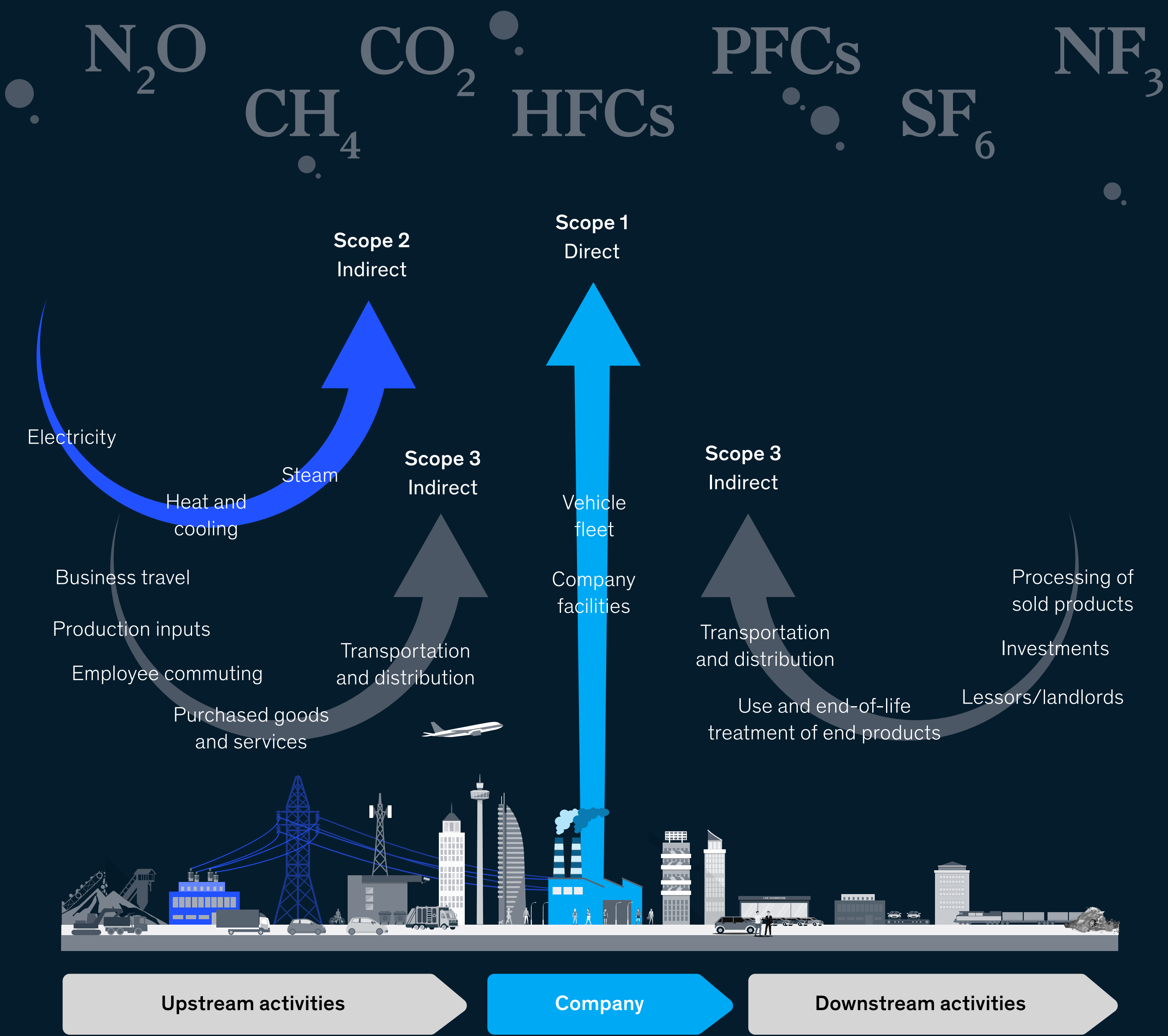
How do we measure emissions?

We can divide emissions into those with a direct cause and those generated in the downstream chain or during the use phase of a product or service – they can be split into emissions categories, also called “scopes.” Scope 1 emissions come from sources inside the observed system boundaries for a sector or company, such as a company’s own production facilities or fleet vehicles. Scope 2 emissions occur during the generation of power that is sourced externally, primarily electricity and heat from energy utilities. All other emissions are classed as scope 3, which are caused by a company but over which it has no direct control. These are emissions generated during the manufacture of supplier products or by service providers (scope 3 upstream) or emissions in the customer and end consumer setting (scope 3 downstream). An example of this would be the CO_2 emissions produced by a combustion engine when someone drives a vehicle (Exhibit 2).[20] The emissions statistics underlying this report generally refer to scope 1 emissions within the respective system boundaries.

[20] GHG Protocol

Exhibit 2

Emission categories (scopes) based on the Greenhouse Gas Protocol



Source: GHG Protocol

II. Fast and consistent action to secure opportunities for Germany

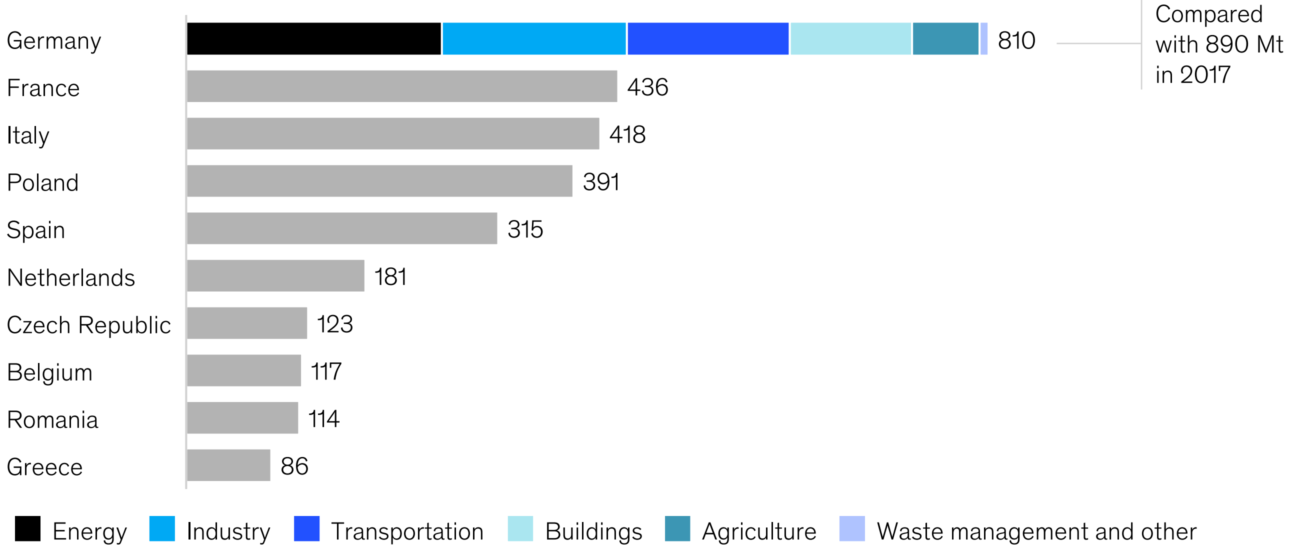
As Europe's largest economy and backbone of the European single market, Germany's transformation to a net-zero society is both a challenge and an opportunity. Countless economic structures have to be adapted, the energy system needs expansion and upgrading, and infrastructure requires modernization and more targeted expansion (Exhibit 3). Every sector in which Germany has historically been strong is facing challenges as well as potential for growth.

Exhibit 3

As Europe's largest economy, Germany plays a central role in the continent's transformation toward climate neutrality

Greenhouse gas emissions of the EU's 10 biggest emitters in 2019[1]

Mt CO_2e



1. In 2019, total EU-27 emissions amounted to 3,610 Mt CO_2e

Source: German Environment Agency

Most sectors are increasingly cognizant of the feasible and optimal transition pathways and decisions to be taken about net-zero trade-offs.[21] If Germany succeeds in establishing the necessary conditions in time and stays firmly on track, not only will we be able to complete the shift to climate neutrality on time, but at net-zero cost across all of society; the resulting savings would amortize the previously incurred costs. Assuming that Germany can realize this consistent and rapid energy transition, it will need to invest roughly another EUR 1 trillion in green capital expenditure by 2045 (excluding investment in research and development), (for example, in plants, motor vehicles, and heating technology (Exhibit 4). So-called "replacement investments" make up another EUR 5 trillion, that is, investments to be spent on replacing or maintaining existing infrastructure, systems, and buildings (for example, buying an electric vehicle instead of one with a combustion engine). The total investment volume of EUR 6 trillion includes public and private investment and equates to an average annual investment of roughly EUR 240 billion through 2045, or about 7% of Germany's GDP[22]. Of that, EUR 40 billion per year is additional investment (or about 1% of GDP).

[21] McKinsey (2020): Net-Zero Europe; Climate Neutrality Foundation; Agora Verkehrswende (2021): Climate Neutrality by 2045; German Energy Agency (2021): dena pilot study – "Aufbruch Klimaneutralität" [German only]

[22] In 2019, Germany's GDP was around EUR 3.5 trillion, of which EUR 2.4 trillion was in the transport sector, EUR 1.7 trillion in the buildings sector, EUR 700 billion in infrastructure, EUR 600 billion in energy, EUR 160 billion in agriculture, and EUR 100 billion in commodities (source: Statista [Germany only]).

Exhibit 4

Capital expenditure needed by 2045 for Germany to reach climate neutrality

~ EUR 1 trn

in additional private and public-sector capital expenditure[1]

~ EUR 5 trn

in replacement investments based on existing volume of private and public-sector capital expenditure[1]

1. E.g., plant, motor vehicles, heating systems

Source: McKinsey (2020): "Net-Zero Europe"

EUR 1 trillion

additional green capital expenditure needed in Germany by 2045

That need for investment arises in the context of a capital market where sustainable investments are steadily rising in both volume and importance, and new financing models are emerging. As such, the capital needed for rapid decarbonization is certainly available, and often at highly attractive conditions.

One consequence of this outlay will be significant potential savings that will help achieve climate neutrality via the optimal path at net-zero cost. The additional investment needed of around EUR 1 trillion would, taking an aggregated view across all sectors, be balanced by savings in operating costs. Buildings and transportation would absorb almost all of the savings generated while also benefiting from lower operating costs compared to a business-as-usual scenario. Around two-thirds of the total savings through 2045 would be generated in transportation, one-third in buildings.[23]

For example, improving insulation and switching to heat pumps reduces heating costs. The annual operating costs for electric cars are lower since electricity costs less than standard fuels, efficiency is higher, and maintenance costs are lower. While this is true from an aggregated and overarching society perspective, the individuals who shoulder the investment are not always going to benefit from the eventual savings. A good example of this would be an energy-based renovation of a rental home.

[23] McKinsey (2020): Net-Zero Europe

While the residents enjoyed lower heating costs, the investment would be made by the housing construction companies or other homeowners and is rarely amortized through rental income. So not every investment will yield a positive return. Where there is a negative cost balance and very long amortization periods, standards need to be defined or government incentives introduced – such as tax relief, subsidies, or CO_2 pricing – to activate the change and the requisite capital investment.

If Germany fails to establish the political, technological, and financial conditions for the transformation in time, then it is very likely that a massive financial burden will fall on private households and industry. This would be driven by higher energy system costs (both for grid expansion and to secure generation capacity, for example, through bottleneck situations) and rising CO_2 prices, which would reflect in household spending as well as production costs in local industry. In other words: the longer Germany takes to realize the energy transition, the greater the cost and the less socially balanced the outcome.[24]

As a leading industrial and export nation, Germany's efforts toward net-zero not only involve climate risk prevention, but also maintenance and growth in wealth and employment. We believe that Germany has an opportunity now to leverage its strengths and respond specifically and rapidly to these imminent challenges:

— Successful decarbonization can safeguard vast proportions of the workforce and GDP. In Germany this will affect around 15 to 20% of jobs and 20 to 25% of GDP,[25] primarily in sectors that make tradable goods, where a successful green transformation will secure the nation's position as a technology leader going forward. However, the transition will also trigger structural shifts in the labor market, for example, from thermal power generation to hydrogen production or from combustion engine manufacturing to battery production.

— Striving for climate neutrality can also serve as a catalyst for higher employment and greater wealth, as well as net growth in jobs – not only for Germany but for the whole of Europe. McKinsey's "Net-Zero Europe" study finds that Europe could see a net growth of up to 5 million jobs by 2050. Germany would be a part of that:

In the German building sector alone, the work to modernize existing buildings and enact other climate protection measures could create up to 200,000 additional jobs by 2050.[26]

Germany currently has more than 6,000 environmental and climate protection startups.

[24] Rising energy and consumer goods prices have a disproportionately negative impact on low-income households.
[25] Statista; McKinsey
[26] McKinsey (2020): Net-Zero Europe


- Employment figures will be driven by the competitive manufacture of green technologies in Germany. Among the fastest-growing areas are electricity generation from renewable energies, hydrogen production and conversion, batteries, grid and charging infrastructure expansion, machines and systems to restructure value chains, and new recycling technologies and processes for high-value secondary materials, including the necessary collection, logistics, and separation processes.
- Also important is the rapid growth in innovative startups in the field of environment and climate protection. Germany currently has more than 6,000 environmental and climate protection startups[27] but right now is still lagging behind other countries.

Scandinavia has seen a number of companies spring up in a very short space of time, including Northvolt (founded in 2016, estimated market value of EUR 10 billion)[28] and Freyr (announced a collaboration with Siemens Energy, Elkem, and others)[29] . Each of these firms has become an important player in the region and beyond, aiming to build gigawatt-scale battery cell factories and already achieving impressive growth.

Pre-IPO investments (that is, investments in unlisted companies) are seven times higher in the US than in Germany. In addition, the number of technology unicorns[30] per 1 million citizens is 4.5 times higher in the US than in Germany.[31]

27 Bundesverband Deutsche Startups: Green Startup Monitor 2020 [German only]
28 CNBC
29 Electrive
30 Startups valued at over USD 1 billion that are active with digital business models in B2B or B2C in Internet, software, or hardware (this definition includes, for example, advanced analytics and ad tech companies as well as semiconductor manufacturers)
31 McKinsey (2021): Germany 2030 – Creative Renewal [German only]

Germany has a good starting position

Germany can draw on its specific economic and industrial strengths to facilitate the transition to a net-zero society:

— The backbone of the German economy is an innovative industrial SME sector with strong export positioning and countless hidden champions; among which are numerous family-run businesses with a focus on long-term and sustainable growth.

- Mechanical and plant engineering and the electronics industry in Germany comprise more than 10,000 companies, many of which are world market leaders.
- The export rate for German mechanical and plant engineering is around 80%; 16% of global machine exports come from Germany. Measuring and testing technology accounts for the largest proportion of exports, yet there are other industries in Germany that rank first in the world on exports (for example, tooling machines, agritech, and process engineering machines and systems).[32]
- Industrial SMEs are hugely innovative: four in five companies launched at least one product or process innovation in the last year.[33] Germany also holds a massive number of patents. For example, more than 20% of all wind power patents have been awarded within Germany.[34]
- Mechanical and plant engineering alone employ around 200,000 highly qualified engineers who constantly strive for high product and service quality alongside innovative product ideas.[35]

— Germany has a sizable automotive industry with close partnerships in other industries and in the field of research:

- A vast research landscape and high R&D spend, especially in industry and transportation (more than one-third of global R&D investments in the automotive sector are made in Germany)[36].
- Many industry innovations in various sectors through close partnerships along the value chain.
- Intensive cooperation between business and academia (for example, through Fraunhofer Institutes); dual-track education and training that blends academics with vocational experience in a profitable way.

More intensive cooperation inside the value chain will be critical to decarbonization, and German companies are already putting in the effort.

In 2020, the CEOs at Volkswagen, SAP, and E.ON, alongside nine other leading European companies, joined forces to form the CEO Alliance to jointly drive the decarbonization of business, and of society itself.[37] Altogether its members bring in EUR 600 million in annual revenue and employ 1.7 million people. Their goal? To hasten the transition to a carbon-neutral economy through specific projects and partnerships; its members announced plans to invest more than EUR 100 million in their respective decarbonization roadmaps.

[32] VDMA (2020): Mechanical engineering in figures and charts
[33] In relation to mechanical and plant engineering; VDMA (2020): Mechanical engineering in figures and charts
[34] Bertelsmann Foundation
[35] VDMA/McKinsey (2018): Strategic Options for European Machinery
[36] German Association of the Automotive Industry
[37] Volkswagen

These companies are convinced that CO_2 targets can only be reached through intensive, cross-industry collaboration – hence the joint projects. In one such project, Scania and several energy suppliers are developing a concept to expand the charging infrastructure for trucks. To realize these concepts and establish the relevant conditions, the CEOs plan to amplify the conversation between business, politics, and civil society.

The key players along the automotive value chain – from raw materials to finished vehicle – (including BMW, Daimler, Volkswagen, BASF, Henkel, ZF, Bosch, and Scheffler) have joined up with leading technology firms (Siemens, SAP, and Telekom) in the European partner network "Catena-X."[38] Through this network, companies in the automotive value chain will be able to share data securely. One key use case is the urgent need for greater transparency on CO_2 emissions in the value chain, without which it will be impossible to identify and realize potential to reduce them.

— Environmental protection has been a hot topic in Germany for years already. As a nation it pursues a strategy of reducing environmental pollution through innovation, while simultaneously allowing new business areas and jobs to emerge.[39]

  - Environmental protection has been a government target embedded in the constitution since 1994. Germany has made considerable progress on air and water quality that helped, for example, lessen forest dieback in the 1980s.
  - Germany was also a pioneer in the growth of renewable energies and heralded the energy transition very early on. A number of wind power and solar companies originated in Germany, and the technologies were industrialized here (for example, more than 20% of all wind power patents have been awarded in Germany).[40]
  - And when it comes to cleantech – technological innovations that support the shift to net-zero – Germany is home to 276 of Europe's leading startups, which is around 24% of Europe's pool of climate tech startups.[41]

38 Catena-X
39 Facts about Germany
40 Bertelsmann Foundation
41 With around USD 3.4 billion, Germany ranks second in Europe behind Sweden in terms of risk capital for climate tech startups; Speedinvest & Creandum Report (2021): The Growth and Future of Climate Tech Startups in Europe

It is important for everyone in Germany to act together, with determination, with ambition, and at speed. The transformation to a net-zero society is a major opportunity for Germany. However, efforts in some sectors have been nowhere near enough. Exhibit 5 shows that the work required to reach climate targets in the next ten years needs to be pushed further in some areas compared to the average between 1990 and 2020.

Transformation projects must be executed with greater resolve and much faster. This entails a regulatory framework and social landscape where green technologies can be realized even faster and more comprehensively. Not to mention the fact that we need to see a marked increase in spending on environmental and climate protection, which in 2019 was still below the EU-27 average.[42] This is the only way to maintain and reinforce Germany's export-driven economy, global competitive ability, and local value creation in a rapidly evolving world.

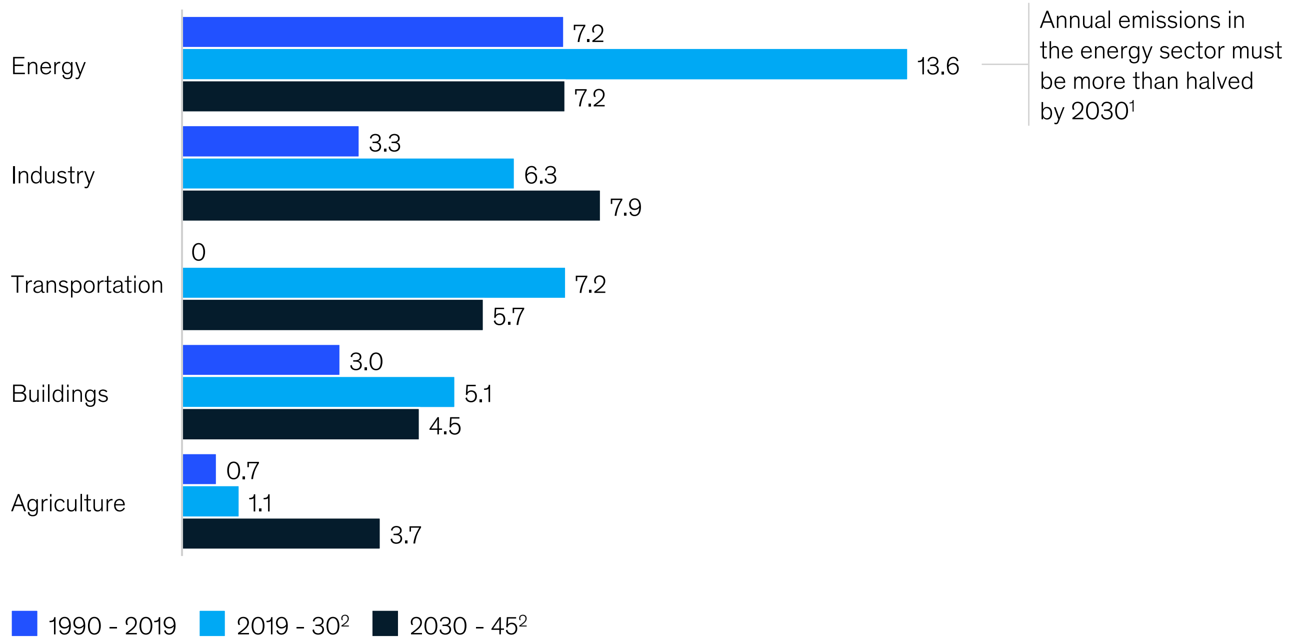
Our next section explores the core initiatives and enablers in various sectors that will facilitate a successful transformation.

42 McKinsey (2021): Germany 2030 – Creative Renewal [German only]

Exhibit 5

Significant cuts are needed in annual greenhouse gas emissions across all sectors

Average annual reduction in emissions by sector
Mt CO_2e



1. Compared with 2019
2. 2030 and 2045 targets according to the amendment to the Federal Climate Protection Act of May 23, 2021

Source: Federal Environment Agency; Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety; McKinsey

It is important for everyone in Germany to act together, with determination, with ambition, and at speed.

III. Tackling sector-specific challenges to set the green transformation in motion

Germany was able to reduce its greenhouse gas emissions by 35% between 1990 and 2019 (Exhibit 6). In the key sectors[43], the largest reductions were in power (-45%) and buildings (-41%), followed by industry (-34%) and agriculture (-22%). In transportation, however, emissions levels have barely changed since 1990 (+/- zero).

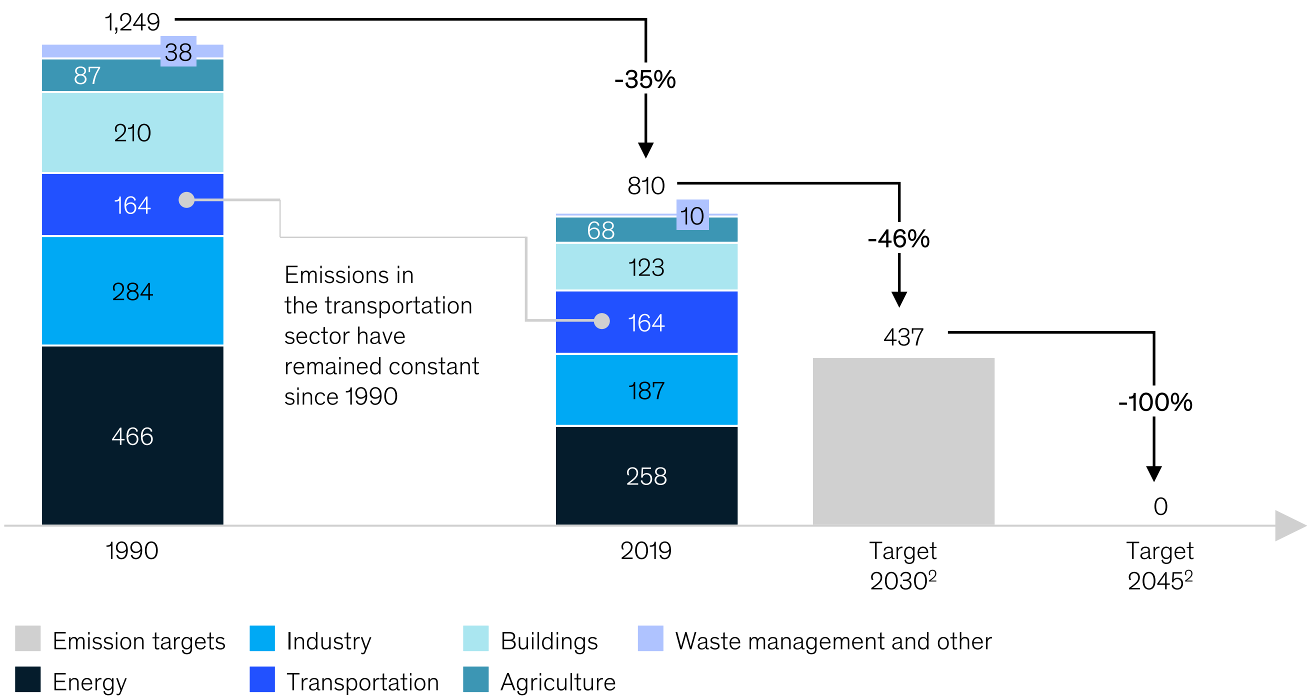
43 Excluding waste management and others

Exhibit 6

An annual reduction in greenhouse gas emissions is needed twice the average reduction achieved in the period 1990 - 2019

Historical and projected greenhouse gas emissions in Germany[1]

Mt CO_2e



1. Annual emissions reduction from 2019 to 2045 must average 31 Mt CO_2e; by comparison, an average reduction of 15 Mt CO_2e was achieved between 1990 and 2019
2. 2030 and 2045 targets according to the amendment to the Federal Climate Protection Act of May 23, 2021

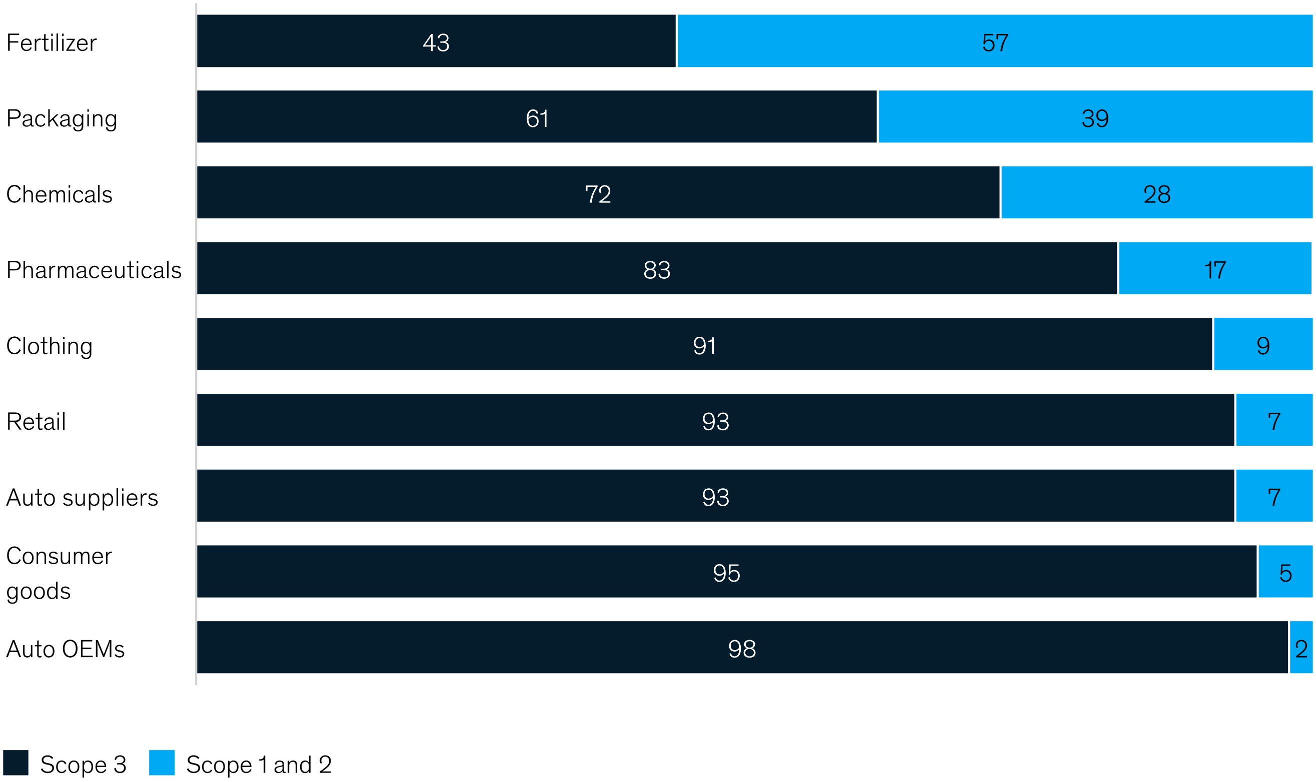
Source: Federal Environment Agency; Federal Government; McKinsey

In the next section we explore the core transformation-related initiatives in each sector. The various sectors are deeply interwoven throughout the value chain: power delivers electricity and heat to all users; the commodities industry supplies raw materials to the manufacturing industry. Which means that a company's or sector's emissions footprint is determined by the emissions it generates itself (scope 1), as well as the CO_2 emissions generated in the power sector for the electricity and heat consumed (scope 2) and the emissions in the supply chain and during the use phase (scope 3).

Exhibit 7

Overview of emissions in selected industrial sectors

Share of scope 3 emissions by sector,[1]
as a percentage of total scope 1 - 3 emissions, 2018, based on CDP[2] published data



1. Of selected companies
2. Carbon Disclosure Project

Source: McKinsey

Exhibit 7 reveals the share of scope 1 and scope 2 emissions compared to scope 3 emissions for various industries. It is clear that decarbonization of these industries will require fully customized approaches. For an automaker, the key issues will be the switch to electric vehicles powered by renewable energies and securing a sustainable value chain, while for the chemicals industry, the key lever will be to optimize internal processes and the raw materials used.

Across the entire value chain, innovations in product design and especially in materials – such as the trend toward fiber-based and recycled materials – are essential levers that can only be realized through intensive collaboration between all parties.

BMW has long emphasized that the raw materials it procures to manufacture vehicles need to be eco-friendly, socially balanced, and ethically responsible. Product designers and developers are experimenting with and using more recycled materials, for example, steel and aluminum, as well as recycled plastics like ECONYL® nylon, which is made from fishing nets and other nylon waste.[44] When it comes to the materials for electric vehicles, BMW is committed to more sustainable extraction of raw materials. To that end, the company procures lithium, for example, out of Argentina from the company Livent. Livent uses its own innovative process in which the brine is returned directly to the surrounding habitat, thus eliminating the standard evaporation ponds that consume vast quantities of water.[45] BMW also serves as an initiator and actor in cross-industry efforts, such as the "Responsible Copper Initiative" and the "Cobalt for Development" project, which is actively engaged in the move toward sustainable mining practices in the Democratic Republic of Congo.[46] Additionally, BMW has started leveraging its position as a key client to influence supply chains and make them more sustainable going forward.

Across the entire value chain, innovations in product design and especially materials are key levers in decarbonization.

44 BMW
45 Electrive
46 BMW

Power

258 Mt CO_2 equivalent greenhouse gas emissions in 2019 (32% of Germany's total emissions)

258 Mt CO_2

The power sector is absolutely central to the net-zero transformation. As part of the energy transition, Germany is phasing out fossil fuels and nuclear power, and so far this has been achieved mainly by drawing on the system's reserves. Growth in renewable energies is not yet keeping pace with the energy transition (Exhibit 8). Given that fossil fuel power plants and nuclear power stations are being decommissioned even though demand for power is rising, renewable energies need to be built out faster than ever before. That push/pull effect presents a major challenge to the power sector. For that reason, it will take larger investments in the very near future in both energy generation and grids to expand the system to a sufficient extent.

The current situation leads to two risk scenarios that feed into every decision and every action relating to climate neutrality. First is the fact that energy costs, especially the price of electricity, could keep increasing through 2030 due to scarcity of supply. We also cannot rule out periods during which demand for energy could exceed the amounts generated. Since these bottlenecks are unlikely to be covered by imports in the short term (Germany's neighbors are also on the path to electrification), it is possible that there might be temporary "load shedding," where specific electricity consumers have their supply shut off.

Germany has no time to spare in countering this through massively scaled and accelerated growth in renewable energies, alongside a steady increase in energy efficiency. The energy system also needs to be smarter and more flexible so that electric cars, for example, can charge up when there are larger quantities of renewable energy available. If the expansion is too slow or the demand for electricity cannot be made more flexible, there are potential alternatives to electrification available. These include the increased use of carbon capture and storage[47] and/or utilization (CCS/CCU) or the competitive import of green energies, especially green hydrogen produced from renewable sources.

Exactly how to derive a cost-effective yet viable transformation pathway from this solution space has not yet been decided or planned in any detail. Any pathway will require establishing the regulatory environment (for example, optimized authorization procedures, see core initiative 1) – and in such a way that the energy transition is structured to account for Germany's status as an industrial hub, as well as various social factors.

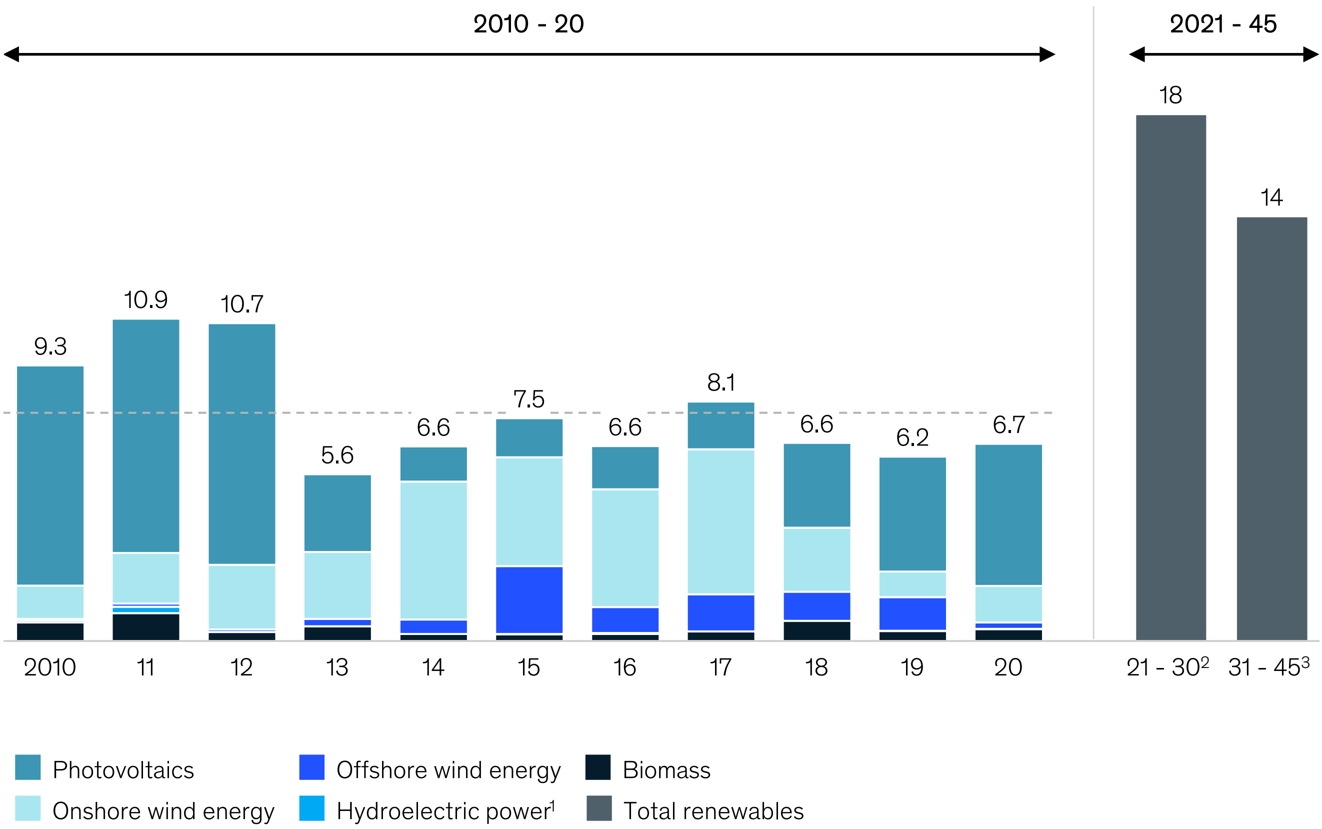
If one thing is certain, it is that unless we change course, private household and corporate demand for energy will not be met and climate targets will not be reached. The next few years will be critical in positioning the energy transition as a real and long-term opportunity for Germany, for example, by creating jobs in the expansion of renewable energies – at a socially just and competitive cost.

[47] We assume that CO_2 will mainly be stored offshore having been transported over land as is the case in, for example, the "Northern Lights" project in Norway.

Exhibit 8

The expansion of renewable energies must be massively accelerated and flanked with green imports

Annual net expansion of installed electricity generation capacity from renewables
GW



1. Run-of-river and storage hydroelectric power plants and pumped storage power plants with natural inflow
2. Based on the assumption that between 270 and 350 GW of renewable energy capacity will be needed in 2030
3. Based on the assumption that between 400 and 650 GW of renewable energy capacity will be needed in 2045

Source: Federal Ministry for Economic Affairs and Energy; McKinsey (2020): Net-Zero Europe

Core initiative 1: Massive acceleration (tripling) of capacity expansion in renewable energies
As mentioned above, it is vital to speed up the growth in renewable energies. Depending on the scenario, between 400 and 650 GW of installed renewable energy capacity will be needed in 2045, with 270 to 350 GW already needed in 2030. If the energy transition is not realized on time, new solutions will have to be found. Regardless of the eventual path taken to transformation, we can already assume that in climate-neutral Germany, various sectors will use 10 to 15 Mt a year of green hydrogen as a primary energy source.

And the majority of that green hydrogen will have to be imported. There are a number of financially viable transport routes: through pipelines – leveraging existing gas infrastructure – or by ship for ammonia and liquid hydrogen from regions further afield. There are various potential origin countries for imports to Germany through pipelines: in Eastern Europe, Scandinavia, and the Netherlands, from the Iberian peninsula via France, from Italy/North Africa via Austria, or from Russia. Imports by ship would also enable transport from the Middle East, South America, West and South Africa, Canada, and Australia. Germany is engaged in developing the relevant international trade agreements and consortia, most recently with its signature to a hydrogen trade agreement with Australia.

Alternative decarbonization pathways might also be necessary in consumer sectors (for example, steel or cement), such as CCS/CCU. This will mean reviewing and implementing cross-border CO_2 transport networks. Depending on how fast renewable energies grow, temporary technological solutions might be needed to bridge those CO_2 reductions, as well as in the long term to fully decarbonize industrial processes where decarbonization is a real challenge (for example, cement). Current calculations assume that up to 60 Mt CO_2 a year will be required (with subsequent transport to offshore storage or use in synthetic fuels or other products).[48]

The public sector will need to establish the preconditions to facilitate this growth. These include optimized participation and approval procedures (for example, adjusting existing regulations that govern the distance between onshore wind parks), development of a repowering strategy for existing renewable energy plants, and the provision of alternative financing models once the EEG levy (surcharge for renewables) is eliminated. The power industry (suppliers, operators, developers, etc.) must drive the expansion of renewable energy capacity at international and national level (including hybrid projects with generation and storage). This calls for active dialog between the energy industry, the public sector, consumers, and the general public to collaborate on speeding up regional expansion projects. Not only that, but the energy strategy must include a clear import strategy for developing future value chains and the corresponding infrastructure, such as refitting pipelines to transport hydrogen or upgrading ports to allow for imports of green ammonia.

Companies in the power sector also have no choice but to get involved in the provision of CCS/CCU infrastructure. One key step here will be to pilot CO_2 separation systems in partnership with local direct consumers (for example, cement and the chemicals industry). Sectors where decarbonization is a more long-term goal will have to tap into international partnerships with European neighbors, for example, Benelux countries, when it comes to carbon transport and storage.

[48] Agora Energiewende, Fraunhofer Institute, McKinsey

Ørsted and Siemens Gamesa launched a project in 2021 combining individual offshore wind turbines and an electrolysis system designed to operate in marine environments and transport the resulting green hydrogen back to shore. The system will also integrate desalination and water treatment processes, allowing it to use seawater as the feedstock for electrolysis. The project is funded by the Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 JU), a public-private partnership of the EU Commission.[49]

The Norwegian government in cooperation with the companies Equinor, Shell, and Total, is pursuing the Northern Lights project. Using a cross-border, open-source infrastructure, this project aims to transport CO_2 by ship to a terminal in western Norway for intermediate storage. From there, it is transported by pipeline for permanent storage in a reservoir located 2,600 meters below the seabed. Scheduled for completion in mid-2024, the first phase of the project will have a capacity of up to 1.5 million metric tons of CO_2 per year.[50]

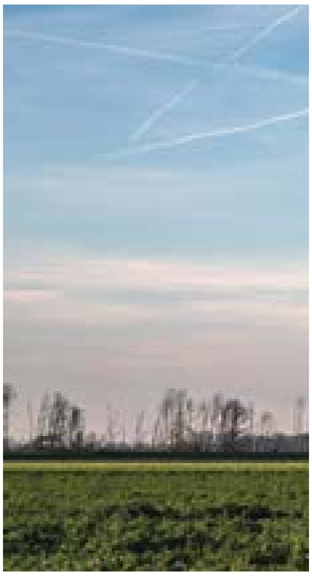
Core initiative 2: Expand (approximately 25% expansion in the power transmission grid) and increase flexibility of the energy grid

Regarding the grid infrastructure, we need smart and fast proliferation of interconnectors between Germany and surrounding countries, as well as faster construction of national power lines, especially along the north-south axis. This is absolutely essential to counter the growing volatility in electricity supply efficiently and effectively; said volatility being driven by the larger renewables share in power generation. A second draft of the grid expansion plan from April 2021 stipulates that by 2040, the electricity transmission grid will more than double in planned length from an additional 6,100 km to more than 12,700 km.[51] Right now the grid in Germany covers around 50,000 km, meaning the plan will add another 25% in length. The distribution grid is bearing the brunt of myriad renewable energies, e-mobility, and the majority of electrification. If we assume that its expansion needs to at least be on the same scale as these developments, Germany will have to add 400,000 kilometers of grid for a total grid length of almost 2 million kilometers.

The public sector will need to optimize participation and approval procedures for grid and interconnector development. Once that is achieved, the power industry (suppliers, operators, developers, etc.) can step in to drive cost-optimized grid expansion, for example, based on planning scenarios. This might involve actions to improve grid flexibility, such as realizing hybrid projects for energy generation, as well as storage or digital platforms for the flexible management and optimization of local energy grids. Given its central role in future energy, hydrogen demands a broader commercial infrastructure to include electrolyzers, pipelines, and reservoirs. To that end, existing infrastructure (for example, gas grids) has to be redesigned to leverage current capacities and organize bundled approvals.

49 Ørsted
50 "Northern Lights" project
51 NEP 2035, Version 2021, 2.Entwurf

By 2040, the electricity transmission grid will need to grow by another 12,700 km (+25% length).



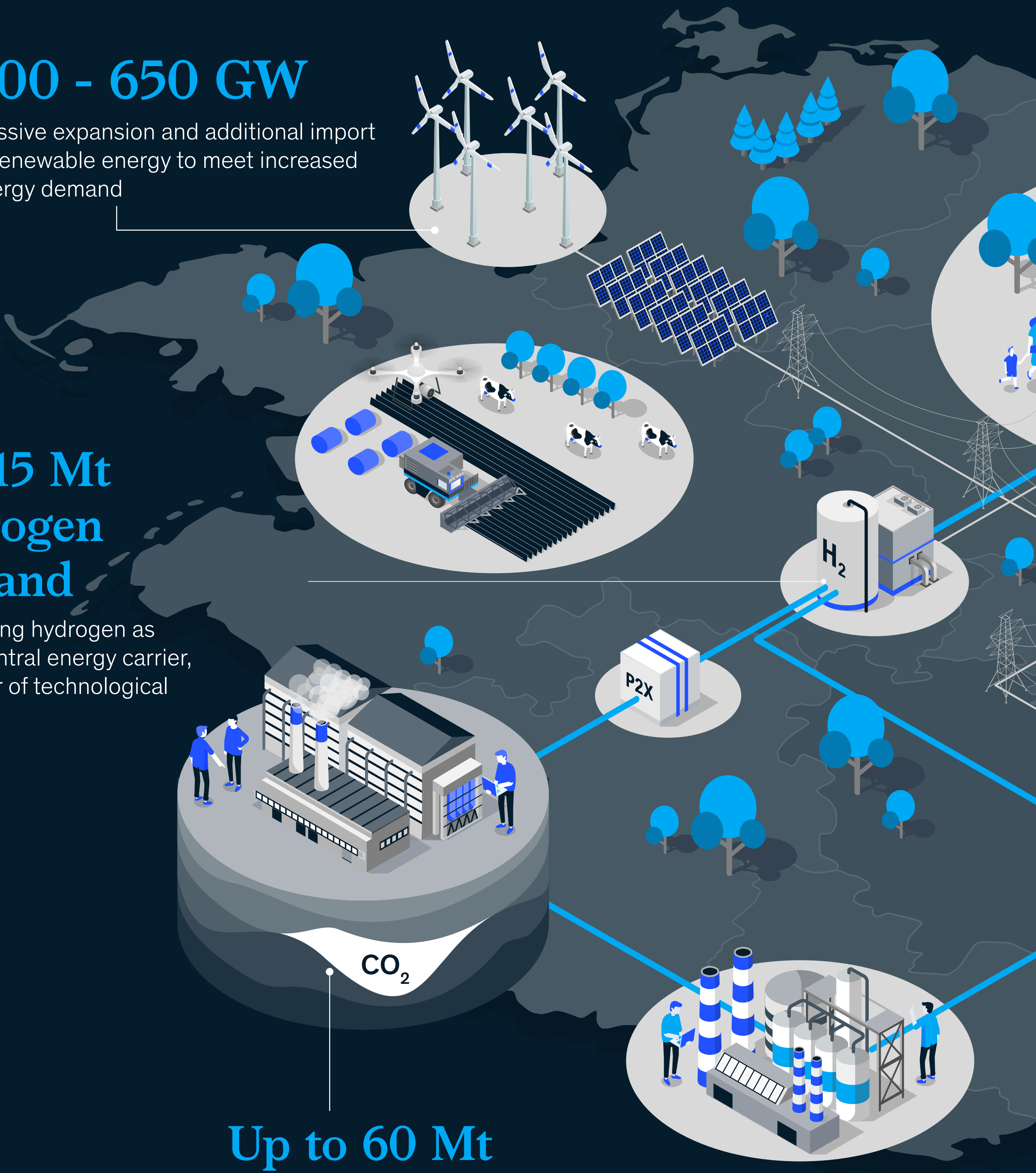
Converting electricity into hydrogen for onward transport can increase the efficiency of the energy grid. Compared to conventional power lines, hydrogen pipelines can carry up to ten times the energy at just one-eighth of the cost depending on how they are constructed. Plus, pipelines have a longer lifespan and serve the dual purpose of transporting and storing green energy.[52]

In July 2021, Shell's Energy and Chemicals Park Rheinland in Wesseling started up Europe's largest electrolysis plant, REFHYNE. The plant is now producing up to 1,300 metric tons of green hydrogen annually. Recent years have seen a cluster form in North Rhine-Westphalia for the production of green hydrogen, which currently covers around 30% of Germany's hydrogen demand. In response to the steep rise in demand, Shell is already planning construction of the successor model, REFHYNE II, for 2022. At 100 MW, the new model could provide up to ten times the capacity of its recently commissioned predecessor.[53]

[52] Hydrogen Council and McKinsey (2021): Hydrogen Insights, see also European Hydrogen Backbone, International Energy Agency
[53] Shell

Exhibit 9

Net-zero Germany 2045



400 - 650 GW

Massive expansion and additional import of renewable energy to meet increased energy demand

10 - 15 Mt hydrogen demand

Establishing hydrogen as a new, central energy carrier, and driver of technological change

Up to 60 Mt CO_2 storage p.a.

Cross-industry use of CO_2 storage systems

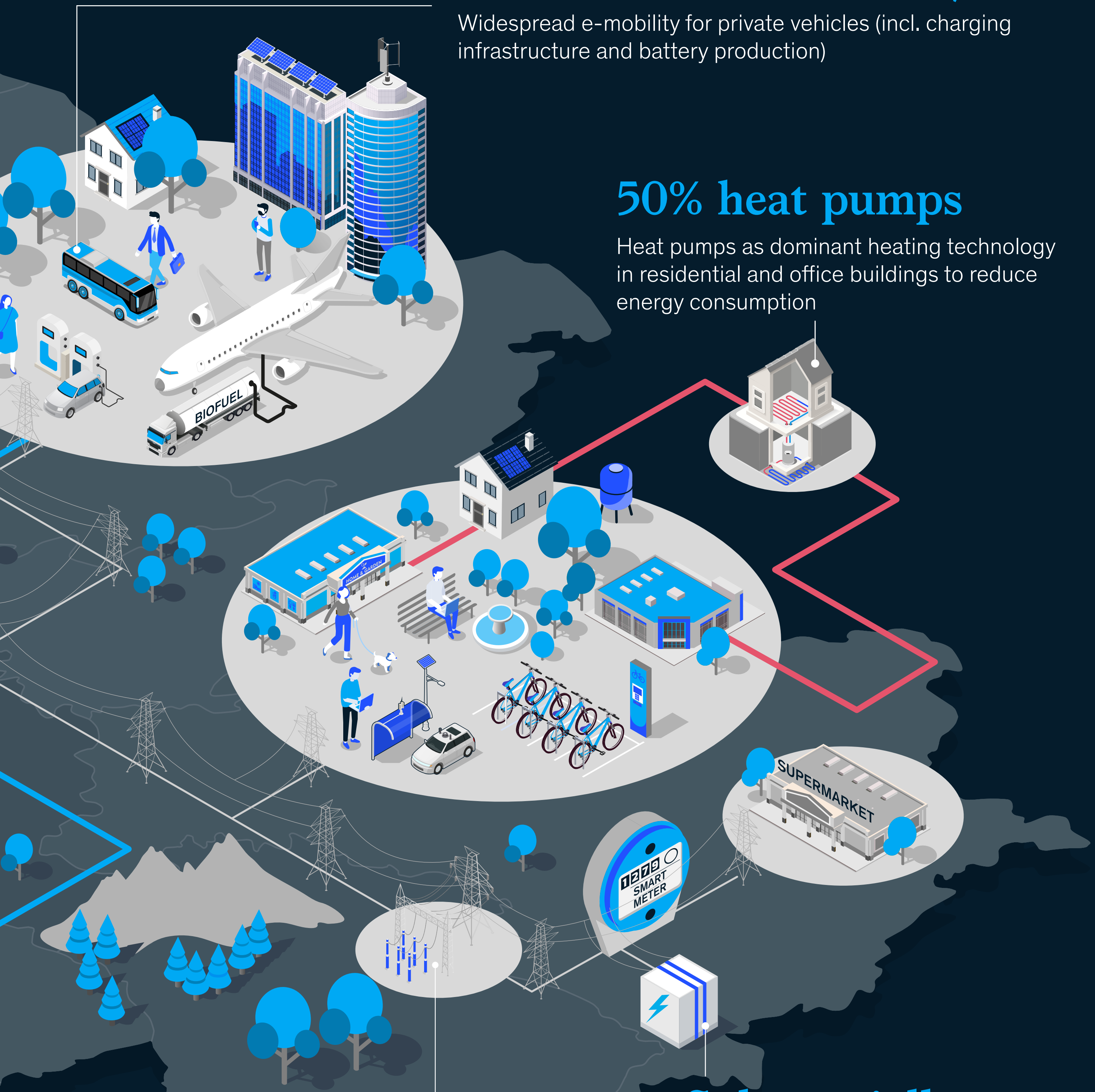
Source: Agora Energiewende; Fraunhofer Institute; NEP 2035, Version 2021, 2. Entwurf [German only]; McKinsey "Net-Zero Europe"

100% fossil-free mobility

Widespread e-mobility for private vehicles (incl. charging infrastructure and battery production)

50% heat pumps

Heat pumps as dominant heating technology in residential and office buildings to reduce energy consumption



> 60,000 km of power grid

According to the grid expansion plan, around 13,000 km of electricity grid are to be added by 2040 to ensure sufficient transport capacity in all directions, e.g., HVDC lines SuedLink, SuedOstLink

Substantially greater storage capacity

Increasing storage capacity and improving grid flexibility through centralized and distributed energy storage (e.g., compressed air storage)

187 Mt CO_2

Industry

187 Mt CO_2 equivalent greenhouse gas emissions in 2019 (23% of Germany's total emissions)

German industry is known for its strongest sector, vehicle and mechanical engineering, which contributes more than 50% of GDP (including electrical plants). The manufacturing industry causes only minimal scope 1 emissions amounting to around 5% of all CO_2 emissions from German industry.[54] However, these scope 1 emissions currently represent only a fraction of the whole footprint (Exhibit 7), which is why manufacturers will play such a vital role in optimizing upstream and downstream value chains.

Direct CO_2 emissions are highest in the commodities industry: metal processing – including steel, cement production, and chemicals – accounts for nearly 60% of Germany's industrial scope 1 emissions (Exhibit 10). Companies in these sectors have even more of an incentive to reduce emissions, not just due to rising CO_2 prices but also the growing demand for low-carbon and carbon-free raw materials for manufacturing. These are required by, for example, automakers, to meet their commitments to make cars that are CO_2-free throughout their entire lifecycle.

To illustrate the point: a typical carmaker today has a carbon footprint determined by the emissions generated during a vehicle's use phase. About 80% of those emissions are produced by fuel combusted as customers drive the vehicles; only 20% are produced during manufacturing, including upstream supplies.[55] The electrification of cars, combined with sourcing electricity from renewables, enlarges the carbon footprint attributable to the product's manufacture since battery production generates more CO_2 emissions than the production of internal combustion engines. A typical all-electric SUV currently produces a carbon footprint of around 10 metric tons of CO_2. 50% of this is attributable to the raw materials used (about 20% steel, 15% aluminum, and 15% plastics) and 35% to the battery.[56] All this makes the decarbonization of these materials by the commodities industry so important when it comes to making climate-neutral vehicles.

Core initiative 3: Decarbonization of the basic materials industry (green materials) through innovations in processes and plant engineering, driven by requirements from the manufacturing industry

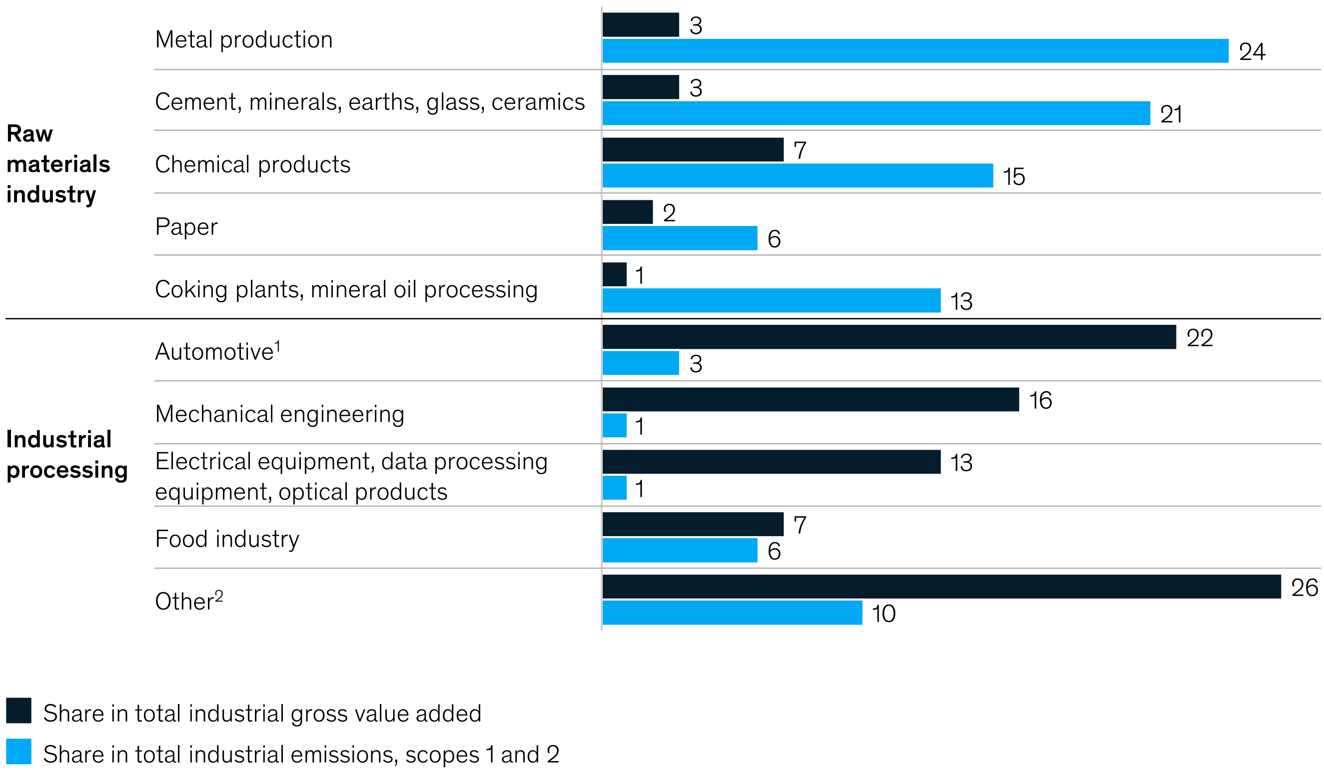
Generally speaking, the decarbonization of industrial processes is often time-consuming, necessitating massive investment and huge volumes of green energy. In light of the size and complexity of these processes, decarbonization requires a portfolio of zero-emissions technologies and actions for each specific industry. The commodities industry has a central role in this.

[54] Federal Statistical Office
[55] ICCT report
[56] McKinsey Sustainability Insights – Zero Carbon Product

Exhibit 10

Total industrial gross value added and greenhouse gas emissions broken down by sector

Percent



1. Motor vehicles, automotive parts, other vehicle construction
2. Wood, rubber, plastics, etc.

Source: German Federal Statistical Office

(1) Steel

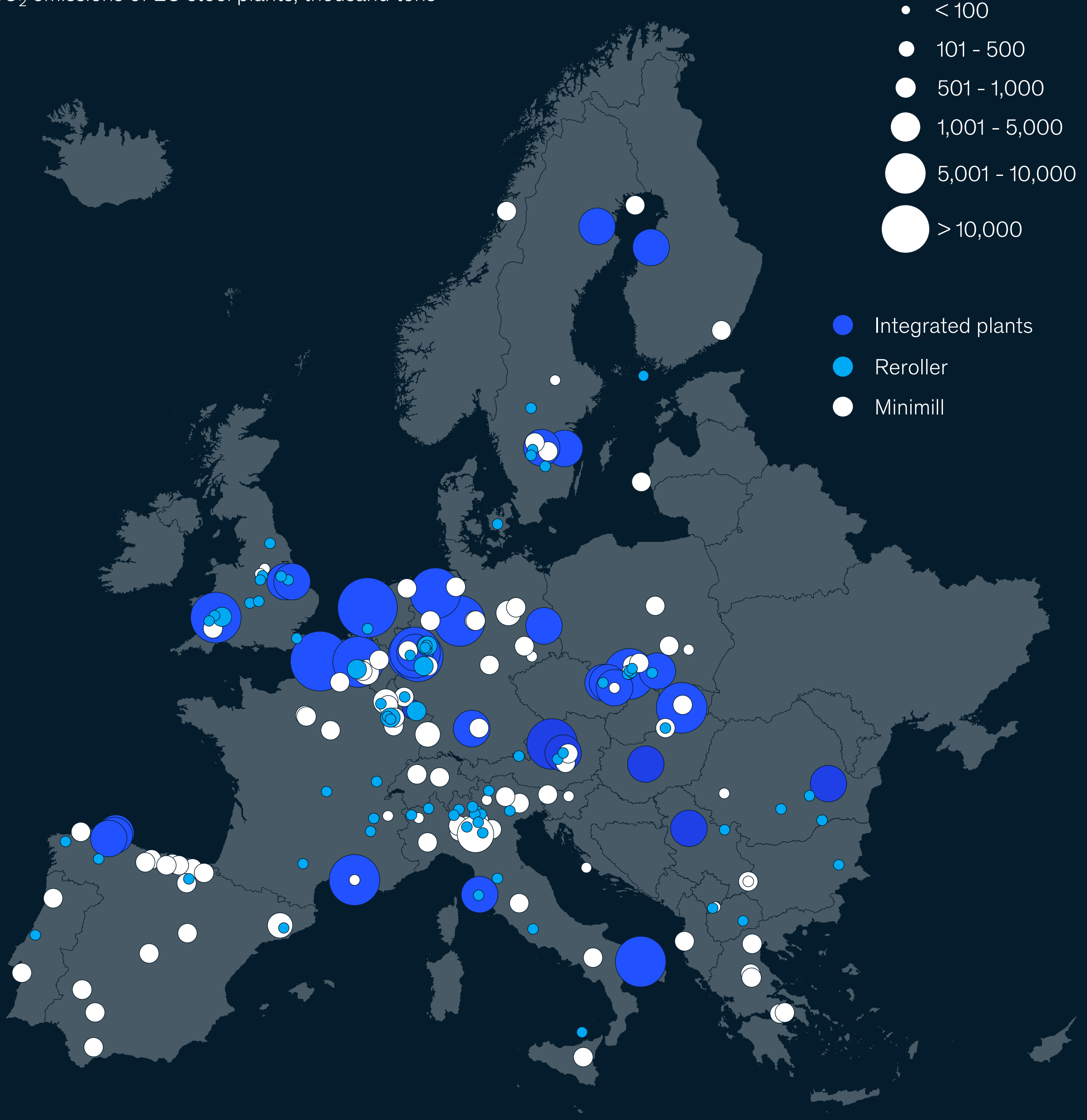
Exhibit 11 describes the CO_2 emissions produced by Europe's steel industry. Germany's steel industry has long produced relatively consistent quantities: 40 to 45 Mt of steel a year,[57] where each ton of steel accounts for around 1.5 tons of CO_2.[58] This chart clearly shows that decarbonization of the steel industry has to be a collaborative, Europe-wide effort, and that simply decarbonizing Germany will not be enough. That said, the higher costs incurred due to decarbonization must not be offset by imports of cheaper, non-decarbonized materials. And this must apply equally in every industry. As a proactive countermeasure, the EU Commission introduced the Carbon Border Adjustment Mechanism (CBAM) to prevent products and services made under less stringent conditions replacing Europe-made low-carbon products and services for cost reasons. This directive will go through a preliminary phase starting in 2023 and come into full effect in 2026.[59]

57 ZBW [German only]
58 IGM [German only]
59 EU Commission

Exhibit 11

CO_2 emissions can be analyzed by region and production process

2019 CO_2 emissions of EU steel plants, thousand tons



Source: McKinsey

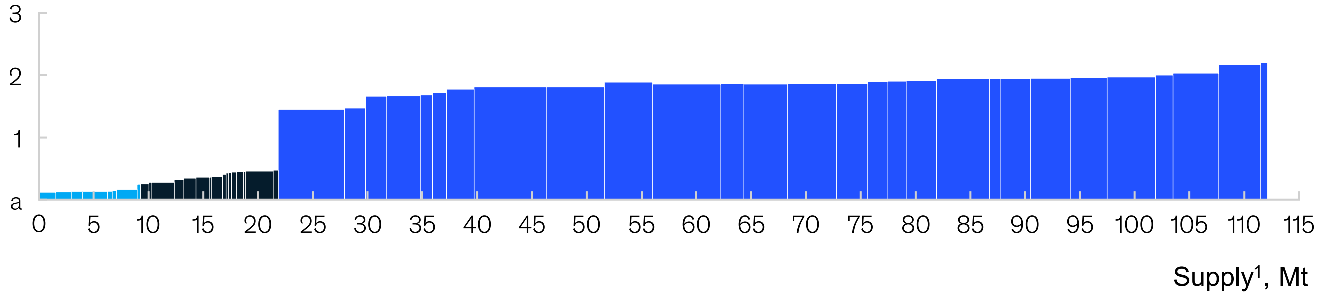
In the steel industry, CO_2 emissions depend on the production route and energy mix, meaning that different locations and technologies generate very different CO_2 emissions (Exhibit 12).

Exhibit 12

Depending on the production process, the emissions per ton of steel produced differ significantly (factor 5 - 10)

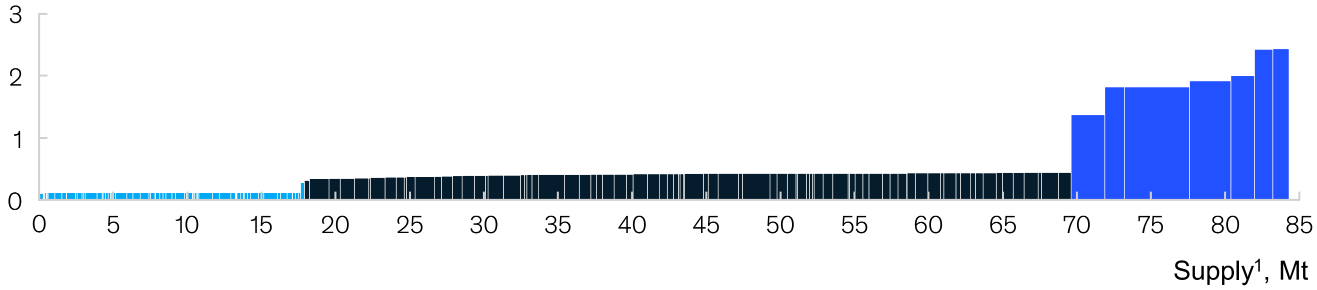
2019 CO_2 emissions for flat steel mills on plant level

Ton CO_2 per ton of hot rolled equivalent



2019 CO_2 emissions for long steel mills on plant level

Ton CO_2 per ton of hot rolled equivalent



Integrated plants Minimill Reroller

Source: McKinsey

Two production routes are in common use today: the blast furnace route and the electric arc furnace route. With the blast furnace route (BF-BOF route), coking coal is used as a reducing agent to make pig iron in a blast furnace. This makes the blast furnace route a "primary" route that turns ore into steel. The primary route is mainly needed to produce especially high-value steel, such as that used in vehicle construction. Not so with the electric arc furnace route (EAF), where electricity is used to smelt the feedstock. It is often referred to as a secondary route since in many cases it creates steel from scrap.

The average CO_2 emitted per ton of crude steel by the blast furnace route is around 2.3 tons, whereas the electric arc furnace route produces around 0.5 tons – depending on the electricity mix used[60] – so is much more efficient in terms of emissions.

There are three options to reduce CO_2 emissions in the steel industry:

— Continue boosting efficiency in the blast furnace route, for example, through the use of coke oven gas, the use of natural gas or hydrogen as a replacement or addition to PCI (pulverized coal injection), or by driving the use of scrap in the converter. We believe that over the next ten years, these actions can potentially reduce emissions by 15 to 20%.[61]

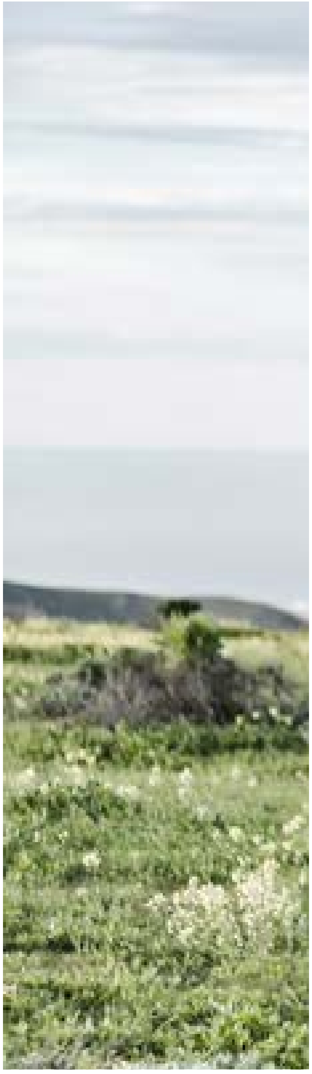
— Increase the share of the far less carbon-intense EAF route combined with higher rates of steel recycling. This demands a stable supply of (high-)quality scrap, that is, containing as few impurities as possible. With the EAF route, it is also vital that the electricity be drawn from renewable sources to reduce emissions even further. This could result in an additional 15 to 25 Mt of steel being produced in Europe each year.[62]

— Use green hydrogen as the preferred reducing agent. In the primary route, green hydrogen is replacing coking coal in the production of pig iron through a combination of direct reduction and an electric arc furnace. Iron ore is fed through a direct reduction system instead of a blast furnace, using green hydrogen to make the process CO_2 free. The resulting sponge iron then moves into an electric arc furnace where it is turned into pig iron or crude steel. This relies on an adequate supply of green hydrogen and pellets of DR iron[63]. Using hydrogen and electricity from renewables makes it possible to almost fully decarbonize steel, which is then referred to as "green steel." This route allows for CO_2-free production of high-quality steel.

Swedish start-up H_2 Green Steel (H_2GS) was founded in 2020 with the aim of producing its first green steel in 2024 – 2.5 Mt per year from 2026 and 5 Mt per year from 2030. Mercedes-Benz was the first carmaker to partner with the start-up to establish a green steel supply chain.[64]

All actions designed to reduce levels of CO_2 emissions in the steel industry result in higher costs (around 20 to 25%)[65] and some will require massive investment in new facilities. Moreover, each action depends on successful infrastructure expansion, especially considering the vast quantities of green energy required.

60 MPP report
61 For a combination of all possible actions but with no improvement in steel performance; McKinsey
62 McKinsey
63 DR = direct reduced
64 H_2 Green Steel
65 McKinsey



(2) Cement

Since 1990, German cement makers have successfully reduced both relative and absolute CO_2 emissions by around 20 to 25%[66] through the more traditional options available to this industry:

— Improving thermal efficiency

— Reducing the clinker-to-cement ratio (cement clinker is the burnt component of cement and acts as a hardener when mixed with water)

— Increasing the use of alternative, biomass-based fuels to replace the majority of fossil fuels.

Producing around 20 Mt of emissions, cement is one of the biggest industrial emitters[67] and decarbonization is considered a major challenge since some of the emissions are a chemical by-product of calcination, the process of making clinker. As such, the German cement industry is rapidly reaching the limits of technical process optimization in its efforts to further reduce CO_2 emissions:

— In 2019, almost 70% of fuel energy requirements were covered through alternative fuels. Boosting this to 85 to 90% by 2050 and switching to 35% biomass might be technically feasible, but assumes constant access to sufficient quantities of alternative, biomass-based fuels.

— The proportion of clinker in cement could be further reduced from the current 71% to less than 60%. The focus has shifted to the recently EU-approved CEM II/C cement, a multi-component cement with clinker, blast furnace slag (slag sand) and limestone. However, this is reliant on the steel industry since it supplies blast furnace slag to the cement industry.

— When it comes to energy requirements, Germany could potentially improve by around 20% compared to world-leading countries where plants and equipment are much newer. Significant capital would be needed for this.

Germany's Holcim Group has entered into a cross-sector joint venture with Raffinerie Heide, OGE, Ørsted, Stadtwerke Heide, Thyssenkrupp Industrial Solutions, and Thüga. The stated aim: to produce green hydrogen from offshore wind energy while also putting to use the resulting waste heat. The hydrogen will then be used to produce climate-friendly aviation fuels and will also be fed into gas grids. Unavoidable CO_2 from local cement production will be used to make non-fossil fuels.[68]

And yet these improvements alone will not be enough to reduce CO_2 on the needed scale. Appropriate actions to tackle, in particular, the CO_2 emissions associated with making clinker, will have to go deeper. One critical factor in the future decarbonization of cement and concrete will be CCU/CCS in cement plants and its further use in the production of synthetic fuels or chemicals.

[66] VDZ
[67] VDZ
[68] Westküste 100

Alternative construction materials, for example, cross-laminated timber, that replace cement are also essential. With valuable material properties and the ability to function as CO_2 sinks, these alternatives are currently enjoying more time in the spotlight (section 3 – Buildings).

Companies will use renewables to produce green hydrogen.

(3) Chemicals and pharmaceuticals
Producing around 30 Mt CO_2 equivalent, the chemicals industry is the third-largest industrial emitter.[69] If we add the carbon found in the fossil fuels (known as feedstock) and the end product to the energy-intensive processes, Germany's chemicals industry generates over 110 Mt CO_2.[70] There are three key mechanisms responsible for these CO_2 emissions:

— The use of fossil fuels for energy-intensive chemical synthesis (requires heat and power, especially for steam cracking to produce ethylene and other basic chemicals, and for hydrogen production in the manufacture of ammonia, methanol, and chlorine)

— The use of fossil sources as raw materials in organic chemistry (mainly polymers but also paints and varnishes), where the carbon is often released at the end of the product lifecycle (end-of-life emissions) as CO_2 through waste incineration, which increases atmospheric levels of CO_2

— Direct greenhouse gas emissions as a by-product of chemical reactions (primarily direct CO_2 emissions as a by-product of chemical synthesis and nitrous oxide production when making nitric acid).

[69] Federal Statistical Office
[70] VCI [German only]

Different products have vastly different levels of CO_2 intensity, driven by the number of conversion and synthesis steps that each product has to go through. Emissions can range in volume from less than 1 ton of CO_2 equivalent per ton of product to over 10 tons (including end-of-life emissions). Given the dependence on fossil feedstocks, diverse process variants, and the resulting energy intensity, decarbonization of the chemicals industry is also considered to be a major challenge. Nevertheless, there are various potential approaches to reduce its CO_2 emissions, such as:

- Reducing the energy needed in existing processes, for example, through better process management, higher equipment efficiency, reducing energy loss, and reducing quality- and process-related wastage of raw materials or the chemicals produced
- Switching to renewables, especially for the core processes of steam cracking and ammonia production. There are essentially two viable ways to achieve this:
  - Electrify the cracking process and switch to renewable electricity. Pilot projects are already underway and demonstration facilities are scheduled to open their doors in two to four years
  - Use green hydrogen to replace the emissions-intensive SMR process (steam-methane reforming). Green hydrogen can be supplemented with biomass (a full switch to biomass fuels is unlikely in the short term due to lack of availability, especially of biomethane)
- Generate extra momentum through changes to other basic processes (to be developed for each individual product, for example, use low-emission green methanol to produce olefin)
- Reduce the use of fossil-based raw materials through recycling or using biomass-based commodities.

End products in the chemicals industry, especially polymers, are often incinerated at the end of their lifespan. But these materials are valuable commodities and incineration should be avoided for sustainability reasons. To that end, we need to develop and put in place advanced recycling processes (including new chemicals processes) and higher-value or single-type circular logistics. Recycled HDPE, for example, is inherently lower in CO_2 and recently experienced a sales boom in the US. As a result, from 2018 through 2021 the price fluctuated between 50 and 150% higher than the price for new fossil-based materials.

Another option is to switch chemicals commodities to biomass. Recycling would initially be preferable over the use of biomass: it is achievable in the short term, whereas further development toward a biomass-based chemicals industry will take more research. Bio-based raw materials, which currently account for less than 1% of the total volume, will still be essential for a long-term net-zero path in certain end markets.

Reducing direct emissions from chemicals processes calls for a two-pronged approach:

— Transform potent greenhouse gases into less potent alternatives (such as the already established procedure to convert nitrous oxide into nitrogen dioxide using catalysts)

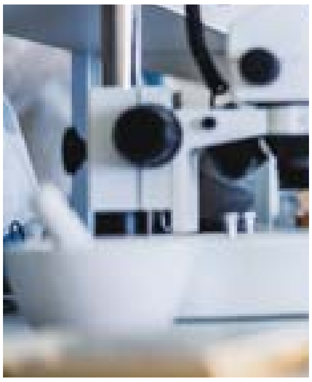
— Promote carbon capture and storage with subsequent direct use of the CO_2 as a chemical feedstock in a mix with green hydrogen (CCU). In Germany this process is limited to demonstration projects due to restrictions on timing and quantities.[71]

Most of these actions are technically feasible but are either still in development or being scaled.

There is one other option, and it is one over which end customers have control: the use of different types of materials with smaller carbon footprints. This is an opportunity for the chemicals industry to act as an innovation partner in product development, working with its customers to optimize the value chain.

Pharmaceuticals

Compared to other parts of the chemicals industry, the scope 1 and scope 2 emissions from the pharmaceuticals sector are much lower, mainly due to the smaller production volumes. The actions this industry needs to take, however, are very similar. Packaging is an essential factor: in many areas with far-reaching product safety and sterility requirements, disposable packaging is a must, though this is frequently made of glass or plastic. Ideally, resource consumption will be reduced through innovations in, for example, packaging technology.



[71] Federal Ministry for Economic Affairs and Energy [Germany only]

(4) Automotive
The automotive industry generates only minimal scope 1 emissions. That said, it will still play a prominent role in the decarbonization of the transportation sector since vehicles emit CO_2 for many years during their use phase. Manufacturers are responding by speeding up the electrification process and, slightly less often, switching to hydrogen engines.

3.1%

of all new vehicle approvals in Germany were for electric vehicles in

2019

including plug-in hybrids

In the first six months of

2021

that share had already risen to

22.5%

As a whole, the industry consumes a range of raw materials during production. These are supplied directly by the commodities industry and also the downstream processing chain. This particular supply chain generates massive emissions, which puts the automotive industry in an ideal position to leverage its requirements of suppliers to drive change throughout the entire value chain. In the past two years, German carmakers have set themselves some ambitious goals. As an example, Daimler intends to make its balance sheet carbon-neutral by 2039, Porsche by 2030.

There are several crucial actions needed to reduce automotive emissions:

— To reduce emissions in the use phase, traditional internal combustion engines need to be replaced with emissions-free drive technologies. Most automakers are opting for fully electric engines and, as a bridging measure, plug-in hybrids that run on battery power alongside an ICE. Green hydrogen in fuel cells or hydrogen drives are still an option for commercial and heavy vehicles.

  - New registrations of electric vehicles are rising fast. Back in 2019, electric vehicles made up just 3.1% of registrations, including plug-in hybrids. In Germany in 2020, 13.6% of new registrations were for electric cars (6.7% electric vehicles, 6.9% plug-in hybrids).[72] In the first six months of 2021, that percentage rose again to 22.5% (10.7% fully electric vehicles, 11.8% plug-in hybrids).[73] Through its most recent tightening of CO_2 targets in the Fit for 55 program, the EU is already leading the way: electric vehicles must account for 60% of new registrations by 2030. Model calculations, though, suggest that 60% will not be enough. By 2030, around three-quarters of new vehicles registered must be electric and continue to run on electric during the use phase (that is, plug-in hybrids would be permitted to use the combustion engine only in exceptional cases).

  - Alternatively, or in addition, there are other potential actions that would impact vehicles already on the road. For example, speeding up the replacement of high-consumption vehicles with newer, more efficient vehicles, and increasing the share of biofuels and e-fuels, that is, using synthetic fuels produced with electricity from water and CO_2. These are compatible with existing combustion engines. However, the majority of the biofuels and e-fuels available now will be needed to decarbonize the shipping and air freight sectors, as well as commercial road freight, for which there are only limited emissions-free options. Combustion-induced CO_2 emissions can be further reduced by driving only short distances, improving traffic management, and cutting the amount of parking available in cities (this currently accounts for 30% of the time for which people use vehicles in cities). Another step is to increase the number of people – the utilization – in each vehicle and encourage people to cycle and take public transport (see section 3 – Transportation). It is essential to speed up expansion of the charging infrastructure for electric vehicles since gaps in the network can be a barrier to adoption.

[72] KBA, vehicles by fuel type
[73] KBA, passenger car sector

- While the first generation of electric vehicle owners mainly charge up at home (in 2020, 80% of them in Europe had access to private charging stations), the next generation will rely more on public charging stations. By then, more than half of Europe's population will live in apartments with no access to private charging facilities. Additionally, charging stations in public spaces and along national transport routes will be needed to facilitate long-distance travel with electric vehicles. Production of charging stations will have to increase to keep pace with EU plans to install more than 15,000 units every week by 2030 (Exhibit 13). Approval procedures need to be faster and simpler – right now it takes up to three years to gain approval for a grid expansion to add a rapid charging station. An EU-wide charging grid is essential if we want to avoid stations being built only in profitable locations, meaning that electric car drivers are limited in where they can travel.[74]
- Stimulating sales of private charging facilities means increasing production capacity for wall boxes. We also need to solve the connection issues that already exist, for example, insufficient capacity in local electricity grids.
- By 2030, electric vehicles will consume on average more than 5% of electricity in Europe – a challenge that grid operators and electricity suppliers need to join forces to overcome. Consequently, during peak usage periods, the charging time, duration, and intensity must be reduced through "managed charging" (assisted by vehicle-to-grid technology as enabler). A scenario with appropriately managed charging facilities and incentives to charge outside peak hours would mitigate the majority of the impact on power grids.

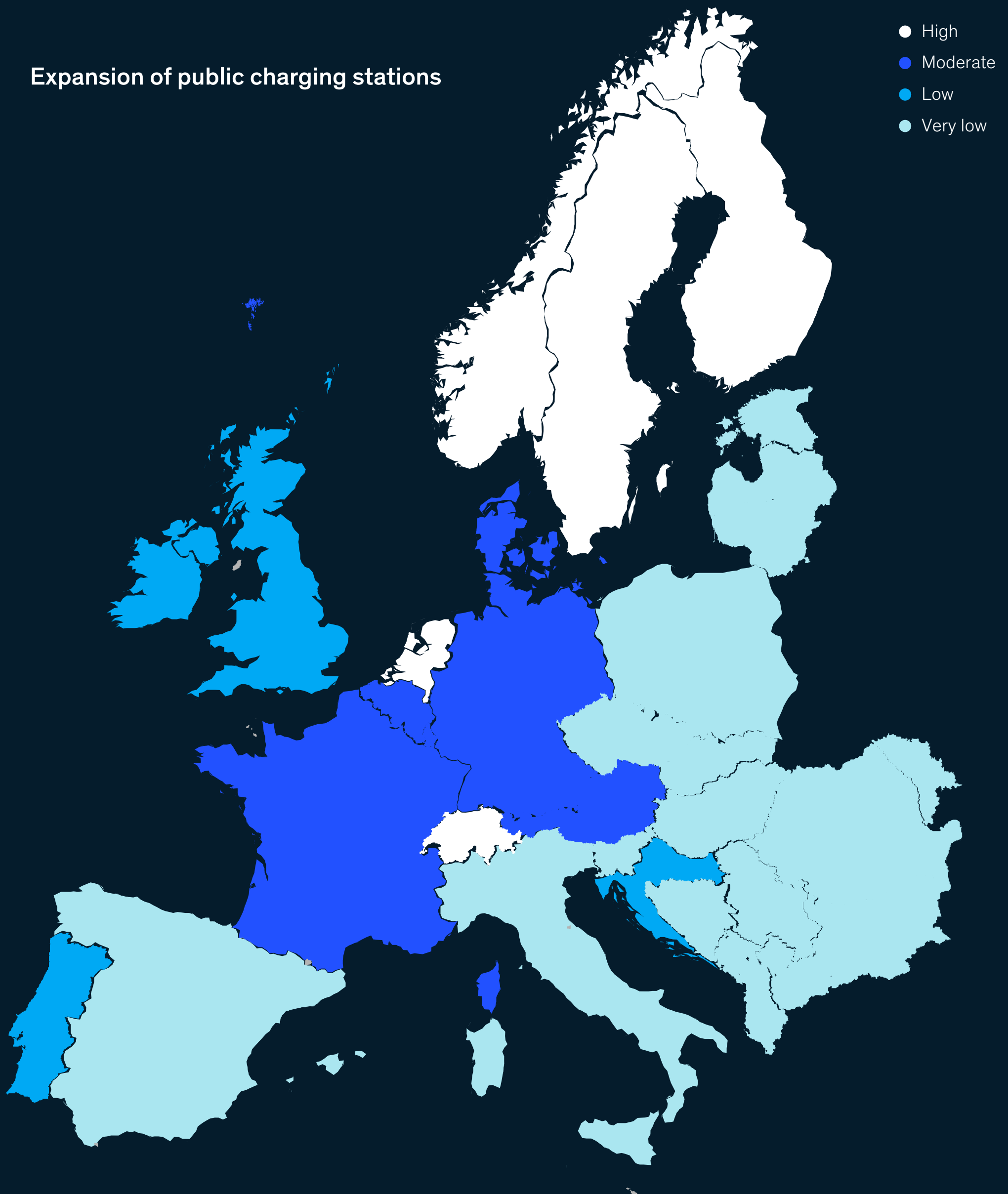
In 2030, electric vehicles will account for an additional 5% of Europe's current electricity requirements.

[74] IAA, McKinsey Center for Future Mobility

Exhibit 13

Electric vehicle charging infrastructure faces operational, regulatory, and financial hurdles

Expansion of public charging stations



Fast rollout

+15,000

charging stations to be installed per week[1]

High investment costs

90%

investments for < 25% of the charging points (fast charging)

Rollout in rural areas

30%

rural population

Public charging coverage

50%

European citizens living in apartments

1. Semi-private (apartments) and public chargers covered

Source: McKinsey Center for Future Mobility

— Expanded sustainable battery production will be needed to meet the increased demand for electric vehicles by 2030.

  - Production of every single component has to be ramped up at unprecedented speed – above all the production of batteries, the heart of any electric car. For three-quarters of newly sold vehicles to run on battery power by 2030, or in other words one in five cars on the road today, battery production needs to increase twentyfold from around 50 GWh in 2020 to around 950 GWh in 2030 (Exhibit 14).[75] At first glance, the production capacities already announced seem sufficient to meet demand. However, given the array of challenges relating to gigafactories (for example, the slow rise in earnings from battery plants, as yet insufficient capacity available with plant construction firms, potential insolvencies of new sector players), a temporary implementation risk is to be expected.
  - This will present opportunities for both German and European industry. Ten years ago, almost all cells were imported from Asia. Now there are local production centers, for example, in Eastern Europe. In future there could be multiple plants in key vehicle production countries (for example, Germany, Great Britain, and France) or in areas where green electricity is readily available (for example, Norway and Sweden). We are already seeing bottlenecks in battery production plants, especially in terms of coating, drying, and calendering. This a short-term opportunity for mechanical engineers that can quickly get to grips with these technologies, since supplier capacities in Asia are already nearly exhausted.

With demand for battery capacity growing, Volkswagen and its partners have plans to start up six cell factories by 2030. Once completed, these will produce cells with an energy value of 264 GWh per year – four times the level of European cell production today. As a first step on that journey, Volkswagen has partnered with Swedish star-tup Northvolt, whose goal is to produce batteries with an 80% smaller carbon footprint.[76]

The battery manufacturers face three main challenges:

— First, the entire battery value chain has to be rigorously decarbonized as batteries contribute almost 35% of scope 3 emissions.[77] Emissions can be drastically reduced through the use of green electricity in energy-intensive production alongside technological innovations (for example, lithium metal anodes).

— Second, the issues with raw material supplies revolve around securing sufficient quantities in a sustainable way to meet ESG criteria. While delivery quantities of all the most important raw materials (for example, nickel, cobalt, lithium, and graphite) need to be scaled at speed, nickel is likely to be the scarcest in the short to medium term.

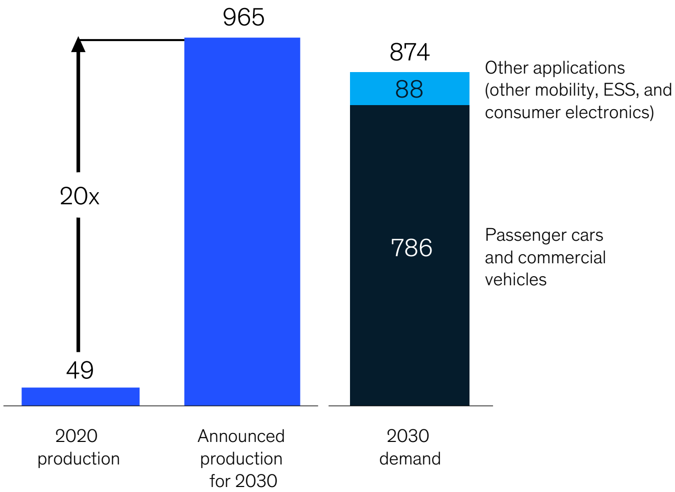
— Third, battery recycling is key. By 2040, 30 to 45% of the raw materials contained in batteries can be introduced into the recycling system.[78] It takes less energy to transform them into new batteries, which reduces the CO_2 emissions.

[75] McKinsey Center for Future Mobility
[76] CEO Alliance, see also: Northvolt, Volkswagen
[77] ICCT report
[78] McKinsey

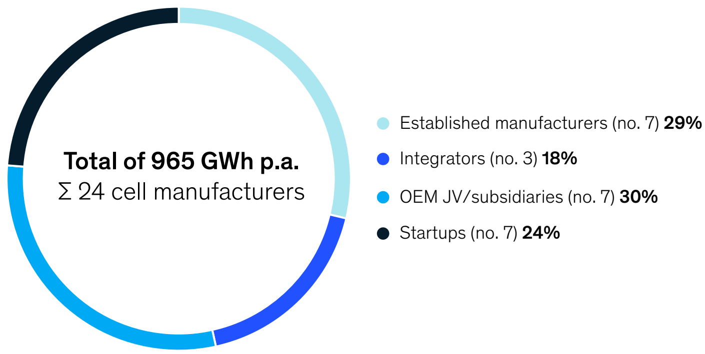
Exhibit 14

The EU has sufficient battery cell production to meet demand

Demand for battery cells and announced supply
GWh, accelerated demand scenario



Battery cell manufacturers by archetype in Europe 2030
Number of manufacturers, percentage market share of total production capacity



Source: McKinsey Center for Future Mobility; McKinsey Battery Support Tracker (August 2021)

— The supplier industry is focusing on imminent structural changes and ways to reduce supply chain emissions.

- Massive structural shifts are underway caused by fast and mammoth changes in drive-train technologies. Components only used in car combustion engines, for example, conventional drives, engines, and fuel injection systems, will see a significant drop by 2030 to around half the 2019 market volume.[79] Components that are critical to electrification (for example, batteries and electric drives) and to autonomous driving (for example, LiDAR[80] and radar sensors) will account for roughly 50% of the total market volume by 2030 (Exhibit 15).[81] This dramatic shift will see the supplier industry forced to adapt, and fast. And this is no small upheaval: according to information from the Institute for Economic Research (ifo) in Munich, by 2030 more than 100,000 jobs in the German automotive industry will be transformed.

- Not only that, but the supplier sector and its own raw material suppliers will have to deal with the decarbonization of products along the entire supply chain. For electric vehicles,

79 McKinsey
80 Light Detection and Ranging
81 McKinsey (2021): IAA article

50%

of the total emissions from manufacturing an electric car come from extracting and pre-processing materials such as steel, aluminum, and plastic.

the extraction and pre-processing of materials such as steel, aluminum, and plastic represent almost 50% of total emissions.[82] Collaboration between manufacturers and their suppliers will be essential in developing lower-emission and emissions-free cost-effective materials and precursors and driving them through to series production. With development times of four to five years, these companies must get started right away if they want to offer a serious contribution to reducing supply chain emissions by 2030. A few OEMs and raw material producers have already launched strategic partnerships to secure access to the most sustainable resources (for example, green steel, or lithium and cobalt for battery production).

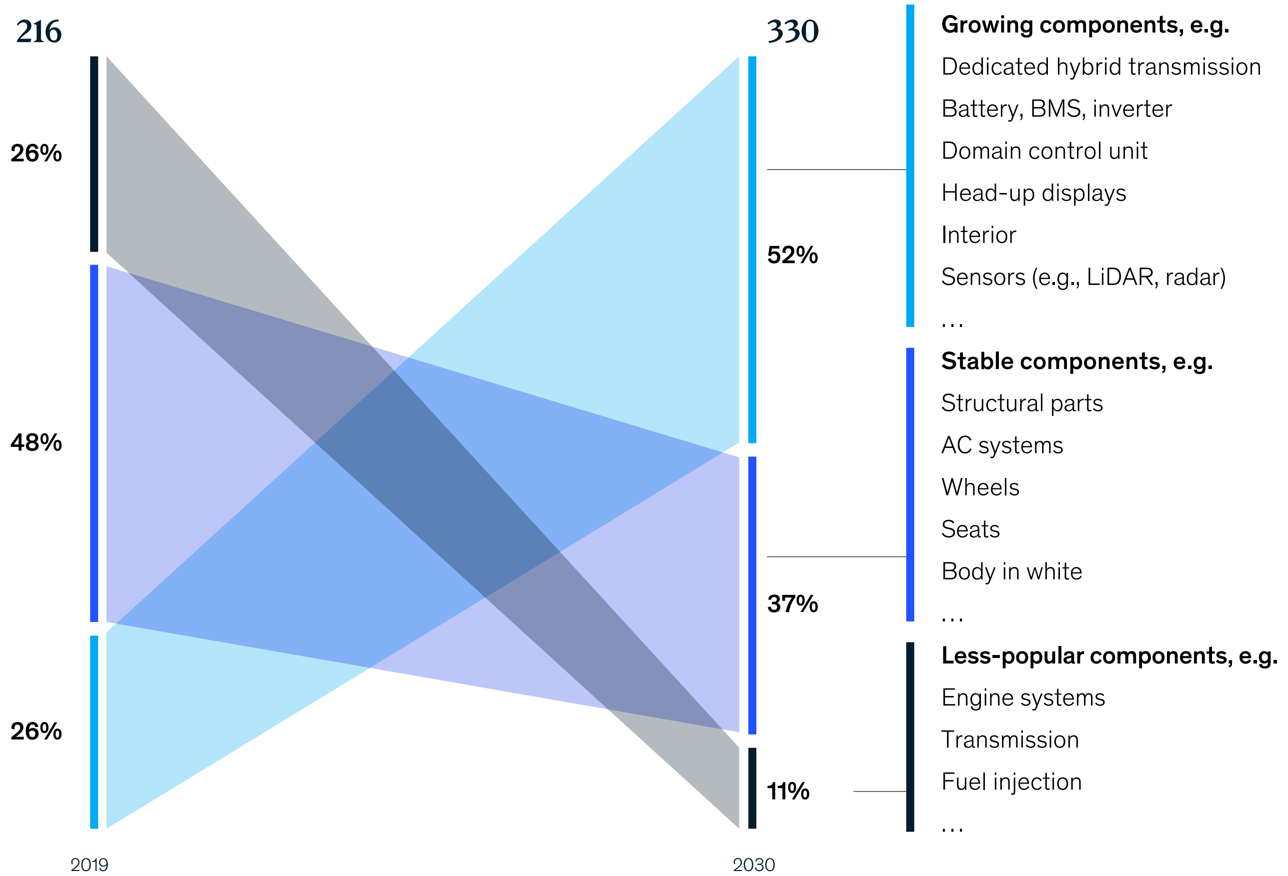
[82] McKinsey Sustainability Insights – Zero Carbon Product

Exhibit 15

Electrification will lead to a major shift across the entire supply chain

Accelerated scenario, European market

Development of market size
EUR billions



Source: McKinsey Center for Future Mobility

Plus, the car industry is working on vehicle concepts to further reduce emissions in the transportation sector: self-driving cars, sharing concepts and business models, and better connectivity should make the transportation sector more resource efficient in future.

In principle, the bus and truck industry is subject to the same measures, though in reality the circumstances are often wildly different. The use of hydrogen in engines is more interesting for use in trucks than in cars, since the heavy batteries rapidly reach their maximum permitted load and longer charging times mean they become less flexible. When it comes to decarbonizing the truck and bus supply chain, the smaller quantities produced mean this sector has far less influence, and manufacturers are reliant on closer collaboration and on suppliers assuming a more active role in decarbonization.

(5) Mechanical engineering
Mechanical and plant engineering tends to produce minimal scope 1 emissions, that is, the emissions from its own processes and systems. However, the industry does have both upstream and downstream value chains (scope 3), giving it significant influence on sustainability and decarbonization: in the upstream chain through buying materials with a specific carbon footprint; in the downstream chain through the emissions generated when operating machines and systems. In this way, for example, a company that makes machines for the food and packaging industry can sway decarbonization efforts by joining forces with its customers to develop sustainable packaging solutions and make machine operations energy efficient. This is the vital role of mechanical and plant engineering in the decarbonization of the economy.

In turn, decarbonization is an opportunity for German mechanical and plant engineering firms to deploy leading technologies to develop a strong sustainability value proposition. While reinforcing the role of the industry in global competition, this will also further improve its export position and create jobs.

Now more than ever, German mechanical and plant engineers are called on to apply their innovative capabilities to drive decarbonization in their industry. Decarbonization presents some significant growth opportunities, for example, as battery cell production capacity in Europe ramps up there will be bottlenecks in the relevant machines and systems. Given the need to meet e-mobility targets, calls for innovation in the battery production process are getting louder. There is likely to be a similar radical increase in demand for equipment to manufacture, transport, and store hydrogen in the next few years. The process technology transition in the commodities industry, increased material recycling, and CCUS[83] systems technology are other potential growth areas.

Nel ASA, a Norwegian supplier of solutions for the production, storage, and distribution of hydrogen from electricity, is the world's largest and most successful electrolyzer manufacturer with annual growth of 15% and an order backlog 1.5 times its annual revenue (around EUR 90 million at the end of 2020).[84]

And who would be better equipped to meet all these needs than Germany's mechanical and plant engineering firms with their powers of innovation? But with this opportunity comes a clear risk: future winners must set out and take courageous decisions right now, not in a few years' time. And the winners will not stand alone, but rather will unite with their customers and partner with other businesses in their upstream and downstream value chains to develop sustainable solutions.

Packaging machine makers, such as Syntegon[85], Multivac[86], and Rovema[87], are developing concepts using mono-materials and fiber-based materials as a way to steer their customers toward more sustainable solutions.

[83] Carbon capture, utilization, and storage
[84] Equinor
[85] Syntegon
[86] Multivac
[87] Rovema

To decarbonize the heat generation involved in industrial processes and district heating in urban areas, companies such as GEA, Siemens Energy, and MAN Energy Solutions offer high-performance heat pumps that replace conventional heat sources (for example, gas and oil furnaces), making a significant contribution to sustainable heat supply. These and other electrothermal systems also allow energy to be stored in the form of heat and cold (for example, for grid stabilization) as well as providing an efficient means of reverse power generation where needed.[88]

[88] European Heat Pump Association (EHPA)

Core initiative 4: Accelerated development of cleantech enablers – hydrogen production and transportation, battery plants, charging infrastructure, recycling

Germany is a vibrant business hub, with a strong industrial structure on which it will still depend in future. For this, there are several preconditions it has to meet:

— **Use electricity from renewable sources.** Green electricity is an energy source in itself and is also used to create green hydrogen (section 3 – Power).

— **Grow the hydrogen economy.** Net-zero Germany will have hydrogen as one of the main energy sources in almost every sector, lending it a system-relevant role. Green hydrogen is, among other things, used as a reducing agent in steel production, in vehicle engines, and as stored reserves to offset fluctuations in power generation from renewables. Building an efficient hydrogen economy – production, import, transport, storage, and conversion – will be absolutely critical. The fundamental aspects of a hydrogen economy have been outlined for example, in publications released by the Hydrogen Council.[89]

— **Switch the raw material base for industry.** Many industries are missing both a raw material base and the corresponding infrastructure to decarbonize.

- In steel production, everything depends on having enough pure, and ideally locally available, scrap for the EAF route, as well as enough (green) hydrogen for the DRI route and adequate procurement of DR iron pellets.
- In the chemicals industry, green hydrogen and biomass feedstocks are increasingly replacing oil-based raw materials.

— **Establish an efficient circular economy for material reuse and recycling.**

- Aluminum and plastics, and to some extent steel, can be recycled at high quality and deliver considerable CO_2 savings. Compared to the most sustainable type of primary aluminum, secondary aluminum, which is acquired through recycling, is one to eight times less CO_2 intense.[90] For recycling to be cost-effective, markets for reusable secondary raw materials have to be built that are large enough to make logistics, separation, and sorting processes efficient while also increasing quality. For this reason, product and process design must now take recyclability into account (for example, reducing the variety of materials, selecting suitable joining techniques and materials).
- Additional progress made on actual recycling (for example, better separation of individual components, chemical instead of mechanical recycling) can help the shift to a circular economy with high-quality recycling materials and lower emissions. It is therefore essential to drive expansion of the requisite infrastructure for collection, logistics, and separation.

[89] Hydrogen Council; McKinsey
[90] ScienceDirect

Assuming the industry can obtain sufficient quantities of high-quality aluminum scrap, it is possible to increase the share of recycled aluminum used in automotive production to as much as 70%, substantially lowering emissions. In 2020, BMW announced it had invested EUR 6.5 million to convert the press shop at its largest plant in Dingolfing, Germany, so it can recycle practically all of its aluminum waste. This is expected to save around 120,000 metric tons of CO_2 every year.[91]

Since January 2020, Daimler has been partnered with Israeli cleantech firm UBQ Materials to trial the use of sustainable plastic in car manufacturing. UBQ Materials has been using nonconventionally recyclable household and garden waste, including diapers, to make a bio-based plastic that is itself fully recyclable. Following a series of successful tests, Daimler and UBQ Materials are ready to test prototypes.[92]

- **Define a CCU/CCS framework.** CCU/CCS is expected to become a core technology in a range of industries, eliminating any emissions remaining after all process improvements. Still in the pilot phase, for this technology to succeed, a clear framework is required, one defined by business, politics, and science. A solution must be found for the storage of the captured CO_2. Support is needed to build a functional infrastructure to underpin newly emerging CCU/CCS value chains.
- **Facilitate a green battery value chain.** (Section 3 – Automotive)
- **Build sufficient charging infrastructure for cars and trucks.** (Section 3 – Transportation)

Other more general conditions also need to be met:

- A financing and subsidy concept for investments in R&D and in the development of new technologies (especially electrification concepts in the commodities industry, bio-based raw materials, and hydrogen technologies) as well as in new plants where significant capital is needed
- Innovative partnerships along the value chain to establish green products as the standard, including reducing investment risks through long-term purchasing agreements
- Transparency on supply chains to reduce specific emissions (for example, set up digital CO_2 tracking and certification for products and processes in the next few years)

In the automotive industry, for example, introducing a battery “passport” not only allows tracking of compliance with guidelines and emissions targets, but would also permit quality checks on the materials used in a battery, making end-of-life recycling much simpler.[93]

[91] BMW [Germany only]
[92] Daimler
[93] World Economic Forum

- Awareness among all employees of the urgency, challenges, and opportunities inherent in the green transformation; an understanding of every individual's contribution to the generation of emissions (scope 1 to 3) and of the countermeasures available (for example, using new technologies, and alternative materials, adjusting process flows); information campaigns, training activities, and development programs to build relevant competencies
- A regulatory environment that creates clear and logical incentives to reevaluate investment in CO_2 reduction technologies (for example, clarify whether raw materials or end-of-life emissions are incorporated into footprint assessments).

31 Mt CO_2

are generated every year through the manufacture of consumer goods and retail.

(6) Consumer goods, retail, and packaging

From toothpaste to razors, food to furniture – shopping is a daily occurrence for most people. Every year, the manufacture and trade in these goods generates around 31 Mt CO_2 emissions in Germany.[94] Of that, around 10.5 Mt CO_2 comes from the food industry, including drinks and tobacco products but excluding emissions generated during the agricultural production of raw materials (section 3 – Agriculture). Retail and wholesale are responsible for around 16 Mt CO_2, which arises through logistics and the energy needed to heat or cool products.[95]

The challenges facing consumer goods producers are as diverse as the products they sell:

- Refocus the product portfolio on sustainable, faster growing, and often higher-margin products
- Contribute to the mobility transition by switching to CO_2-free transport and logistics solutions
- Optimize packaging, and replace disposable with reusable packaging
- Develop a circular economy – build effective recycling value streams and new business models to enable product reuse and second lives, for example, for refurbished electronic devices like smartphones and tablets
- Use sustainable basic materials to reduce scope 3 emissions in the supply chain (for example, plantbased substitutes for cow's milk).

The industry, and more specifically retail, have a dual role to play in decarbonization. They need to consistently implement their own measures to achieve net-zero. Yet they also have direct contact with consumers, and so it is essential to create transparency on and highlight sustainable alternatives on the path to a greener future, to reduce CO_2 emissions, and to establish new recycling systems.

[94] Federal Statistical Office; including food and beverages, tobacco processing/textiles, apparel, leather goods and shoes/furniture and other goods/digital video devices and optical products/electrical fixtures/retail and wholesale; excluding ceramics, glass, rubber, paper, and plastic goods

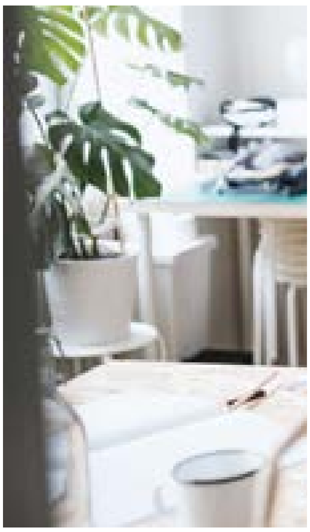
[95] Additional emissions come from: furniture and other goods (approximately 2 Mt CO_2) and electronic goods (approximately 1 Mt CO_2). Other emissions attributed to the consumer goods industry are generated in the chemicals industry (for example, detergents, cleaning products) and pharmaceuticals industry (consumer health); these are not included here.

Reduce scope 1 emissions and cut scope 3 emissions

We use a simple breakdown for the consumer goods sector: apparel, food, and other consumer goods. Each of these faces unique and very different challenges. Below we outline some potential options for decarbonization in the apparel industry; food is discussed in the section on agriculture.

Since clothes are not primarily made in Germany, the domestic apparel industry generates comparatively few scope 1 and scope 3 emissions at just 1 Mt CO_2. Worldwide, however, that figure is around 2.1 Gt CO_2 (2018) – equivalent to roughly 4% of global emissions.[96] Through global brands and trade volumes, German consumers are responsible for some of these global emissions, and at a rate higher than that for emissions caused in Germany.

Unless further steps are taken, the industry's global CO_2 emissions are likely to rise to around 2.7 Gt CO_2 per year in 2030 as a result of growth in demand. That would be a 2.7% annual growth rate and more than double the maximum emissions permitted under a 1.5° C pathway. For this reason, the clothing industry must intensify its efforts and roughly halve its current emissions by 2030.[97]



[96] McKinsey Fashion on Climate Report
[97] McKinsey Fashion on Climate Report

Manufacturers and retailers need to work more closely with their partners in the value chain to reduce CO_2 emissions. We see three main areas for action here:

1. Cut emissions in the upstream textile value chain. Reducing the CO_2 emitted from material production and processing, minimizing production and manufacturing waste, increasing energy efficiency, and moving away from fossil fuels to renewables could help cut emissions almost 50% by 2030 (approximately 1 Gt p.a. global reduction).

2. Reduce emissions in textiles firms and in transportation and retail. With a different material mix (for example, recycled fibers), sustainable modes of transport (for example, electric vehicles), different packaging using recycled and lighter materials, changes in the retail setting (for example, greater energy efficiency in stores), and reducing overproduction (only 60% of clothing items are currently sold without any kind of discount), the clothing industry could save up to 15% of current global annual CO_2 emissions by 2030.

3. Encourage sustainable consumer behavior. As consumers home in on sustainable fashion, wearing items of clothing multiple times and keeping them for longer, adapting business models in parallel could result in another 20% reduction in emissions by 2030. A circular economy, with more reselling, repairs, upcycling clothes, and less washing and drying are the key actions here.

Many of the steps needed to reduce emissions are not even that expensive: around 90% can be achieved at less than USD 50 per ton of greenhouse gas emissions. Around 55% of actions will result in net cost savings across the industry. Other actions will need incentives, such as changes in demand and legislation. Some – around 60% – actually require investment in advance. So manufacturers and retailers will have to support each other and cooperate to invest in the long-term future of our society and the environment. Already there are signs that reducing emissions will become even more of a challenge post-2030. Keeping the 1.5-degree target in sight, the industry has to fundamentally alter its business model and reconceive the current mindset of growth and rising consumption.[98]

Outdoor brand Patagonia is a pioneer in this. Not only does it emphasize the longevity of its products and the use of recycled textiles, but its Worn Wear marketplace gives customers the opportunity to buy and sell used and secondhand items.[99]

[98] McKinsey Fashion on Climate Report
[99] Worn Wear Patagonia

Offer consumers transparency and more sustainable alternatives

Alongside investors and regulators, consumers are the motivating force behind greater sustainability. Particularly younger adults, Generation Z, and millennials are driving the boom in sustainable consumer behavior. We have known for years that there are vast differences between the consumer preference for sustainable consumer goods as expressed in surveys and actual decisions made in store (the attitude-behavior gap); still three-quarters of Germans say that they keep sustainability in mind while shopping.[100]

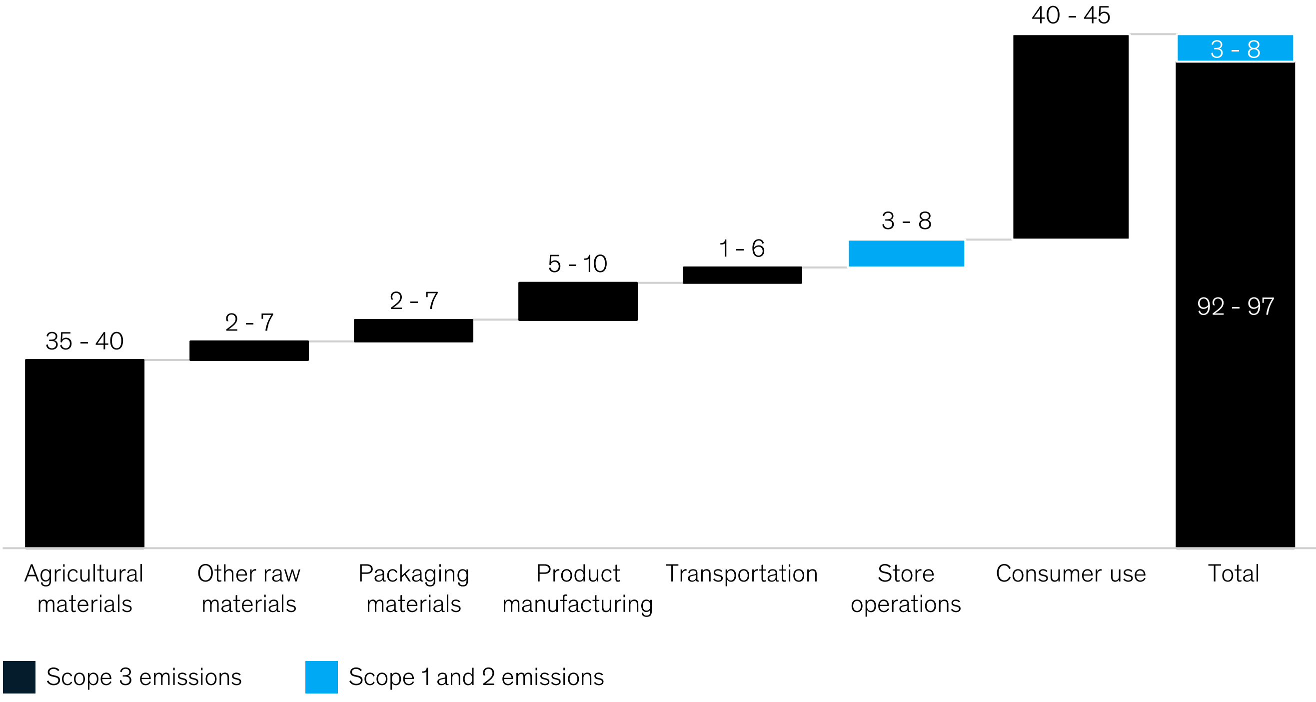
Retailers are key here. They can influence consumer behavior through transparency on supply chains, locally sourced products, and sustainable alternatives in the assortment. Many retailers, such as OTTO and Zalando, now flag products that are more sustainable. Food retailers like Kesko have an app to help customers track and reduce their own carbon footprint. Other retailers have gone so far as to ban nonsustainable products from their range. In this way, retailers are having an impact on scope 3 emissions, which make up the majority of their emissions (Exhibit 16).

[100] McKinsey [German only]

Exhibit 16

Breakdown of the grocery retail emissions footprint

Distribution along the value chain, percent



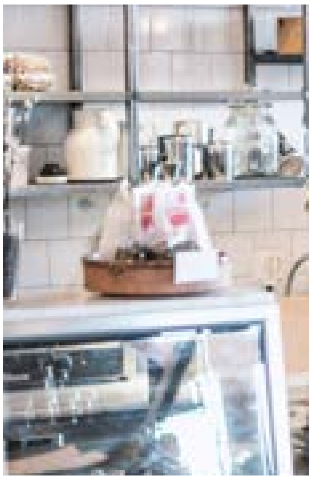
Source: 2018 CDP carbon data; Tesco reports

Retail can adopt that same approach to push for less packaging material, especially packaging made of plastic. Avoiding product waste and leveraging recycling options are also key levers in reducing emissions. Steps to avoid food waste include optimized sales and inventory planning and smart expiration dates. Many parts of the consumer goods industry will have to find new business models to reduce product waste after the use phase.

Overarching challenge: switch and reduce packaging while maintaining product safety and protection; simultaneously build and scale recycling systems[101]

Packaging presents an inordinate challenge for every consumer goods producer – even beyond the actual packaging itself. In the past, manufacturers and retailers focused on recycling and the use of recycled materials. But today, carbon footprints for packaging are being analyzed and optimized in great detail. A resource cleansheet based on product analysis is a good starting point for optimization.[102] It is also important to use materials containing fibers that can be more easily recycled, and in particular to replace composite materials with, for example, mono-materials. Packaging design has to take recycling into account and achieve the delicate balance of optimum weight, raw material composition, functionality/protection, and reusability.

If one thing is clear, it is that it will take imagination and creativity to separate value creation from volume growth and achieve an absolute reduction in CO_2 emissions.



[101] McKinsey True Packaging Sustainability Report
[102] McKinsey

Transportation/mobility

164 Mt CO_2 equivalent greenhouse gas emissions in 2019 (20% of Germany's total emissions)

164 Mt CO_2

Around 95% of transportation emissions are caused by road traffic (of which 60% are from private cars, 30% from heavy and 7% from light commercial vehicles). The remaining 5% is shared between aviation, rail, and other modes of transport.[103]

The implementation of a smart, electrified transport system will be an especially valuable countermeasure against the steady rise in personal transport, which increased by 34% between 1991 and 2019 and that forecasts say will continue along that same trajectory without targeted interventions.[104] The key emission reduction lever for all road-based transport is a full and complete transition from combustion engines to emissions-free – electric and hydrogen-based – alternatives combined with energy-efficient vehicle concepts (see section on the automotive industry). Yet electrifying the current transport landscape will not suffice to achieve climate-neutral mobility. Rather, new mobility concepts must be found for various use cases, especially smart and shared mobility in personal transport, alongside optimization of modal splits and innovative last-mile transport concepts for goods.

Core initiative 5: Switch to 100% emission-free mobility

Road-based freight has significant potential to reduce emissions, accounting for almost one-third of total transportation emissions. For this to be almost fully emissions-free requires the parallel use of electric drives (batteries and hydrogen) and synthetic fuels[105] (for example, biofuels) by 2045. Battery-electric trucks are well-positioned to take on the last mile and delivery runs in particular. However, thanks to the higher energy density and resulting shorter fueling times, hydrogen-powered trucks are generally deemed better for long-distance transport. Around 60% of newly registered trucks in Europe are used for long-distance transport.[106] Buying decisions in the freight sector are more focused on cost than, for example, in the passenger car segment. Regulatory measures and cost incentives, such as toll exemptions, are therefore ideal to encourage more firms to opt for low-emission and emissions-free trucks.

Currently, the availability of the supply infrastructure and that of clean hydrogen are limiting the use of these technologies in freight. Which means the infrastructure for trucks needs to undergo both massive expansion and upgrading. Since freight transport is concentrated along specific key routes, it will be relatively easy to grow the infrastructure: nine pan-European key routes cover around 20% of the long-distance transport network. Europe's Fit for 55 plan suggests increasing the number of rapid charging stations and hydrogen filling stations for trucks, building at intervals of 60 to 150 km along these main transport routes. This would give 100% coverage of all key north-south and west-east truck routes in Germany. A Europe-wide approach is especially important so that cross-border freight is not neglected.

[103] UNFCCC
[104] German Federal Environment Agency, Federal Ministry for Economic Affairs and Energy
[105] Also called "e-fuels"
[106] Of the 330,000 newly registered trucks over 7.5 t each year in Europe, around 60% are used for long-distance transport; these trucks are also responsible for disproportionately high emissions due to their higher mileage.

The need to develop alternative technologies and concepts for freight and long-distance transport delivers opportunities for companies to capture new markets.

The three leading commercial vehicle manufacturers – Daimler Truck, TRATON Group, and Volvo Group – have signed an agreement to establish and operate a public charging network for electric heavy trucks and coaches within Europe. Their shared mission: to initiate and accelerate the construction of charging infrastructure in order to boost customer confidence and support the EU's transition to climate-neutral transportation.[107]

H2 MOBILITY is a joint venture between Shell, Total, OMV, Daimler, Hyundai, Linde, and Air Liquide that operates the world's largest network of hydrogen filling stations, which is located in Germany. Over the next few years, the goal is to expand the network to cater to heavy haul and fleet applications.[108]

Additionally, a shift from road to rail would further reduce emissions, since freight trains currently emit roughly 80% less CO_2 per thousand kilometers than trucks.[109] In Germany, around 20% of goods are currently transported by rail; its neighbors, Austria and Switzerland, boast rates 1.5 to 2 times higher. Enabling this shift requires creating additional infrastructure capacity, especially at node points, as well as greater reliability on the part of the rail system.

Deutsche Bahn is planning to address these issues through its "Strong Rail" program. Installing a digital control and safety system that covers the entire rail network will increase capacity and improve punctuality in the existing network. Additionally, new access points to the rail system are needed so that freight can get onto the tracks as quickly as possible, and to keep truck-based first and last runs on the road to a minimum.

When it comes to personal transport, there will be a complete switch to e-mobility in the medium to long term. This transition has been driven in recent years by Tesla and various Chinese firms, such as BYD. In Europe, tighter CO_2 laws for cars are adding to the momentum for electric vehicles: their share of the total new registrations in Germany has almost quadrupled since 2020 to approximately 200,000 vehicles, partly driven by incentives to buy electric.[110]

All German carmakers are in the process of bringing new fully electric and plug-in hybrid models to market (more than 75 new models from BMW, Daimler, and Volkswagen Group between 2020 and 2025)[111] and have announced dates when they will stop using combustion technology. The planned production volume of electric vehicles (including plug-in hybrids and fuel cell vehicles) needs to cover three-quarters of annual car sales by 2030.[112] In Europe that means around 10 million vehicles a year; nearly 2 million in Germany alone (see section on the automotive industry).[113]

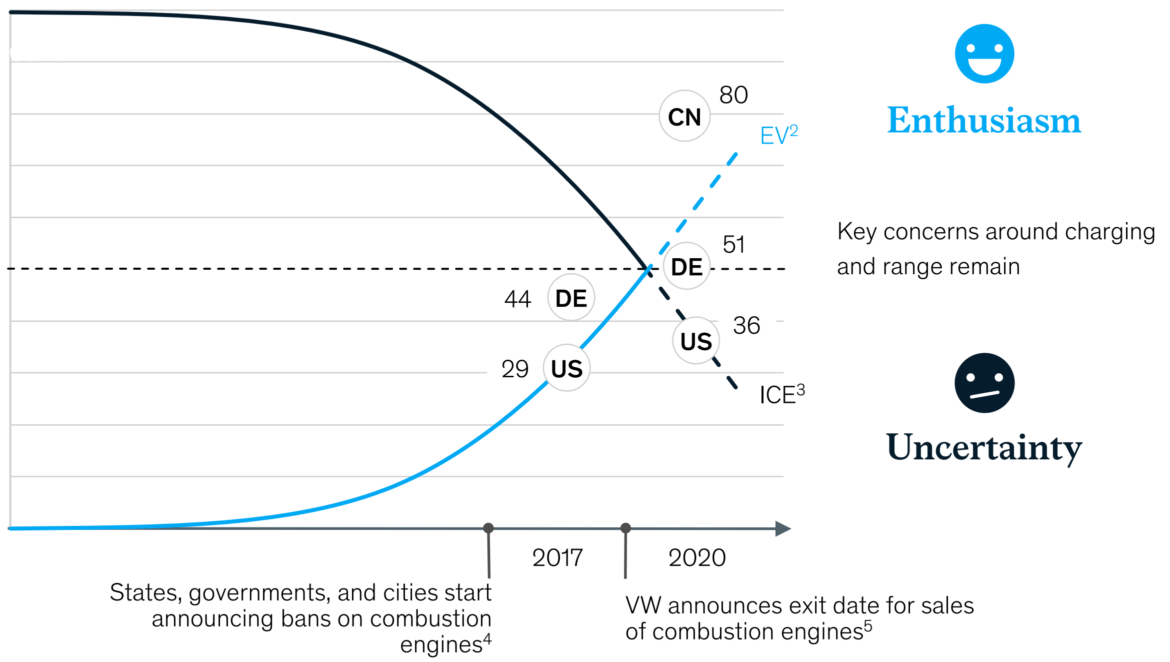
107 Daimler
108 H2 MOBILITY
109 Allianz pro Schiene
110 KBA
111 IHS Markit, Light Vehicle Powertrain Forecast (August 2021)
112 McKinsey Center for Future Mobility
113 IHS Markit, Light Vehicle Sales Forecast (August 2021)

This transition to alternative drive technologies, as in e-mobility, depends on customers accepting the technology; this has increased significantly in the last five years (Exhibit 17). Concerns about charging infrastructure remain: 40% of customers worry about availability of charging stations, closely followed by concerns about range (38%). All manufacturers are working intently to improve range at an acceptable cost.

Exhibit 17

Customer interest and enthusiasm for electric vehicles has seen a drastic rise in the last 5 years

Share of consumers considering buying an electric vehicle[1], percent



1. Incl. battery-powered electric vehicle (BEV) and plug-in hybrid electric vehicle (PHEV) based on McKinsey EV Consumer Insights Survey
2. Electric vehicle
3. Internal combustion engine
4. By year of announcement and date of ban/sales stop (not complete): 2016 Norway (2025); 2017: Paris (2030), Netherlands (2030); 2020: Great Britain (2030), California (2035), Québec (2035)
5. Last production start on combustion engine platform in 2026, announced in December 2018

Source: McKinsey EV Consumer Insights Survey

For acceptance of the technology to increase, a comprehensive and user-friendly charging infrastructure for electric vehicles actually has to be available. The German government has already set out some ambitious goals for electric vehicle charging stations: there should be at least 1 million public charging points by 2030.[114] For that to happen, infrastructure growth needs to pick up pace quickly (see section on the automotive industry). In mid-2021, there were just 45,000 charging stations in Germany. To realize the 2030 target, that means building an average 2,000 new stations every week in Germany. For comparison: between early 2019 and the middle of 2021, the number was around 200 a week – a mere one-tenth of what is required.[115] Expanding local power grids to facilitate connections to this charging infrastructure will be essential.

Norway is frequently featured in the media as an e-mobility utopia,[116] as it has the highest per capita density of electric vehicles in the world. In June 2021, 85% of new cars sold there were plug-in electric models. Norway's extensive public fast-charging network (with at least two stations every 50 kilometers along main roads) was partly developed through public-private partnerships. Since 2015, the government has invested almost EUR 13 million in grants through ENOVA. Most of this funding has gone to projects run by Finnish energy company Fortum and by Mer, a local provider of fast-charging stations, which is a subsidiary of the state-owned utility Statkraft.

Fortum, Mer, and other players are also establishing a presence in cities with on-premises charging options at supermarkets, shopping malls, and even fast food drive-ins.

Only 10 - 15%

of newly purchased buses for public transport in Europe are electric (60% in China).

Cities especially need to change to e-buses – in Europe currently 10 to 15% of newly purchased buses for public transport are electric.[117] In China, 60% of new city buses were electric in 2020, and China has more than 420,000 electric buses total, representing 99% of the global electric bus market.[118] The shift to e-buses could reduce CO_2 emissions by 50%, eliminate NO_X and SO_2 completely, and cut particle emissions by 80%. It would also decrease noise levels by about 10 dB(A). It will be cheaper for operators to implement this change though it requires more upfront investment in the buses and charging infrastructure,[119] which operators will have to shoulder. There are also a number of hurdles relating to connections to the infrastructure and its realization at an operational level. However, China has shown that these can be overcome. Manufacturers like BYD and Ytong are profiting from the clear strategy in China's cities: they already dominate 40% of the European electric bus market.

[114] Federal Government
[115] Federal Government [German only]: Master plan for charging infrastructure, Federal Network Agency, McKinsey
[116] Including Wirtschaftswoche
[117] CEO Alliance project
[118] CEO Alliance project
[119] Hydrogen infrastructure might also be necessary.

Shifting personal transport from road to rail also has the potential to reduce CO_2. A train produces 20 to 30% less CO_2 emissions than a car.[120] Capturing this potential means making rail transport competitive (that is, competitive prices compared to other types of mobility) and attractive (for example, an extensive route network, fast speeds, access to other modes of public transport, such as through a mobile app).

Only one year since the inauguration of the high-speed line between Berlin and Munich, which reduces the commute from 6 to 4.5 hours, Deutsche Bahn has managed to double its share of journeys between the two cities from 23% to 46%, thus saving more than 175,000 metric tons of CO_2 .[121]

The aviation industry also needs to seek out attractive alternatives for short- and medium-haul travel and improve efficiency (for example, through hybridization), as well as switch over to hydrogen, biofuels, and synthetic alternatives to kerosene.[122] One initial approach to cutting aviation CO_2 emissions involves reducing fuel consumption, reducing weights, and optimizing flight routes. At this time, there is also a focus on alternative fuels, which are already certified for up to 50% mixes with fossil kerosene.[123] That said, sustainable fuels are hard to find and much more expensive than kerosene. Fully synthetic fuels based on green hydrogen and CO_2 also require huge quantities of renewable energy. Covering around 5% of a major airline's annual needs would take a solar panel field twice as large as the island of Manhattan.[124] Disruptive technologies, including hydrogen engines, are a clean option for the future. Though only in the initial phases of development, these will be ready to install in planes within a few years in the form of high-performance fuel cells or liquid hydrogen tanks. Airbus, for example, is developing planes with hydrogen drives and expects to go into production after 2035.[125]

[120] German Federal Environment Agency [German only]
[121] INDUSTR.com
[122] Sustainable aviation fuel (SAF)
[123] IATA
[124] McKinsey WEF Clean Skies Report
[125] Airbus

Core initiative 6: Improve resource productivity by establishing smart and shared mobility

A full shift in transportation to sustainable drive technologies and energy-efficient modes of travel is urgently needed yet insufficient to meet the constant rise in demand for mobility while optimizing the use of resources. That will take a transition to attractive shared and smart mobility: an ecosystem of shared means of transport to include public transport as well as, for example, car sharing, especially in urban areas. These need to be widespread, readily available, and attractive, and provide an optimal digital interface (for example, booking, all means of transport offered, seamless transitions between public transport and micromobility). An important next step here will be autonomous vehicles for shuttle services and other driving services.

In future, innovative and optimized vehicle concepts are likely to emerge for use in, for example, individual passenger and group transport for city day trips, commuting, or even cargo transport. This is yet another opportunity to boost energy efficiency through smaller vehicles (one and two seats), lighter vehicles, lower engine performance (for example, three-cylinder), and range (over 100 km) – counter to the trend of increasing size and performance.[126]

Alongside the comprehensive use of decarbonized means of transport with high density and population coverage, for smart mobility to be successful it requires city planning that satisfies these new mobility needs. Cities must create space for micromobility: safe, efficient, and emissions-free private transport for people who prefer to cycle or walk. If the pandemic has shown us anything, it is just how quickly cities can act to do exactly that. Berlin, for example, converted the much-loved Friedrichstraße into a bike and pedestrian zone. Bogotá used traffic cones to create 76 km of temporary cycle paths, and Brussels plans to extend its cycle network by an additional 40 km. Brussels and Paris also turned their city centers into predominantly pedestrian and bike zones, with speed limits of 30 km/h for cars, trams, and buses.

By 2030, micromobility (that is, means of transport like e-scooters and bikes designed to transport individuals over short distances) is expected to cover 20 to 30% of last-mile trips in major cities, given appropriate regulatory incentives. In the case of Munich, this could reduce CO_2 emissions by an amount equivalent to the average annual emissions of 10,000 people in Germany.[127]

Hamburg is also trialing a range of solutions including HEAT (Hamburg Electric Autonomous Transportation), a research and development project by Hochbahn (operator of Hamburg's subway and bus systems) and various partners that is designed to test driverless minibus services in Hamburg's public transit network.[128]

[126] The SUV share of new car registrations in Germany has been increasing for years. In the first six months of 2021, they accounted for approximately 24%; in 2016 it was around 13% (source: Federal Motor Transport Authority).
[127] McKinsey (2020): Net-Zero Europe, McKinsey (2016): Urban Mobility 2030
[128] Hochbahn

124 Mt CO_2

Buildings

124 Mt CO_2 equivalent greenhouse gas emissions in 2019 (15% of Germany's total emissions); additional emissions caused as a consumer of commodities for new builds and when operating construction machinery (these emissions are discussed in the sector on industry and transportation)

The buildings sector has successfully saved 41% of emissions in the last 30 years. The majority of the remaining share of energy it needs, and the resulting emissions, are caused by space heating and hot water systems (Exhibit 18). These are typically generated inside a building, for example, through oil, coal, gas, or wood heating and hot water systems; a smaller share of the building stock are served with district heat. Around 70% of Germany's buildings are residential while 30% are used for commercial purposes.

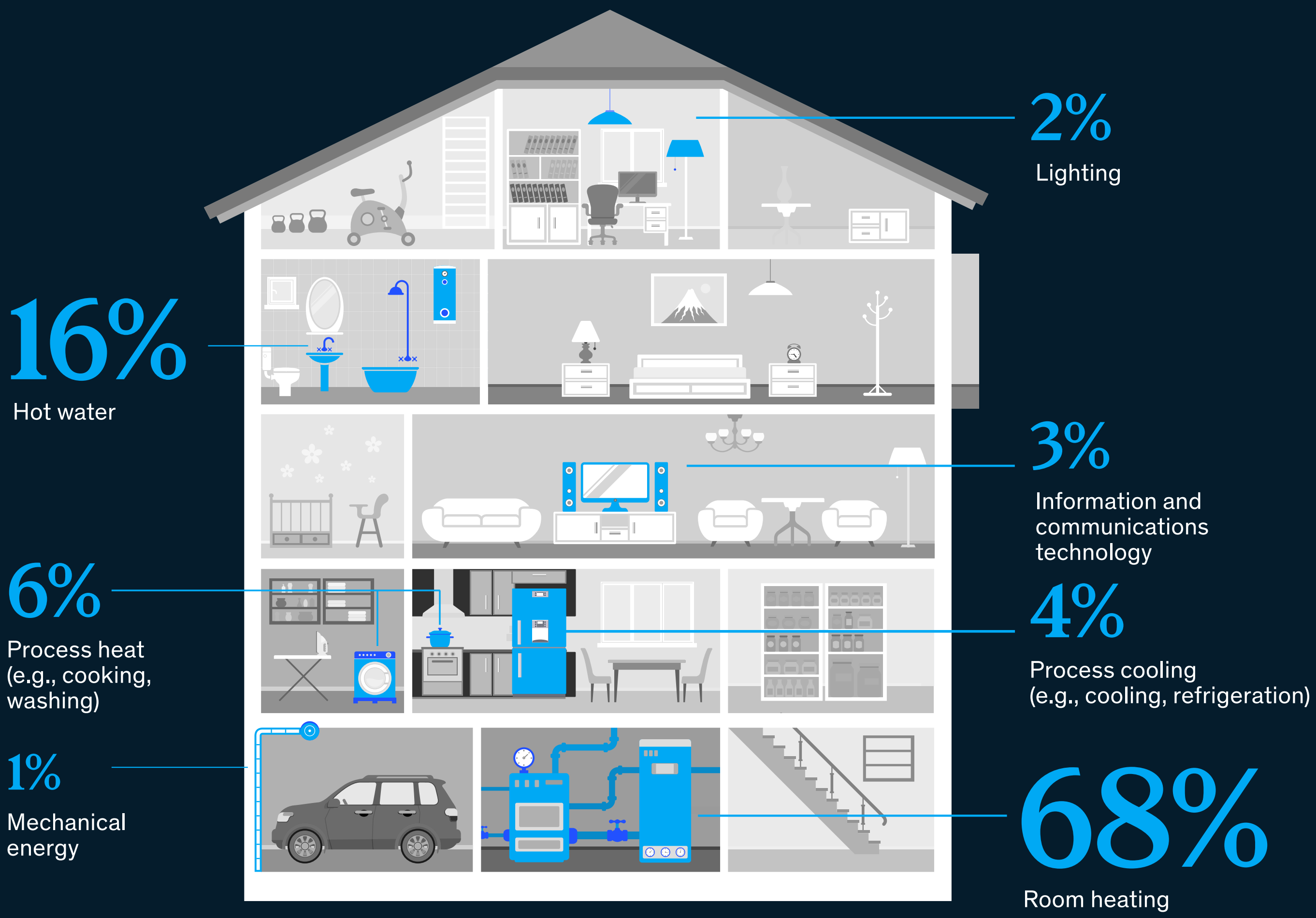
Germany is currently home to approximately 24% of all buildings in the EU[129] and represents 18% of the EU population. On top of this above-average use of space, Germany's emissions per square meter are higher than in most other European countries. The colder climate (compared to southern Europe) is partly responsible, as is the high share of fossil fuels used for heating (compared to northern European countries).

[129] Building Statistics Observatory – EU, Enerdata, CBS, Eurostat, Hotmaps (2017)

Exhibit 18

Heating accounts for the biggest share of energy consumption in buildings

Energy consumption of households in Germany by energy type 2019[1]



1. Total consumption in 2019 of 666 TWh

Source: German Environment Agency

Assuming the use of space stays the same, decarbonization can basically be accomplished through two actions:

— **Reduce heat needs through improved demand management and better insulation of roofs, walls, and windows.** The current EU guidelines on overall building energy efficiency set out a high level of insulation for new builds. In addition, the level of insulation needs to improve by around 55% by 2050 – mainly by moving from minimal insulation (EPC[130] classes F and G) to medium (EPC classes C, D, and E).[131]

— **Replace fossil-based heat sources with sustainable technologies, such as heat pumps and district heat.** Oil heat sources must be fully replaced by 2040; gas sources by 2050. In that same timeframe, the heat pump share of total heat sources should grow to up to 50%. Given that heat pumps are so energy-efficient, they would cover 50% of the heat needed while only accounting for around 28% of heating energy consumed.[132] The share of buildings served with district heat must double to over 20%. The remaining 30% of buildings would be heated with biogas, hydrogen, and solar thermal systems.[133]

These actions are usually implemented together and frequently also reduce operating costs, which generates additional economic value in the long term. Overall, the cost of decarbonization in the buildings industry is relatively low.

Despite this, the buildings sector is still too slow to change. To reach the climate targets, emissions reduction must be faster than in the last 30 years by a factor of 3.[134] Part of this relates to an annual refurbishment rate above 2% for existing buildings, which is more than double the years-long stagnant rate of 1%.[135]

Two challenges make building decarbonization more difficult:

— Existing buildings play a vital role but are considerably harder to decarbonize than new builds. Germany has roughly 45 million buildings total,[136] of which 97% were erected prior to 2011.[137] That means more than 80% of those properties will still count as existing buildings in 2050.[138] So almost all extant buildings will need an energy upgrade, most during their use phase. Since residents generally find renovation work disruptive, it tends to take many years to complete. At the same time, the share of owner occupation in Germany is below the European average of around 70%. Meaning that many owners are not motivated to upgrade since the energy cost savings only benefit their tenants.

— Buildings are generally very different when it comes to layout, materials, and structures. Every renovation project therefore needs a tailored concept. That increases the planning effort and the complexity.

130 Energy Performance Certificates
131 McKinsey (2020): Net-Zero Europe
132 McKinsey; we expected energy demand of roughly 1,100 PY in the power sector in 2045.
133 McKinsey (2020): Net-Zero Europe
134 UNFCCC
135 German Energy Agency (dena)
136 Building Statistics Observatory – EU, Enerdata, CBS, Eurostat, Hotmaps (2017)
137 Federal Statistical Office (2018)
138 McKinsey

Core initiative 7: Modernize heating systems of building stock, especially with sustainable heating systems (over 50% heat pumps)

A variety of actions are needed to speed up the modernization of existing buildings. For years now, the building sector has defined an increasing number of standards for itself. Combined with financing, these standards have successfully improved energy efficiency. It is vital to keep pursuing this approach, for example, through an EU directive and the definition of binding minimum renovation rates for commercial buildings, residential construction firms, and real estate investors. Financial incentives to accelerate energy efficiency upgrades are also useful.

To speed up implementation and make it economical, all actions must be urgently digitized. One example would be a comprehensive analysis of how renovation potential is distributed. This creates transparency on financing options that are both economically and ecologically valuable. On that basis, a locally differentiated, specific vision can be developed for a heat generation technology mix (gas, hydrogen, heat pumps, and remote heat), as well as the corresponding roadmap.

However, these changes demand broader acceptance of building insulation among the general population, and especially of green heating systems. Campaigns to explain the need for change, as well as the costs and benefits of these steps, can motivate and increase people's willingness to act.

Investors and financiers are calling for improvements in energy efficiency through their investment criteria, thus creating incentives for business. Companies need to initiate the implementation of new approaches to renovation, as well as cross-industry partnerships, for example, between the construction trade and insurance sector, or through alternative financing that allows for shorter payback times. The goal here is to standardize and industrialize renovation projects.

To speed up implementation and make it economical, all actions must be urgently digitized.

Resource-preserving and recyclable materials must be used more in renovation projects as well as new builds. These are wrongly perceived as being temporary, degradable, and fragile. When developing sustainable construction materials, these preconceptions have to be dispelled so that pilot projects can, for example, demonstrate large-scale usability. There is an opportunity here to establish supply chains that are as local as possible (for example, for heat pumps and insulation materials). Another approach would be urban mining. This takes secondary materials that have already been deployed, and reuses them through faster material brokerage to cut down on the use and dismantling of primary materials.

"Bauhaus der Erde" was unveiled in 2021 with support from the German Federal Environment Agency. This initiative advocates the replacement of reinforced concrete with organic building materials. Similar to the Bauhaus movement of the early 20th century, "Bauhaus der Erde" strives for the implementation of a holistic approach based on the principles of sustainability, participation, and aesthetics, to be realized within the next decade.[139]

Online marketplace Restado is a place to buy and sell building materials in Germany. This start-up uses urban mining principles to leverage the potential of cities as sources of raw materials. Some 50 billion metric tons of material are theoretically available for dismantling and thus for reuse in new buildings.[140] This start-up is demonstrating exactly how we can reduce the use of new construction materials – which in Germany alone amounts to 534 million metric tons per year.[141]

Decarbonization and the subsequent modernization of the building sector could be key drivers in the German labor market. The sector needs to transform faster by modernizing heat technologies in building stock, deploying newly standard renovation approaches, and improving the carbon footprint for new builds. Ideally this will happen at the same time as the increased use of locally generated renewables to turn consumers into "pro-sumers"[142] Furthermore, local supply chains will be needed to deliver vital construction materials and building technology (for example, insulating materials, heat pumps) and sufficient capacities for implementation (for example construction firms, suppliers).

Overall, the transformation of the building sector could create around 1.1 million additional jobs in the EU by 2050, around 25% of which would be in Germany.[143] Especially well-trained and highly qualified workers will be needed in future, for example, to manufacture and install heat pumps or fit materials to improve building insulation.

[139] German Federal Environment Agency [German only]
[140] Restado [German only] (2021)
[141] German Federal Environment Agency [German only]
[142] People who consume and produce at the same time, in this case: energy (for example, via their own photovoltaic system)
[143] Share of expected total increase (includes, for example, the power sector); McKinsey (2020): Net-Zero Europe

Agriculture

68 Mt CO_2

68 Mt CO_2 equivalent greenhouse gas emissions in 2019 (8% of Germany's total emissions)

Germany's agricultural sector deals with both plant and animal products, as well as energy (for example, biogas) made from agricultural products. It is currently responsible for around 8% of Germany's greenhouse gas emissions; of these, animal production accounts for roughly 63% and crop cultivation 28%, including fodder crops for livestock farming. This sector also has a role to play in decarbonization, though it could serve as a frontrunner through the potential for soil carbon storage, for example, through humus formation, and help offset other industries' emissions. However, in this sector, reducing emissions comes at a high cost. Since 2015, greenhouse gas emissions have fallen by just 2% a year.[144]

Core initiative 8: Develop future-proof key technologies to assure resilient, sustainable agriculture

Emissions could be cut to around 10% by 2035 if technologies that already exist, such as anaerobic manure treatment (for example, in biogas plants) or direct incorporation of animal manure into the soil, are deployed systematically and comprehensively (Exhibit 19).[145] The costs of these individual measures vary; slightly more than half the available potential can be captured at a price of more than EUR 50 per ton of CO_2 equivalent.

Next-generation technologies, such as direct methane capture or gene editing technologies, have the power to cut greenhouse gas emissions by a further 21 percentage points by 2035.[146] However, many are still in the pre-commercial phase so there is a great deal of uncertainty surrounding them. Currently in development, for example, are the use of chemical-biological agents to reduce methane production in the bellies of ruminant animals, and accelerated breeding methods for plants and animals through gene technology (for example, CRISPR).

Dutch firm DSM (Dutch State Mines) has developed a special feed additive for cows that reduces the methane they produce by 27 to 40%. That translates to potential annual savings of 1 metric ton of CO_2 equivalent per cow.[147]

In Germany, the fundamental research behind CRISPR has built a solid foundation. Now, more applied research is required to mature processes to market-readiness and facilitate growth in earnings per hectare, as well as the use of climate-friendly plant varieties. This could be achieved, for example, through more collaboration between research institutes as well as corporates and startups.

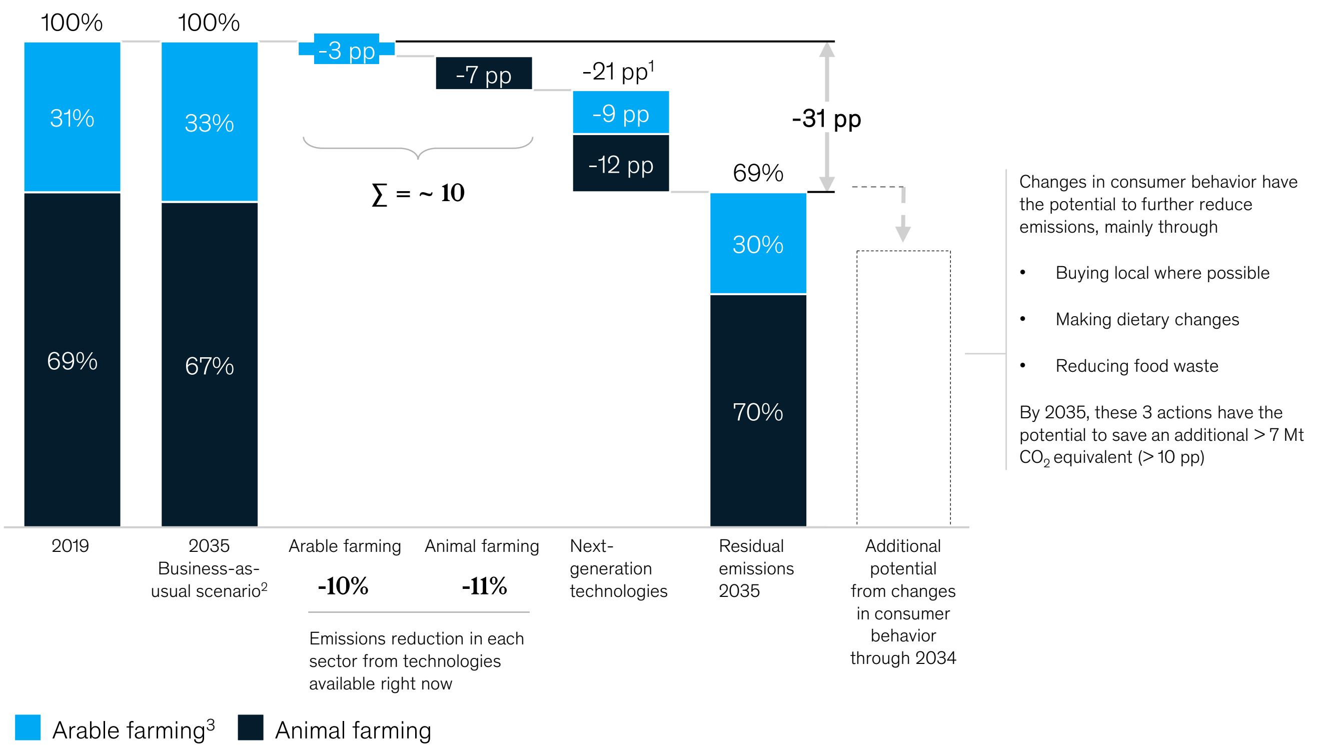
All in all, German agriculture can deploy technical measures to reduce its greenhouse gas emissions by around 30% by 2035. Approaching the net-zero target in the German agriculture and forestry industry, as proposed in the EU Fit for 55 strategy, would take significant extra work. In the timeframe as defined, the only way to succeed would be through changes in consumer behavior.

[144] UNFCCC
[145] McKinsey
[146] McKinsey
[147] Business Association Chemistry Pharma Life Sciences

Exhibit 19

Germany can use technology to reduce emissions from agricultural production by 31% by 2035 – changes in consumer behavior could reduce emissions even further

Changes in agricultural emissions in Germany[1]



1. Excl. energy consumption
2. Realizing this potential depends on circumstances, e.g., regulation, maturity of technology
3. Assuming stable export/import patterns and stable emissions when switching from conventional to biological land management

Source: EU Commission; analysis of optimization factors for decarbonization pathways; Food and Agriculture Organization (FAO); McKinsey

Core initiative 9: Accelerate the trend toward healthy eating and sustainable consumer behavior

Consumers, retailers, and producers make decisions every day that impact emissions. Various actions could help reduce emissions:

— **Reduce food waste.** Less waste and loss in agricultural products could prevent nearly 1 Mt CO_2-equivalent greenhouse gas emissions in the short term. There are other actions relevant to consumers and processors (for example, restaurants), but also to storage and sales and manufacturing processes. For example, from a sustainability perspective, decreasing the use of films to shrink-wrap food might cut back on the use of plastic wrap but it significantly increases waste caused by food. So we need to develop and apply new methods for harvesting, storage, and packaging.

— **Increase local food supply.** Promoting supplies of local goods would significantly reduce emissions caused by transporting, for example, animals and refrigerated products. This requires the support of local businesses as well as changes to logistics chains and trade partnerships.

By summer 2022, German supermarket chain Rewe Group hopes to procure 95% of its classic range of fresh pork products from Germany, including the entire value chain (birth, rearing, fattening, slaughter, and processing). To that end, from September Rewe Group will raise the minimum prices guaranteed since 2020 for pig farming and so give a boost to German pork production.[148]

— **Make dietary changes.** Greenhouse gases can be further reduced by consumers making changes to what they eat – especially by eating less meat. One model calculation shows that if 15 to 20% (vs. 8% in 2020) of the German population ate a mainly vegetarian diet, it could cut agricultural greenhouse gas emissions by another almost 10% (7 Mt CO_2 equivalent).[149] This would entail faster product development to find more suitable, plant-based alternatives to animal products (for example, made of soy, rapeseed, or pea protein).

All of these actions require greater consumer awareness. Clear labels highlighting the carbon footprint of various agricultural products, alongside general education of the public, can help increase people's willingness to consume B and C goods, which after all only differ from A goods in how they look.

[148] Rewe Group [Germany only], Agrarheute [German only]
[149] McKinsey

Agriculture has a further role to play beyond the actions just described: it can act as a carbon sink, that is, binding carbon in the soil and/or in its products. For example, increasing the humus content of the soil results in much higher carbon binding. This would also have a number of positive side effects, for example, on water resources and soil structure. Making changes to crop rotation, seeds, and tillage would help achieve this. Subsidy programs could be useful here, as could authorizing certain pesticides and seed types combined with research at universities and colleges.

Restructuring the German agricultural sector like this means taking account of other factors as well, including:

— Emerging new value pools and sources of income for farmers thanks to emissions reduction credits (ERCs) that are awarded, for example, for the above increase in humus with subsequent carbon binding.

— A drastic shift in economic values along the value chain for producing plant and animal products. Greater use of new technologies will increase equipment and resource utilization Without corresponding compensation, this will impact profitability levels as well as the cost and price of agricultural products.

— Significant changes in production volumes of plant and animal products through shifts in consumer behavior (due to localization) or more space allocated to reforestation or biomass cultivation. Subsequent changes in how agricultural space is used (for example, expansion, intensification) and in production methods (for example, catch crops). However, any intensification could run contrary to the other targets set out in the EU's Green Deal, for example, to reduce the use of chemical pesticides, expand organic farming, and promote biodiversity.

— Fluctuations in trade flows between other EU and non-EU nations as a result of predicted changes in production volumes and costs. To safeguard food supplies and prevent production migrating to other regions with less sustainable production methods, it will be important to retain production in Germany and Europe.

The scope of these changes is still unknown. What is clear is that how effective they are depends on how farmers, end consumers, and regulators adopt and implement them.

Banking

Banking in Germany is, by tradition, hugely important in financing the economy and supporting structural transformations. That same role will be its remit in the net-zero transformation.

As well as optimizing its own footprint,[150] the opportunities and risks for banks mainly concern the need to adapt current business models so that the investments needed for decarbonization can be effectively financed and realized. Since banks are also responsible for the portfolios they finance (scope 3), they face considerable challenges in reaching the accelerated targets stipulated in the amendment to the Federal Climate Change Act.

And if that was not enough, the sector simultaneously needs to satisfy significant newly emerging regulatory requirements and mitigate the physical and transition risks to its own assets. So far there are insufficient reference scenarios or detailed data available, such as regarding sector- and customer-specific emissions levels and pathways. And as highlighted in our most recent report on banking, the sector is already experiencing a period of significant transformation-related challenges.[151]

This situation demands the full attention of Germany's financial institutions.[152] According to the European Banking Authority (EBA), of the total exposure for Europe's banks, 35% is currently still allocated to EU companies that generate greenhouse gases above the mean.[153] Initial estimates suggest that the "green asset" rate – the share of climate-friendly assets – at EU banks is a mere 7.9%.[154] Very recently, the ECB issued a stark warning that institutions should take a hard look at their implementation plans – and speed – to make improvements in managing climate and environmental risks;[155] the banks themselves report that only 10% of them meet the ECB's expectations.[156]

The German banking sector needs to take concrete steps if it plans to meet regulatory requirements, to support the decarbonization of the real economy, and to capture the resulting financing and advisory opportunities.

[150] German banks currently employ more than 500,000 people and operate 24,100 branch offices and branches.
[151] McKinsey (2021): German banking returns to the playing field; digitization, low interest rates, and an ongoing highly fragmented sales approach, German banks saw earnings drop by 8% between 2010 and 2019; the five-year average return on equity is just 2.9% and so far below the average in other established European banking markets.
[152] McKinsey (2021): German banking returns to the playing field
[153] Friede, G., Busch, T, and Bassen, A. (2015): ESG and financial performance: Aggregated evidence from more than 2,000 empirical studies, Journal of Sustainable Finance and Investment, Book 5, Number 4, p. 210 - 33
[154] EBA (2021): Mapping climate risk: Main findings from the EU-wide pilot exercise
[155] ECB Supervision Newsletter (2021): The clock is ticking for banks to manage climate and environmental risks
[156] Frank Elderson (2021): Patchy data is a good start: from Kuznets and Clark to supervisors and climate

Core initiative 10: Finance and support the net-zero transformation by developing a green portfolio

Define an ambitious strategic climate target to further support the transition through financing and innovative offerings

The trend toward sustainable finance is not new in Germany. Even before COVID-19, the 2019 fiscal year saw ESG-compliant financing (including, for example, wind park projects) account for nearly EUR 8.6 billion of the EUR 146 billion in syndicated loans.[157] Certain German institutions are already pioneers in Europe when it comes to financing renewable energies. In the course of investments to realize by 2045, that focus must be developed further, beyond the power and infrastructure sector toward industry and SMEs. Their long-standing expertise should help these institutions fulfill that role.

In parallel with leading international providers, German banks have taken their first steps toward formulating ambitious, science-based net-zero targets for their scope 3 emissions. Building on an emissions analysis for the current portfolio in each sector, they define specific targets and decarbonization pathways for individual portfolios. Especially emissions-relevant portfolios (for example, energy, mortgages, and cars) are also substantiated with detailed plans, control processes, and key actions (for example, supporting companies with emission reduction projects, neutralization through green products and offsetting) to gradually decrease overall emissions.

Members of the Net Zero Banking Alliance Germany include BNP Paribas, Commerzbank, Deutsche Bank, DKB, DZ Bank, ING, and LBBW. Having joined forces, they have all committed to making their portfolios climate neutral and consistent with the targets set out in the Paris Climate Agreement.[158] The Green and Sustainable Finance Cluster Germany has submitted a discussion paper titled "Lending to a climate-neutral Germany by 2045," which presents an initial position on the end-to-end management of loan portfolios consistent with the Paris Agreement; a final proposal is expected by the end of 2022.

The subsequent restructuring of lending processes can deliver a vital contribution to the net-zero transformation. After all, with loans amounting to almost EUR 1.2 trillion[159] to domestic businesses, Germany's banks not only play a central role in financing the nation's economy,[160] they also act in a supervisory capacity.

- The replacement investments needed – on average EUR 200 billion per year – and the associated capital restructuring make it essential to fully comprehend the dynamic forces at play in each sector from an insider perspective, as well as the opportunities and risks – including effects relating to supply chains, legislation, and interactions with the public sector. Not forgetting the new investments totaling around EUR 40 billion a year that require significant additional loan and capital approvals. Alongside lending standards, the financing costs incurred have had a mitigating effect. Looking to the growing risk of unaccounted-for climate risks, for example, lending conditions could become more expensive in the long term for businesses without a climate agenda than for those that are actively involved in the transformation.

[157] Dealogic (2021)
[158] Last updated August 2021
[159] Loans to domestic companies in the 2020 fiscal year (Federal Bank statistics)
[160] According to the EU Commission's SAFE study, bank financing is relevant to 44% of all businesses.

Sector-specific approaches and lending strategies can address supply chains and the financing of collective decarbonization projects. In the energy sector, financing could focus on CCU/CCS and hydrogen consortia, for example, or low-carbon partnerships in transportation and real estate. In retail banking, interest has been piqued by the German government's recent announcement that it will mandate the installation of solar energy systems in new builds and larger-scale renovation projects,[161] which means sooner rather than later these criteria will have to be factored into mortgage lending decisions.

The finance industry can shore up this development with new, ESG-specific products and services in every area – private and corporate customers as well as asset management. Potential actions include:

— Using ERCs to establish effective and efficient markets for voluntary carbon offsets in all sectors so as to compensate any residual greenhouse gas balance. Related to this, McKinsey has supported the international Taskforce on Scaling Voluntary Carbon Markets (TSVCM) that is under the direction of the Institute of International Finance, most recently in setting up a roadmap[162] to grow the carbon credit market by a factor of 15 by 2030. After extensive consultation (involving various sources and 130 international feedback reports), the TSVCM defined a set of core principles for this marketplace and for the integrity of the credits (Core Carbon Principles – CCP). The next step will be to formally establish the umbrella organization as it stands today.

— Dedicated advisory units for climate-neutral investment, especially for SMEs where bank advisors experience and support a variety of transformations

Sustainable funds today already boast assets totaling around

EUR 250 billion

— ESG-compliant investments in asset management through positive and adverse selection. Sustainable funds already boast assets totaling around EUR 250 billion[163] and rising. It is entirely feasible that structured funds, in collaboration with public banks, will play a key role in financing the necessary investments while offering investors an alternative at low risk and attractive interest rates. In this way, investments can be channeled by institutional investors as well as retail customers.

Build essential skills to manage the net-zero transformation and associated risks

This climate-sensitive reorientation of lending, the development of supporting financial products and services, and regulatory requirements mean that banks must invest and continuously grow their green finance capabilities. Our latest benchmarks suggest that this involves taking action in governance, business, risk, data and disclosure, and employees and culture.

The first step is to analyze climate-relevant positions and risks in detail, and to speed up the integration of comprehensive CO_2 accounting. Next comes an audit of internal risk and management approaches (for example, including risk tolerance, limit system, lending decisions, or pricing). New industry standards, such as those defined by the COP26[164] Portfolio Alignment Team,

[161] Handelsblatt [German only]
[162] Institute of International Finance
[163] German Investment Funds Association (BVI)
[164] 26th Conference of the Parties (2021 UN climate conference)

will go a long way to realizing any improvements.[165] But it will also take additional data and analytical skills as well as targeted capability building in the workforce (training and development, retraining, and recruitment of new talent). As ever, the success of any climate agenda too often depends on the individuals within the organization.

To make the newly required products and services cost effective and tailored to the market, climate and ESG expertise will have to dovetail with existing sector, product, and advisory competency in every business area. The funds industry is an ideal role model here with its diverse approaches to integrating ESG criteria into the investment process and increasing standardization in disclosure.

Our experience has shown that a dedicated transformation structure is needed to trigger the internal transition and drive climate-friendly change – for example, in the form of a specific competency cluster. This cluster can define guidelines and set long-term targets, trickle down standards through all key banking processes, and mobilize the necessary resources. That last action is vital to rapidly translate today's still mainly project-based ESG IT prototypes into a productive and integrated IT and data infrastructure.

□ □ □

In summary, a successful transformation depends on the following key elements (Exhibit 20):

[165] McKinsey most recently supported the COP26 Portfolio Alignment Team – set up by Mark Carney – in publishing best practices for overarching portfolio management.

Exhibit 20

10 key initiatives in 6 sectors for a successful transformation

Energy

1: Massively accelerate (triple) capacity expansion in renewable energies

Expand up to 650 GW capacity in renewable energies by 2045 – by 2030, need to triple annual expansion compared to 2020; imports needed to supplement this
Grow the green hydrogen economy by 10 - 15 Mt p.a.

2: Expand (~ 25% expansion in the power transmission grid) and increase flexibility of the energy grid

Expand the power transmission grid to > 60,000 km by 2045, and increase flexibility through increasing storage capacities and intelligent load balancing. Mandatory enabler: accelerated approval procedures

Industry

3: Decarbonize the basic material industry (green materials) through innovations in processes and plant engineering, driven by manufacturing industry requirements and innovations

Implement industry-specific decarbonization and scaling of sustainable processes and systems
- Steel: deploy direct reduction technology with green hydrogen
- Chemicals: electrify core processes such as cracking, use sustainable feedstocks (e.g., green hydrogen instead of SMR), further optimize existing processes
- Cement: use biomass fuels, reduce proportions of clinker, modernize plant parks to reduce energy consumption

The manufacturing industry offers 2 types of impetus to decarbonize the basic material industry:
- Demand for decarbonized materials, e.g., in the automotive and consumer goods industries
- Innovations that enable decarbonization, especially in plant engineering

4: Accelerate development of cleantech enablers: hydrogen production and transport, battery production, charging infrastructure, recycling

Build a green battery value chain (20 -fold increase), establish an efficient circular economy, change the raw material base (e.g., recycled or bio-based materials), develop CCU/CCS, accelerate charging infra-structure development: construct an additional ~ 2,000 charging points every week in the coming decade

Transport

5: Switch to 100% emission-free mobility

Realize comprehensive use of sustainable drive technologies (electric and hydrogen drives) in personal and goods transport; use alternative fuels in aviation

6: Improve resource productivity by establishing smart and shared mobility

Increase use of shared and smart mobility concepts, incl. use of micromobility and self-driving vehicles. Create space for safe, emission-free personal transport, such as cycling and walking

Building

7: Modernize existing buildings, especially with sustainable heating systems (> 50% heat pumps)

Implement region-specific concepts for the technology mix for climate-neutral heat generation and accelerate rates of upgrading – improve insulation levels from ~ 55% in current buildings, mainly from class F/G to C/D/E

Agriculture

8: Develop future-proof key technologies to assure resilient, sustainable agriculture

Scale up existing technologies, e.g., anaerobic manure treatment in biogas plants in the field, commercialize next-generation technologies, e.g., reduce methane emissions using chemical-biological agents, and develop climate-protecting plant varieties

9: Accelerate the trend toward healthy eating and sustainable consumer behavior

Encourage consumers to buy local where possible and reduce food waste, and create incentives for switching diet to more sustainable foods

Banks

10: Finance and support the net-zero transformation by establishing a green portfolio

Develop and launch green financial instruments: ESG -specific financing, ESG-compliant asset management, introduce new instruments such as voluntary carbon markets; at the same time, increase awareness and knowledge of ESG and ESG capabilities within banks

Source: McKinsey

IV. Sustainability as an integral element of any business strategy

Realizing all of these opportunities and driving a successful green transformation means every company making sustain-ability an integral part of its strategy and pushing for it at every level and in every area of the business.

Sustainability, and thus the striving toward net zero, is a duty now placed on every company and its stakeholders, but it also offers a number of benefits:

— Sustainable companies are more profitable, enjoy stronger growth, and have a lower risk profile. This leads to higher ratings, which benefit shareholders.

  - Consumers are already willing to pay more for goods produced sustainably.[166]

  - An analysis of the chemicals industry revealed that the industry's "green leaders" earned 20% higher yield per year in the last five years than competitors that do not focus on ESG.[167]

— Investors and banks are incorporating ESG criteria into their decision making, and those same criteria are becoming the benchmark for special green financing instruments. As a result, they now represent a basic criterion for accessing capital.

— Climate-neutral companies offer meaningful and fulfilling jobs for their workforce, consequently securing themselves an advantage in the battle for the best talent.

— In many areas, the decarbonization of production and the value chain has a positive impact on costs, especially in view of rising CO_2 prices.

Companies that hope to be successful in future must adopt an entrepreneurial approach to dealing with the risks and uncertainties inherent in this disruption, while also seeing and exploiting it as an opportunity.

A determined, fast, and clear new direction opens up possibilities to focus the portfolio on new value pools and growth markets as a way to add value, to capture growth through new business models, and to stand out from the competition through value chain decarbonization.

This means that the green transformation has the potential to completely overhaul entire competitive landscapes. First movers will enjoy a key advantage: they can get a firm foothold as frontrunners in the new world, or can transform decisively and rapidly to realize higher margins during the transition phase. So a comprehensive sustainability strategy sometimes means a fundamental transformation of the core business, as well as new business opportunities.

The next section looks at several ideas for companies to take on board as they head out on this journey.

A comprehensive sustainability strategy sometimes means a fundamental transformation of the core business, as well as new business opportunities.

[166] McKinsey
[167] McKinsey; CPAT; Refinitiv

1. Define a sustainability strategy

Companies that want to remain successful going forward must come up with a "green vision," which must be concretized and implemented by way of a sustainability strategy. At the core of this strategy, the company should set out its path to sustainability in general, and specifically with regard to climate neutrality. It is recommended to base this work on the target-setting method outlined by the Science Based Targets Initiative (SBTi). Now an acknowledged industry standard, this method builds on scientific findings and, in line with the 1.5-degree target, helps define concrete goals for reducing greenhouse gas emissions.

A holistic perspective is essential, as is the consideration of all relevant business areas. This means incorporating various aspects into the strategy: future customer preferences, changes in competitive ability, portfolio restructuring, development of new technologies, availability of natural raw material sources, provision of supply chains and infrastructure, financing options, political leadership, and so on. The issues at play are complex and frequently interlinked, requiring a structured strategy process to answer key questions.

— **Ambition.** What level of ambition does the company and its shareholders/stakeholders have (net zero leader, fast follower, or last man standing)?

— **Diagnostic of the current situation.** What position is the company in right now? How can the net-zero target be achieved and how much capital will that take (company-specific net-zero cost curve)?

— **Value pool predictions.** How will existing value pools evolve, and what new value pools are likely to form? How will customer preferences change? What about the competitive situation?

— **Broader solution space.** What options are available for portfolio optimization and direction, green growth, and new business models, as well as value chain decarbonization? How attractive is each of these options in terms of feasibility (for example, technologies, innovations, and competencies needed) and efficiency (for example, return on carbon)?

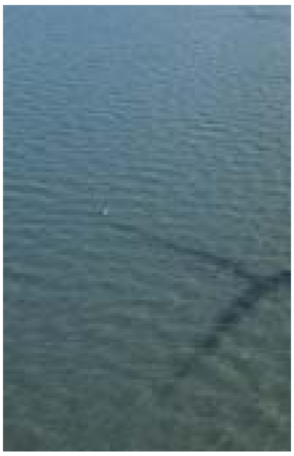
— **Winning plays.** Which options will be prioritized and realized? How will these options contribute to reaching the company's targets (financial, ESG, and decarbonization)?

— **Equity story and financing.** How will the strategy be positioned on the capital market, and how will the initiatives be financed (conventional investors or banks, impact investors, or green bonds)?

Organizations that manage to translate their vision into a compelling sustainability strategy will benefit from the reallocation of capital and higher ratings on the capital market. In Europe, funds with ESG criteria already make up three-quarters of the total market.[168] This is an opportunity to finance those investments in decarbonization that are necessary to realize the strategy. Companies with this approach already enjoy much better access to green capital and a diverse array of financing models.

Austria's largest energy group VERBUND has issued a EUR 500 million bond, the proceeds from which are earmarked exclusively as financing for green projects. The company has committed to expand its energy production capacity from hydroelectric stations, wind turbines, and photovoltaics by at least 2,000 MW, as well as to upgrade its grid capacity.[169]

Finnish company Neste has shifted its portfolio away from oil (approximately 50% EBIT in 2015) and toward renewable products and biofuels (approximately 90% EBIT in 2020). As a result, the company saw its EBITDA more than double from USD 0.9 billion (2015) to USD 2.1 billion (2020). At the same time, its share price rose 900% between 2015 and late 2020, earning a valuation of 21 x EV/EBITDA – a number more commonly seen in technology companies.[170]



[168] Q1 2021, Morningstar Direct
[169] Verbund
[170] Neste Financial Statement 2020 dated February 5, 2021, Market Screener

2. Be courageous and tailor the portfolio to new value pools

The net-zero revolution is creating new, dynamic growth areas with new markets, market players, and power struggles. Right now there is a unique chance to focus on this and rework existing portfolios.

Both portfolio and capital allocation should be targeted toward the vision of becoming a sustainable company. Areas that no longer fit the future portfolio must be divested and spun down, while attractive and sustainable green areas undergo organic and inorganic growth.

Companies often find it difficult to ditch the more traditional parts of their business. An analysis of developments in current and new value pools can reveal whether a business is positioned in attractive segments of the future market. In these circumstances, producing an impartial and objective forecast about value pools can serve as a fact base for making decisions. Decisions about new business models, for example,, are often mired in bias or a lack of courage to enter new areas. Yet innovative business models, new products and materials, and new digital services are exactly what is needed to expedite growth. The capital needed for this can be generated through optimizing or selling parts of the company that are being removed from the portfolio.

Following the financial valuation, portfolio options should be assessed for feasibility and risk to determine the company's direction. Challenging whether the company is going far enough to realize its vision and stand out from competitors in future is a constant and obligatory task.

Having rebranded from Statoil to Equinor in 2018, the Norwegian state-owned energy company has turned its back on fossil fuels and committed to expanding its activities in renewable energy. Equinor is working with SSE Renewables off the North Sea coast of Britain on Dogger Bank, which it says is the world's largest offshore wind farm. Equinor is also striving for a leading role in floating offshore wind farms.[171]

Organizations that manage to translate their vision into a compelling sustainability strategy will benefit from the reallocation of capital and higher ratings on the capital market.

[171] Equinor [German only]

3. Leverage green growth and capture opportunities faster
Key to this is delivering cutting-edge innovations as a contribution to the green transformation: courageous pioneers will be able to set the standards and stay one step ahead of the market, for example, on zero-emissions products. That will mean breaking new ground in terms of financing, development, and implementation of new technologies. Restructuring where decarbonization is the goal is often too slow when attempted alone. Hence the need to systematically seek out innovative solutions, for example, in partnership with start-ups and investors or by spinning off new business models into agile units.

In many cases, building new business models will require massive investment in a short space of time, with minimal solid planning. This is where partnerships come in, helping to share the risks and to benefit from economies of scale, especially when it comes to developing technologies, which is complex and risk prone (for example, increasing CCS capacities in cooperation with the Benelux nations and H_2 Green Steel in Sweden).

In 2015, Swedish carmaker Volvo, along with its Chinese parent Geely, acquired Polestar, also based in Sweden and with roots in motor racing.[172] Polestar became a standalone brand for the production of high-performance hybrid and electric cars and has seen strong growth ever since. A decarbonization pioneer, the company has set out to build fully climate-neutral cars by 2030.[173]

When developing and building these new, green businesses, the same best practices can be applied as for establishing (corporate) start-ups. The goal is always maximum speed with minimal use of resources, and above all at minimal risk. It is essential to rapidly implement any lessons learned, for example, through early customer feedback, and adjust plans accordingly. Financing must be linked to milestones. This allows for a flexible response that helps speed up business growth but also quickly put a halt to any initiatives that are not getting the expected traction.[174]

[172] Volvo
[173] Polestar
[174] Overview of business building

Green business building requires companies to address several other issues:

— **Idea development.** What are the ambitions for the sustainable business? What problem does the idea solve? How fast does the idea need to be realized to make a tangible contribution, for example, to reducing CO_2 emissions? Which customers and investors need to be convinced of this idea?

— **Business plan.** The business plan has to evaluate the business idea as a whole. From the underlying purpose of the business activity, the corresponding sustainability targets (emissions, water consumption, waste, biodiversity, use of raw materials) as well as financial targets, every aspect must be coherently defined. Guidelines for decision making are also critical when it comes to introducing clear standards, for example, that deal with stopping the use of pesticides in food production, or establishing internal settlement costs (for example, CO_2 pricing).

With regard to future markets and customers, companies need to clarify who needs to be persuaded that the idea is a good one and how much customers are willing to pay for it. Sustainable products are often more expensive, which is why it is so important to help customers understand exactly what is involved. This also means looking to the future and anticipating not only short-term business developments, but also changes that will take place in the medium to long term. A perspective on potential changes in the regulatory environment can also be helpful. Particularly for business ideas requiring significant investment (for example, green steel) it is imperative to negotiate early on with selected customers about everything from partnerships through to purchase guarantees.

In terms of a product or service, assessing technical feasibility is just as important as the resources to be used (HR, capital, production facilities, raw materials, ecosystem), the potential sustainability impact, and the question of possible partners. Impact assessments involve looking at the value a product or service will deliver during its use phase – but also which resources are needed to manufacture the product or service and what emissions that will generate (along the entire supply chain in each case).

— **Minimum viable product (MVP).** In this phase, the company needs to develop its MVP, or minimum viable version of the product or service, as well as the corresponding business processes. The purpose of the MVP is to test additional hypotheses. The first customers are also acquired during this phase. In green business building, special attention must be paid to ensure that business processes are developed with a sustainable mindset so they use as few resources as possible and generate zero CO_2 emissions.

— **Scaling and continuous development.** The core sectors have no choice but to put pedal to metal in the next ten years – depending on the sector up to twice or even ten times faster than today – to transform the entire system. Rapid scaling of business models that contribute to reducing CO_2 emissions is essential. However, this brings with it a number of challenges: how can new technologies be quickly brought to maturity? How can the associated business processes be set up quickly, and how can improvements be made flexibly? This is a complex task for the core technologies, since it requires effort on the part of everyone involved to clarify the following: how can partnerships or joint ventures with other, possibly established companies, help expedite these efforts? How can we leverage public subsidies, networking within the ecosystem, and collaboration with scientific institutes and other research organizations? What does optimum collaboration look like across the entire value chain? How can we secure the financial success of this new undertaking so as to scale faster?

Building green businesses is a pressing need in the process of decarbonizing our country, and presents opportunities to create "green unicorns" that offer substantial potential in terms of economic performance and jobs. So we must succeed in scaling our more than 6,000 environmental and climate protection start-ups – not only to protect our planet but also to safeguard the future of our country.

We must succeed in scaling our more than 6,000 environmental and climate protection start-ups.

4. Consistently push for decarbonization

For companies to realize the opportunities available, they will have to decarbonize their own processes in line with their ambitions, including the corresponding supply chains. One key step here is to create transparency on the emissions these processes generate. (Exhibit 21 shows an example emissions analysis along the value chain for oat milk – this type of analysis serves as the basis for identifying potential).

Scope 1 and scope 2 emissions can be reduced in three ways: by switching all process steps that consume substantial quantities of primary energy to electricity (see the section on industry), reducing energy requirements, and switching electricity and power supplies to renewables.

In many industries and businesses, scope 3 emissions are the biggest challenge. Capturing emissions in the supply chain is especially difficult since often the "real" emissions have not been identified, and the relevant information is not shared between parties in the value chain. Reducing emissions is not so simple either, given that low-carbon production methods for various precursor products are only just being developed or piloted.

One automaker's design-to-sustainability-and-cost project scrutinized the carbon footprint of aluminum rims. The manufacturer had previously assumed an average of 21.9 metric tons of CO_2 produced per metric ton of aluminum. However, the analysis revealed that the rims were sourced from a plant that used a coal-fired smelting furnace, making their actual carbon footprint around 3% larger. The project went on to identify two potential measures to reduce the footprint while keeping costs roughly the same:

- Switching to a supplier that processes aluminum in a plant powered by hydrogen electricity would make the footprint around 56% smaller.
- Using recycled aluminum would reduce the footprint by 80 to 90%, assuming the product was made from 100% recycled aluminum and continued to meet the same specifications. This is currently impossible, though, due to insufficient data regarding the stability and safety of the recycled material. That said, if 50% of the conventional aluminum was sourced from a hydrogen-powered plant, with the other 50% being recycled aluminum, it would save around 70% of the emissions.

This example clearly shows how important it is to have information about the carbon footprint of raw materials and intermediate products. For this reason, the World Business Council for Sustainable Development (WBCSD) is working intently to establish standards for carbon tracking, tracing, and accounting. The WBCSD and its members have launched a number of initiatives in various industries to create future transparency on the carbon footprint along value chains.

Originally launched in the consumer goods industry, the WBCSD Carbon Transparency Pathfinder seeks to generate verified transparency on product-specific carbon footprints based on primary data. The goal is to tap into a range of valuable use cases, such as carbon labeling, support for procurement decisions, offset management, etc. Another similar initiative is underway in the German automotive industry, the Catena-X Automotive Network, which among other things plans to create transparency on CO_2 emissions across the entire supply chain.

US retail giant Walmart sees the decarbonization of its supply chain as the biggest lever for reducing emissions. So the company is supporting its suppliers' decarbonization efforts by partnering with NGOs and a digital knowledge center for emissions mitigation. In this way, Walmart intends to transform its supply chain and save 1 billion metric tons of CO_2 starting in 2030.[175]

This is another example of companies wanting to decarbonize their value chain will have to source their upstream products from the lowest-emissions plants in future. That will increase demand for raw materials and intermediate products from the plants with the smallest product-specific carbon footprint. And so companies that have decarbonized their plants will reap a competitive advantage. Which also means that emissions certificates and plant audits will become increasingly important in the next few years.

Innovations and massive investment will be needed in the course of decarbonizing some materials and processes. In these cases, cross-industry and overarching supply chain collaboration will be necessary to ensure planning is reliable and to minimize risks. One example currently being hotly debated is the production of green steel, which has been made possible by early partnerships between start-ups and steel producers with automakers.

Introducing circular economies and increasing recycling rates are additional levers to reduce the use of resources in a supply chain. This relies on materials being accurately identified and rigorously separated to enable recycling for high-value use cases. Collection and logistics processes, as well as separation and processing, will have to be established to reintroduce these recycled materials into the supply chain.

Decarbonized products see higher rates of growth.

[175] Walmart

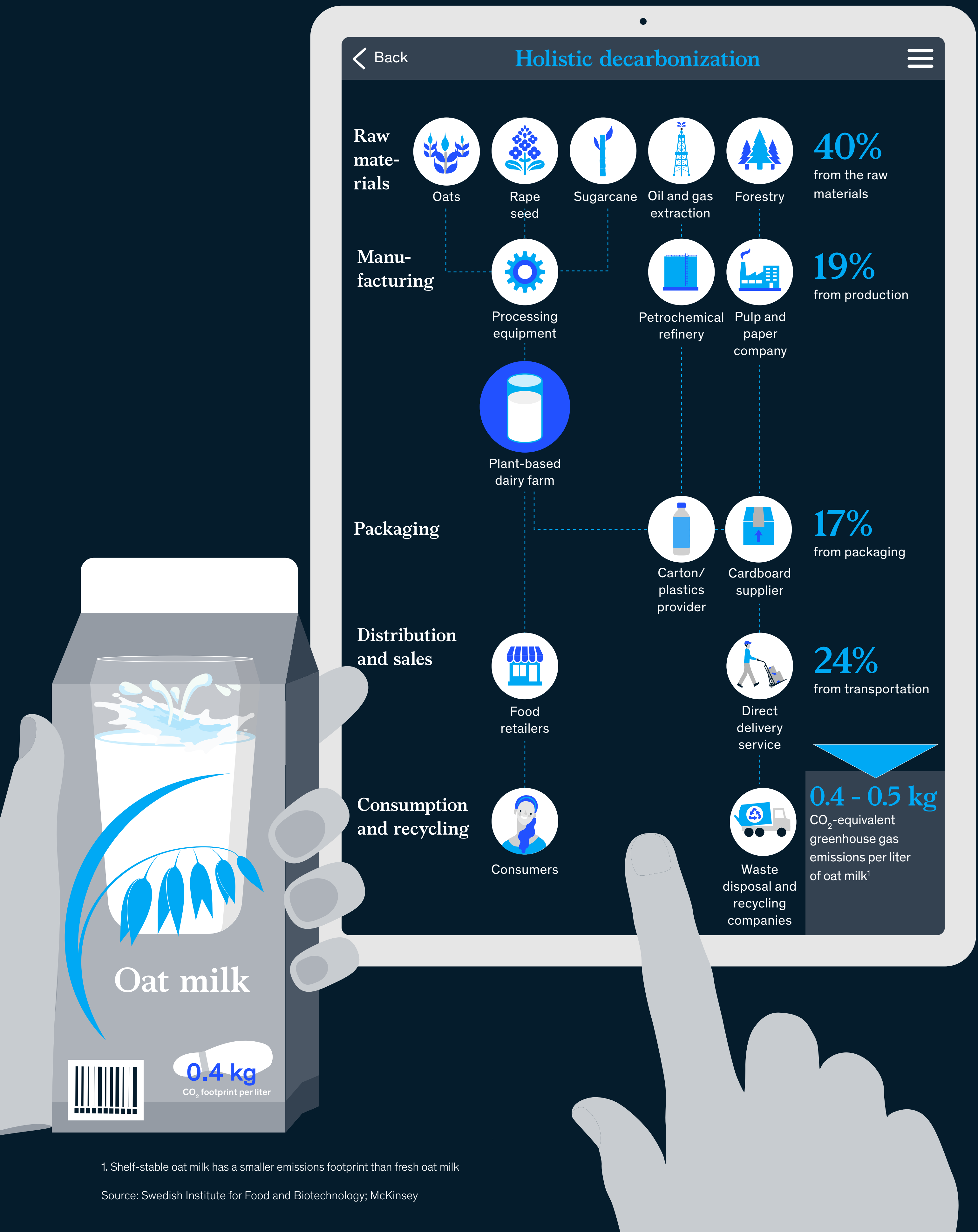
To ensure efficient, comprehensive business decarbonization, the following questions need to be answered:

- What is the breakdown of the actual carbon footprint? What innovations or new technologies need to be implemented? What are the most effective levers for reducing CO_2 emissions? How readily are these available? Which of these can be captured quickly and at no great effort? What is the cost, and what is the underlying business case?
- What changes in product and process design do we need to make, and when, to capture this potential? What does the supply chain decarbonization roadmap look like? What preconditions need to be met in the organization to implement the roadmap (KPI systems and targets, business case logic expanded to include CO_2 aspects, competency building in CO_2 emissions for employees in finance, development, and purchasing)?
- What will tracking and accounting look like? What information will be passed to customers, and how will the validity be certified and/or audited?

Those companies that make a determined effort to tackle these challenges will secure a competitive advantage: decarbonized products typically see higher rates of growth and can secure scarce resources early on, for example, recycled materials, which has a positive effect on the carbon footprint and with relatively little difference in cost.

Exhibit 21

Emissions performance management



1. Shelf-stable oat milk has a smaller emissions footprint than fresh oat milk

Source: Swedish Institute for Food and Biotechnology; McKinsey

Outlook

Germany's transformation to a climate-neutral society will take enormous effort, investment, and behavioral change in politics, business, research, and among the general public. In short: each of us has a part to play.

The next ten years will be critical: the technological approaches to decarbonization that have already been identified need to be rapidly implemented in every industry. Other innovations in technologies, processes, and materials must be developed and scaled to deliver on decarbonization. Almost everyone in politics, business, and society in general has acknowledged the need to take action. Now everything hangs on stepping up these changes and establishing, or improving on, the conditions and prerequisites for the transition ahead. Fast, comprehensive, and simultaneous competency building is also essential to the green transformation.

Without this, we will be unable to realize the opportunities presented by advances in technology or to benefit from growth in new markets.

With Net-Zero Germany, McKinsey wants to make a contribution to ensuring the success of Germany's decarbonization. We are proud of the support we have already been able to lend to many companies – in Germany and worldwide – as they take on the challenges they face on the road to climate neutrality. It is our declared aim to factor in decarbonization and climate neutrality as key decision-making parameters in all our consulting projects in future.

The preconditions for Germany's successful transformation have never been better. So say all of our global analyses. We are convinced that the transformation to a net-zero world can – and must – succeed so we can preserve a livable planet for our children and future generations.

Authors and contacts

Authors

Stefan Helmcke, Ruth Heuss, Solveigh Hieronimus, Hauke Engel

Sectors

Power
Alexander Weiss, Stefan Helmcke, Sebastian Overlack

Industry
- **Steel:** Benedikt Zeumer, Christian Hoffmann
- **Cement:** Thomas Czigler
- **Chemicals:** Ulrich Weihe, Christoph Witte, Christoph Schmitz
- **Automotive:** Ruth Heuss, Andreas Cornet, Harald Deubener, Martin Lindner, Patrick Schaufuss, Markus Wilthaner
- **Mechanical engineering:** Dorothee Herring, Thorsten Schleyer
- **Consumer goods:** Frank Sänger, Sebastian Gatzer, Sandra Welchering

Transportation
Andreas Cornet, Harald Deubener, Martin Linder, Patrick Schaufuss, Florian Neuhaus, Bernd Heid, Anna Herlt, Markus Wilthaner

Buildings
Focko Imhorst

Agriculture
Martin Lösch, Ulrich Weihe, Alexander Bülow

Banking
Max Flötotto, Holger Harreis, Susanne Maurenbrecher

Transformation approach
- **Strategy and portfolio:** Stefan Helmcke, Stefan Kemmer
- **Green business Building**: Florian Wunderlich, Markus Berger-de Leon, Holger Klärner
- **Decarbonization:** Ruth Heuss, Peter Spiller, Karsten von Laufenberg

The authors would like to thank:

Daniel Abraham, Birgit Ansorge, Alice Barwich, Anja Bühner-Blaschke, Katharina Busch, Victoria Faber, Marcin Hajlasz, Jörg Hanebrink, Nadine Janecke, Caroline Kopf, Heinke Maria Kunze, Magdalena Kupfersberger, Esperanza Mata, Tobias Neise, Fridolin Pflugmann, Marie Rebmann, Friedrich Sarrazin, Jan Schubert, Vera Schulhof, Johanna Schulze-Berge, Daan Walter, Thomas Vandieken, Cedric Walder, Jana Wilken, Maaike Witteveen

Media contact

Kirsten Best-Werbunat

List of abbreviations

CCP // Core carbon principles

CCS // Carbon capture and storage CCU // Carbon capture and utilization

CCU/S // Carbon capture, utilization, and storage

CRISPR // Clustered regularly interspaced short palindromic repeats

DR // Direct reduction

DRI // Direct reduced iron

EAF // Electric arc furnace

EBA // European Banking Authority

EBITDA // Earnings before interest, tax, depreciation, and amortization

ECB // European Central Bank

EEG // German Renewable Energy Sources Act [Erneuerbare-Energien-Gesetz]

EPC // Energy performance certificates

ESG // Environmental, social, and governance

ESS // Energy storage system

EV/EBITDA // Enterprise value/Earnings before interest, tax, depreciation, and amortization

EV // Electric vehicle

EZB // Europäische Zentralbank

GW // Gigawatt

HDPE // High-density polyethylene

ICE // Internal combustion engine

KBA // Federal Motor Transport Authority [Kraftfahrt-Bundesamt]

LULUCF // Land use, land-use change, and forestry

MVP // Minimum viable product MW // Megawatt

NGO // Nongovernmental organization

R&D // Research and development

ROCE // Return on capital employed

SMR // Steam-methane reforming

SOP // Standard operating procedure TRS // Total return to shareholders

TSVCM // Taskforce on Scaling Voluntary Carbon Markets

UNFCCC // United Nations Framework Convention on Climate Change

WBCSD // World Business Council for Sustainable Development

October 2021

Designed by Visual Media Europe

www.mckinsey.com

@McKinsey
@McKinsey