McKinsey & Company

Pathways to decarbonize the Czech Republic

Carbon-neutral Czech Republic 2050

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Our purpose as a firm is to help create positive, enduring change in the world. Our approach to social responsibility includes giving back to our communities, managing our firm in socially and environmentally sustainable ways, and intentionally addressing societal challenges across our client work.

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One key area in which McKinsey & Company has engaged extensively to achieve such positive change is environmental sustainability. Through our own internal practices, our work with clients, and published research, McKinsey helps businesses and governments reduce risk, manage disruption, and capture opportunities in the transition to a low-carbon, sustainable-growth economy (see also our recent publication, *Climate risk and response: Physical hazards and socioeconomic impacts*). In writing this report, we hope to provide a rigorous approach and a valuable fact base for decision-makers across the public, private, and nonprofit sectors to assess and potentially expand actions to achieve a lower-carbon future.

About McKinsey & Company in the Czech Republic

Established in 1994, McKinsey's Prague office has been working with leading international and local companies and institutions in the Czech Republic and Slovakia. With about 50 consultants and specialists, the Prague office taps into our global network of experts, both in our cross-border client engagements and in our internal research efforts. In addition to the consultancy office, Prague is also home to McKinsey Global Services, with its more than 400 specialists in technology, digitization, data science, and other areas. Increasingly, our projects are composed of hybrid teams that include consultants, data scientists, designers, and developers.

In just the last few years, McKinsey's Prague office has worked on more than 200 projects in the energy, manufacturing, telecommunications, and financial sectors. In addition, we regularly provide pro bono expertise in areas of critical importance to the future of the Czech Republic, including sustainability, education, and healthcare.

Pathways to decarbonize the Czech Republic

Carbon-neutral Czech Republic 2050

By Viktor Hanzlík, Vít Javůrek, Bram Smeets, and Daniel Svoboda

Preface

At McKinsey, we see climate change as one of the defining issues of our age—an issue that will have profound effects on people, governments, and industries, as well as on individual companies. We believe that it is important for citizens, government officials, and business leaders to understand the pathways and actions required to limit climate change to what scientists deem to be acceptable levels.

The intent of this report is to present a cost-effective pathway for the Czech Republic to meet European Green Deal targets, outlining the actions and investments required in each sector of the Czech economy. Our objective is not to predict the future but to present our analysis of the costs and implications of the decarbonization efforts currently being discussed. In so doing, we are attempting to provide what appears today as the most optimal route to achieving the European Green Deal's carbon emission mitigation goals.

This analysis serves as a follow-up to our 2008 report, *Costs and potential of greenhouse gas emissions reduction in the Czech Republic*, as well as a series of internationally published papers. Over the past two years, we have analyzed the optimal decarbonization pathways for several countries in Europe (the Netherlands, Poland) and beyond.

This report presents the results of McKinsey & Company's independent analysis based on the sources listed in the Bibliography section. The preparation of this report was led by consultants in McKinsey's Prague office, working with international experts from McKinsey Energy Insights and McKinsey Power Solutions. The report was prepared on a pro bono basis.

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Executive Summary

Scientific evidence shows that to avoid the most serious effects of climate change, the Earth's average rise in temperature would need to be limited to 1.5°C above pre-industrial levels. To do this, human-generated greenhouse gas (GHG) emissions would need to fall to net-zero by the middle of this century.[1] Accordingly, in December 2019, the European Commission announced the EU Green Deal, which, if approved by its 27 member states and the European Parliament, would require the EU to reach net-zero emissions by 2050.

For the EU to reach this target, every member country would have to contribute. Although GHG emissions in the Czech Republic have fallen since 1990, it remains the fourth-largest emitter per capita in the EU.[2] The Czech power sector is the largest contributor, accounting for 35 percent of the republic's total GHG emissions, followed by industry, transport, buildings, agriculture, and waste.[3]

Reaching net-zero GHG emissions by 2050 would be a significant challenge. The good news is that many of the green investments that would be required could come with economic and social benefits: reducing operating costs for businesses, shifting the economy towards industries with a promising and viable future, and reducing damaging pollution.

However, to reap these benefits and meet its obligations under the Green Deal, the Czech Republic would need to accelerate its GHG reduction efforts. It could significantly reduce emissions by 2030 primarily by curtailing its dependence on coal. But to meet the 2050 targets, businesses in the transportation, industry, and building sectors would already need to have made other significant changes by 2030.

This report presents a cost-effective pathway for the Czech Republic to reach its goals and outlines actions and investments for each sector. Our objective is neither to predict the future nor set the country's policy objectives, but to present the costs and implications of the decarbonization efforts currently being discussed and to describe what today appears to be an optimal route. There are multiple possible pathways to reaching net-zero emissions—the one presented in this report focuses on achieving this objective with minimum total costs to society and, hence, we'll be referring to it as the "cost-optimal pathway".

For our analysis, we used McKinsey's Decarbonization Pathways Optimizer (DPO), a proprietary toolkit. The DPO uses over 500 business cases covering every sector to find a cost-optimal way to meet the Green Deal's targets while accounting for resources, supply chains, technology adoption, and various constraints. The report uses 2017 emissions data, latest available at the time of analysis.

Many of the green investments could come with economic and social benefits.

Reducing emissions by 2030

1% of GDP

(CZK 500 billion) is the additional investment needed over the next decade to achieve 55% emissions reduction by 2030

The existing target under the EU's 2030 Climate and Energy Framework is to reduce greenhouse gas emissions by 40 percent compared to 1990 levels. The Czech Republic's draft climate and energy plan defining the Czech portion of the commitment calls for 2030 emissions to fall to 104.5[4] million metric tons of carbon dioxide equivalent ($MtCO_2e$).[5]

The EU Green Deal, if approved by member states and the European Parliament, would introduce a more ambitious target. By 2030 the EU would reduce its GHG emissions by 55 percent from 1990 levels.[6] Assuming a matching effort by the Czech Republic (which also would reduce its GHG emissions by 55 percent), our calculations show that the country would need to intensify its emission reduction efforts to 3.2Mt per year from 2018 to 2030 (or 2.5 percent of emissions from the beginning of the period), and 4.4Mt[7] per year from 2031 to 2050 (or 5 percent of emissions from the beginning of the period).

Our analysis shows that achieving the 55 percent reduction by 2030 would require additional investments of CZK 500 billion (EUR 18 billion, corresponding to an estimated 1 percent of GDP) over this decade. Most of these investments would pay for themselves (or generate a profit) as new technologies that lower business operating costs are adopted.

Our analysis shows that a 55% reduction in GHG emissions by 2030 is achievable. The primary levers that could be used to meet the 2030 target include further reductions in the country's reliance on coal for power and heat and reduced coal mining. On the cost-optimal pathway, this would account for 75 percent of the GHG emission reductions by 2030. This is already underway. Several coal power plants either have shut down or are scheduled to close in the next few years. The EU Emissions Trading Scheme (ETS) raising permit prices further encourage a move away from coal, as do low natural gas prices. On the cost-optimal pathway, the reduction in coal power generation capacity could be partly offset by a significant increase in renewables capacity, adding 3.2GW of new solar photovoltaics (PV) and wind by 2030, and an increase in natural gas generation capacity.

On the cost-optimal pathway, three other sectors—industry, transportation, and buildings—would contribute the remaining 25 percent of the required gross GHG emissions reduction. This percentage reflects the greater difficulty and higher costs of decarbonization in those sectors relative to power. Decarbonization activities in industry, transportation, and buildings would include electrifying process heat production in industry, increasing the share of electric vehicles—cars, light trucks, and buses—improving the insulation and phasing out coal boilers in buildings. Even though these sectors' contribution to the 2030 reduction target might appear modest relative to coal-based power generation and heating, businesses and government would still need to make major changes in these areas by the end of the 2020s to ensure that the country is on track to meet the 2050 net-zero target.

A significant potential obstacle to achieving the 2030 target is a bark beetle outbreak causing mass deforestation. It is turning Czech forests from carbon sinks into significant sources of GHG emissions, up to 10 Mt[8] per year in the mid-2020s, which corresponds to 8 percent of 2017 emissions. Managing the bark beetle outbreak to ensure the total volume of living biomass in these forests rises is critical to achieving the 2030 target.

An ongoing bark beetle outbreak causing mass deforestation is turning Czech forests from carbon sinks into significant sources of GHG emissions.

Reducing emissions by 2050

Reaching net-zero GHG emissions would be a major undertaking for the Czech Republic. Full decarbonization would require far-reaching technological changes in every sector and the deployment of both natural and artificial carbon sinks to eliminate emissions in hard-to-abate sectors such as cement production and agriculture.

On our cost-optimal path, there would be residual emissions of 17Mt in 2050, offset by 9Mt of negative emissions from the land use, land-use change, and forestry (LULUCF) sector. And while 8Mt of emissions would have to be abated through carbon capture, use, and storage (CCS), it has not been proven yet at the required scale. However, even if CCS is not feasible at the required scale by 2050, the result would still be a GHG emissions reduction of more than 95 percent compared to the baseline year of 1990. Also, before 2050, new technologies may emerge, or the economics of some technologies may improve faster than expected, allowing the Czech Republic to decarbonize fully without CCS.

Based on our analysis, reaching net-zero would likely require additional investments amounting to CZK 4 trillion (EUR 150 billion) from 2031 to 2050, or roughly 4 percent of GDP over that period. This investment would be necessary for the large-scale electrification of transport and heating and cooling for technology changes in industry, scaling up renewable power generation, completing the construction of two new nuclear units in line with the 2019 Czech National Investment Plan,[9] reducing energy consumption of buildings throughout the country, and deploying the carbon sinks necessary to offset residual GHG emissions. The majority of these investments would be profitable or would at least fully pay for themselves through reducing operating costs for businesses and would contribute to reducing local pollution.

Although the costs of achieving net-zero by 2050 would be substantial, the next 30 years offer significant opportunities for making capital upgrades as existing infrastructure and industrial equipment reach the end of their useful lives. However, many of the changes would have to be underway by the end of the 2020s to remain on track for reaching net-zero by 2050. Specifically, efforts to switch from fossil fuels to electricity in transportation, scale up renewable power sources significantly, considerably increase the energy efficiency of buildings and finding a long-term solution for heating in the Czech Republic all need to be well underway by 2030.

Full decarbonization would require far-reaching technological changes in every sector.

Chapter 1

Motivation to reach a carbon-neutral economy

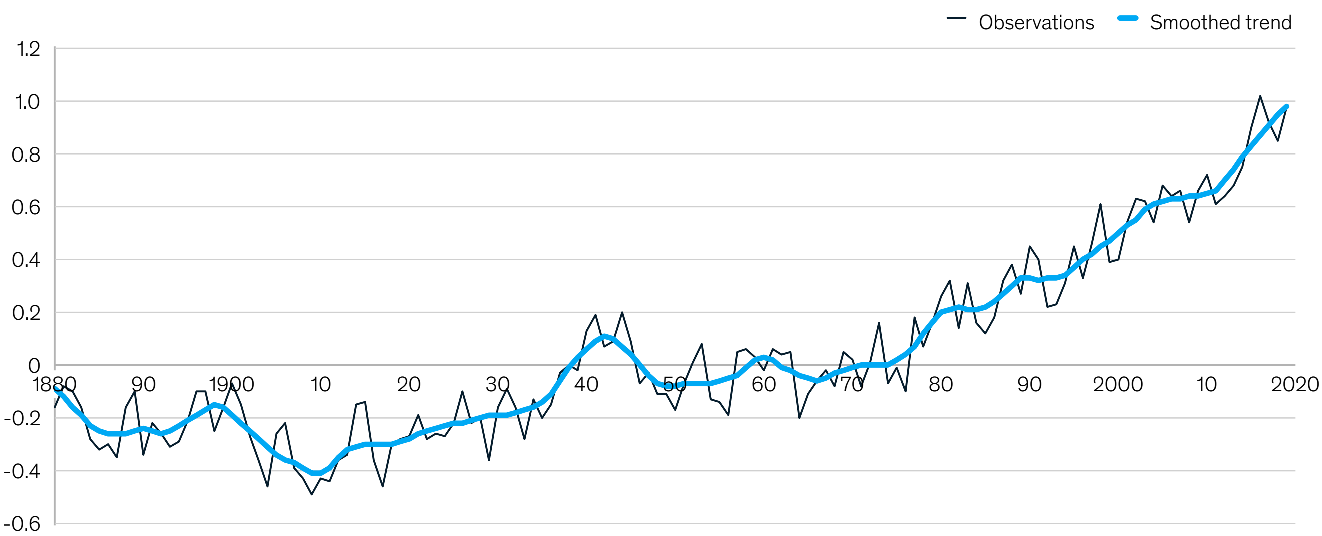
Why aim for net-zero GHG emissions by 2050?

The planet's temperature has risen by about 1.1°C since the 1880s. As average temperatures rise, acute hazards such as heatwaves, extreme precipitation, and forest fires grow in frequency and severity, and chronic hazards such as droughts and rising sea levels intensify.

To avoid the most severe effects of a changing climate, average global temperatures need to be kept from rising more than 1.5°C by 2100, and man-made GHG emissions would have to reduce to net-zero by 2050.[10] For this goal to have a chance of being met, decarbonization needs to accelerate now.

Earth has warmed by roughly 1.1 degrees Celsius since the late 1800s

Anomaly relative to 1951–1980 average temperatures; °C

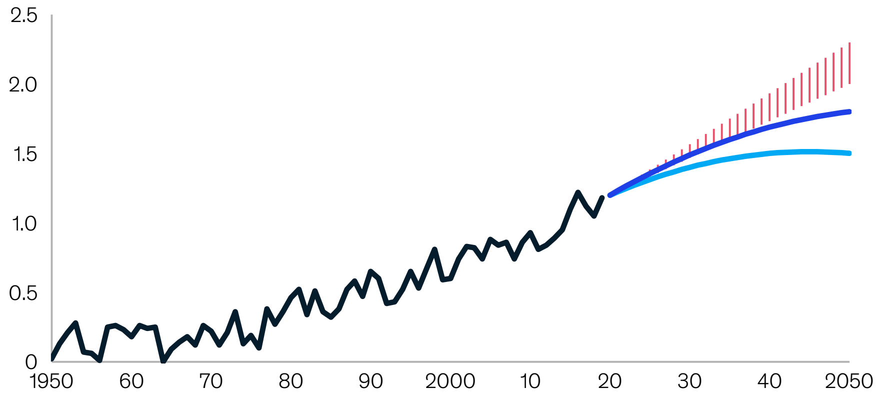


Source: NASA Goddard Institute for Space Studies (GISTEMP – 2019)

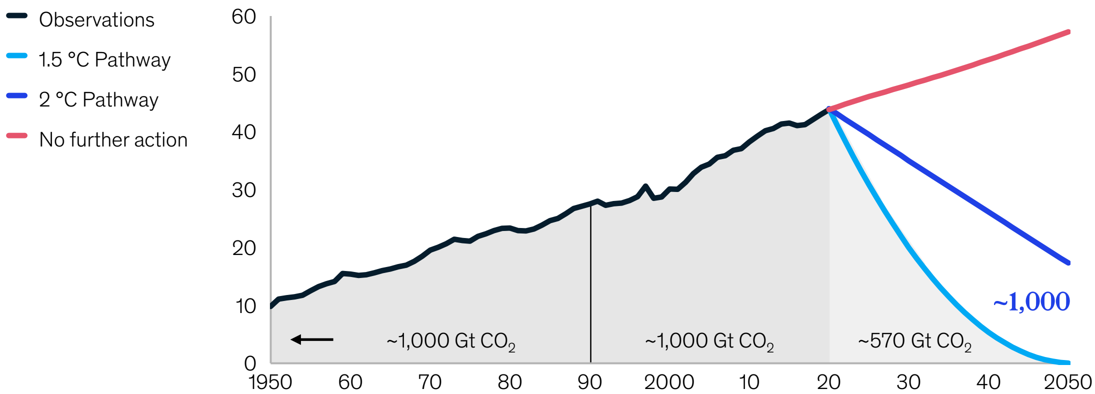
To avoid the most severe effects of a changing climate, average global temperatures need to be kept from rising more than 1.5°C by 2100.

Declines in annual CO_2 emissions are necessary to mitigate the most severe effects of climate change

Rise in average global temperature; °C



Annual global CO_2 emissions; $GtCO_2$



Source: CO_2 emissions: Carbon Dioxide Information Analysis Centre, Oak Ridge National Laboratory. Friedlingstien et al. "Global Carbon Budget 2019." Earth Systems Science Data. (2019). Forward projections are illustrative, based on carbon budgets estimated from Rogelj et al (2019) and the IEA CP Scenario, following Hausfather and Peters (2020). Temperature Record: NASA Goddard Institute for Space Studies (GISTEMP – 2019). Warming for "No further action" is the range between RCP8.5 and RCP4.5 ranges, as IEA CPS plus estimates for non-energy emissions following Hausfather and Peters (2020) puts cumulative emissions roughly 3/4[ths] of the way between RCP8.5 and RCP4.5

In the Czech Republic, temperatures are also rising, although the impact of climate change has not been as severe as in other countries because of its moderate climate and lack of coastline. In the last 60 years, the average temperature, as measured by the Czech Hydro-meteorological Institute (CHMI), has risen by 2°C.[11] The country has experienced severe droughts in the past few years, and 2019–2020 was the second-warmest winter on record.[12]

Public awareness of the dangers of global warming has also grown. According to the STEM Institute, 84 percent of Czech citizens believe that climate change endangers the future. Nine out of ten people think that unless climate change is addressed, the country will see more droughts, deforestation, and other natural disasters.[13] While the Eurobarometer shows that support for taking climate action is weaker in the Czech Republic than in Western Europe and the Nordic states, 89 percent of Czech respondents agree or tend to agree that the EU economy should be made carbon-neutral by 2050. Fifty-two percent of Czechs agree or tend to agree that adapting to the adverse impacts of climate change can have positive outcomes for citizens of the EU.[14]

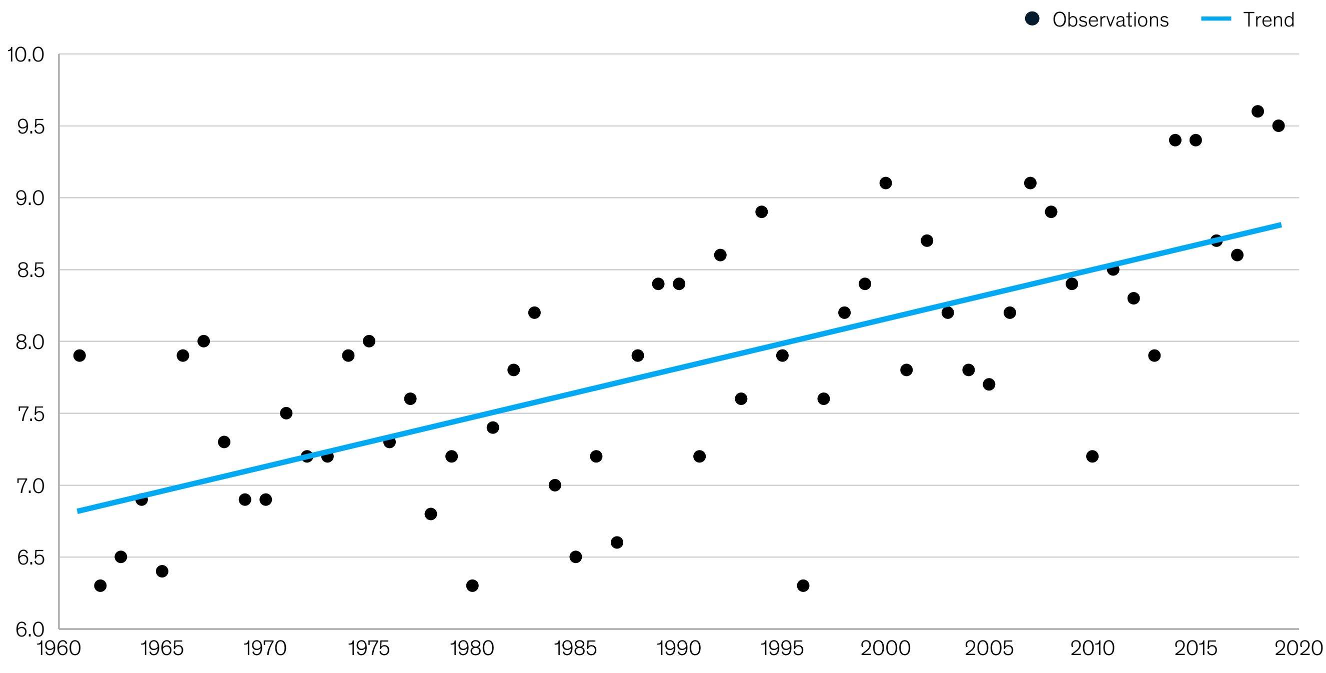
The European response to the threat of global warming

In December 2019, the European Commission (EC) announced the European Green Deal, a new policy framework to accelerate decarbonization in the European Union. Among the policies under consideration is a law that, if approved by the European Union's 27 member states and the European Parliament, would require the bloc to lower GHG emissions by at least 55 percent by 2030 versus 1990 levels, and to net-zero by 2050.[15] As a member of the European Union, the Czech Republic has been consulted and is part of the approval process of the Green Deal.

At the time of writing, the Green Deal's aspiration to create a climate-neutral Europe is one of the world's most ambitious decarbonization plans. Its goal of net-zero by 2050 is consistent with the targets of the 2015 Paris Agreement. The Green Deal aims to ensure that member states have the financing they need to make the transition towards green technologies and infrastructure. The EU has a history of meeting its decarbonization targets. When it signed the Kyoto Protocol in 1997, it committed to reducing its GHG emissions by 8 percent compared to 1990 levels by the end of the Kyoto Protocol's first commitment period in 2012. It over-delivered, reducing them by 19 percent instead.[16] In 2010, the EU set another target: reducing the continent's emissions by 20 percent by 2020. By 2018, the EU had already surpassed that.[17]

Over the past 60 years, the average temperature in the Czech Republic has risen by nearly two degrees Celsius

Average annual air temperature; °C



Source: CHMI

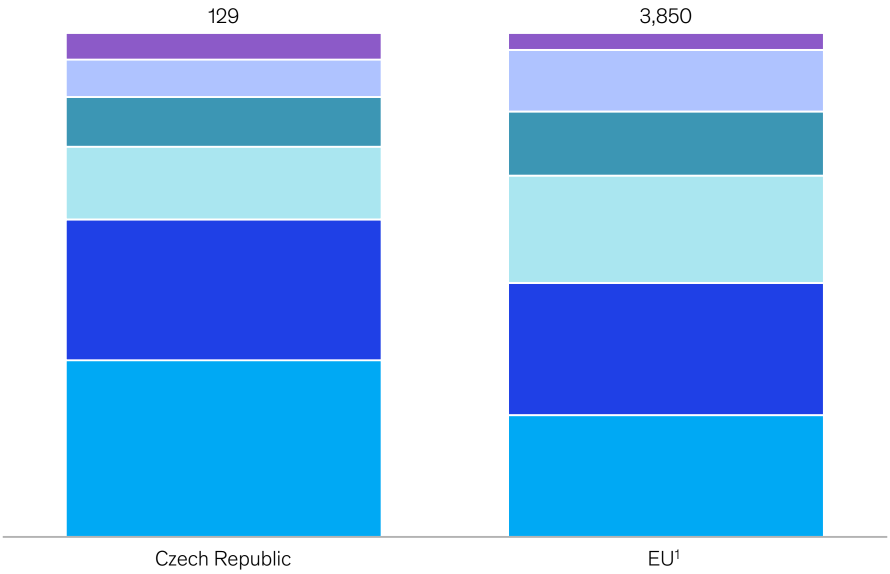
The starting position of the Czech Republic

In 2017, the EU's total GHG emissions were 3.9 $GtCO_2e$,[18] excluding 0.2 $GtCO_2$ of negative emissions and all emissions from international transport. The equivalent number for the Czech Republic was 129 $MtCO_2e$, excluding 2 Mt of negative emissions; that is, 3.4 percent of the EU total.[19]

The Czech Republic has undergone a significant transformation of its economy in the last 30 years, reducing its GHG emissions (excluding LULUCF) to 129 $MtCO_2e$ in 2017,[20] down from 199 $MtCO_2e$ in 1990.[21] Despite this drop, the country was the fourth-largest GHG emitter in the EU on a per capita basis. Electricity and heat generation accounted for most Czech GHG emissions, at 45.3 $MtCO_2e$, followed by industry (36.2 Mt), transport (18.7 Mt), buildings (12.7 Mt), agriculture (9.7 Mt), waste, and others (6.8 Mt).[22]

Power and heat generation produce a greater percentage of GHG emissions in the Czech Republic than in the rest of the EU

$MtCO_2e$; excluding LULUCF, international aviation and transport; 2017



	Czech Republic	EU
Waste & others	5%	3%
Agriculture	7%	12%
Buildings	10%	13%
Transport	14%	21%
Industry	28%	26%
Power & heat	35%	24%

1. Includes EU 27 countries

Source: Eurostat

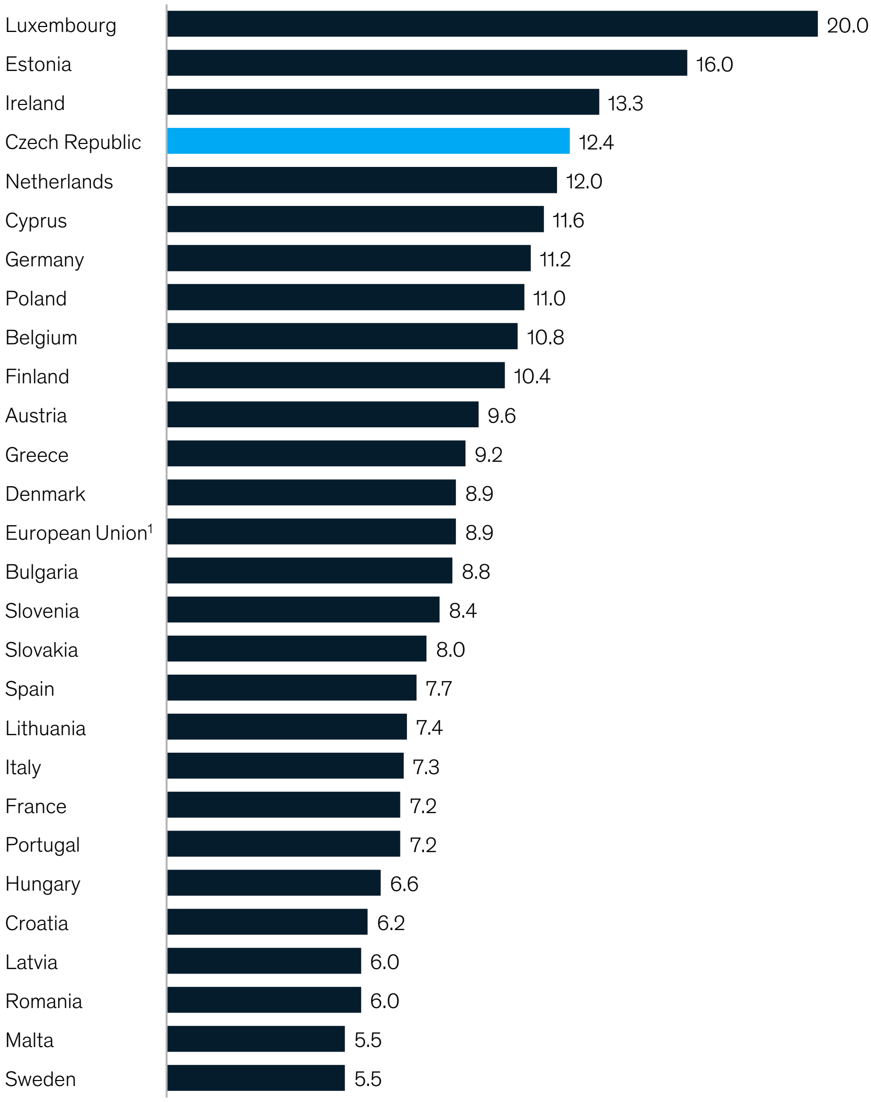
Czech emissions have declined from 199 $MtCO_2e$ in 1990 to 129 $MtCO_2e$ in 2017.

4th

Czech Republic was 4th largest GHG emitter in EU on per capita basis

In 2017, the Czech Republic had one of the highest per-capita greenhouse gas emissions in the EU

Tons of CO_2e per capita; 2017



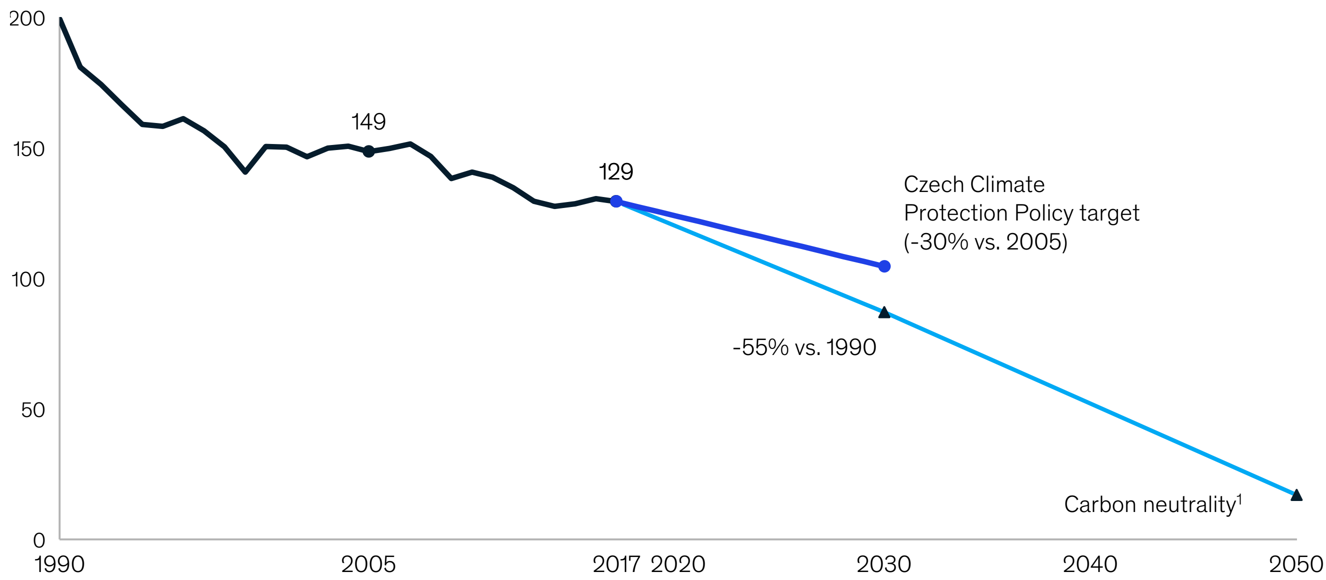
1. EU 27 countries

Source: Eurostat, European Environment Agency

The initial drop in emissions after 1990 was primarily driven by the dismantling of the command economy in 1989, which decreased the country's heavy industrial exports to socialist bloc countries. Since that drop, GHG emissions have declined slowly, resulting in an average fall of 2.6 Mt a year from 1990 to 2017. However, if the Czech Republic only continues on this trajectory, it will not meet the Green Deal's targets. According to our analysis, in order to meet them, emissions would need to drop by 3.2 Mt a year over the next decade, then by 4.4 Mt every year from 2031 to 2050.[23]

The Czech Republic would need to accelerate its decarbonization to achieve a 55% reduction compared to 1990 and achieve net-zero by 2050

$MtCO_2e$



Note: Excluding LULUCF

1. Emitted GHG are equal to absorbed GHG

Source: EEA, Vnitrostatni plan CR v oblasti energetiky a klimatu 2017; European commission; McKinsey analysis

In order to meet the Green Deal's targets, emissions would need to drop by 3.2 Mt a year over the next decade, then by 4.4 Mt every year from 2031 to 2050.

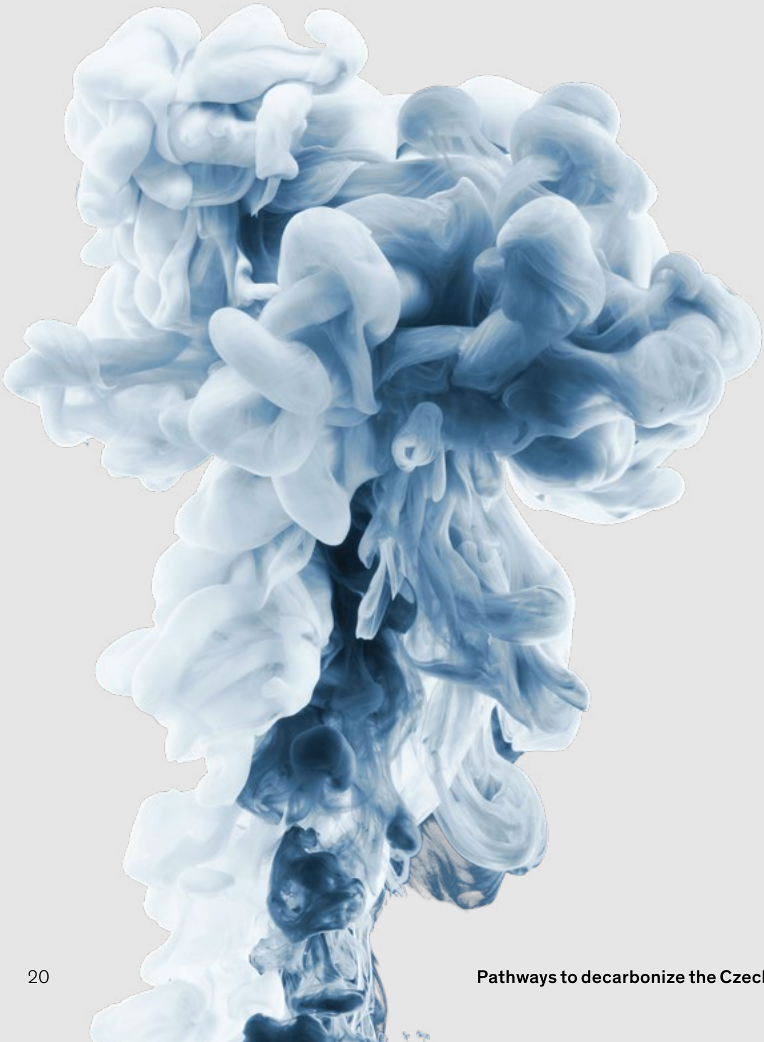
EU ETS and Effort Sharing schemes

There are two main mechanisms through which the European Union tracks and enforces the achievement of GHG reduction targets, the Europe-wide Emissions Trading System (ETS) and Effort Sharing Regulation, which sets a binding greenhouse gas emission target for each EU member state.[24]

— The ETS is a Europe-wide 'cap and trade' system which covers GHG emissions from over 11,000 heavy energy-using installations in the power and industry sector as well as domestic air transport. Under the scheme, a cap on the total amount of emissions is set for the sectors covered by the ETS, and a corresponding amount of ETS allowance is allocated or sold to companies in the relevant sectors, which need to surrender allowances to cover their emissions or face fines. The permits are freely tradeable and incentivize companies to reduce their emissions to be able to sell their excess allowances or avoid having to buy additional ones. In theory, the scheme achieves the target level of emissions with the lowest societal costs. The decisions to acquire or sell allowances, reduce or cease production, or to reduce the GHG intensity of production are made by companies, and there is no target for individual member states. In 2017, emissions covered by the ETS accounted for about 45 percent of the EU total.

— For emissions not covered by the ETS (mostly from the transport, building, and agricultural sectors), there are binding targets for each EU member state defined by the decision on a joint effort. Failure to meet the targets may result in an infringement procedure and penalties against a member state.

The European Commission is currently preparing a plan to increase targets for ETS and Effort Sharing consistent with the more ambitious targets of the Green Deal.



Chapter 2

The pathway to net-zero emissions in the Czech Republic

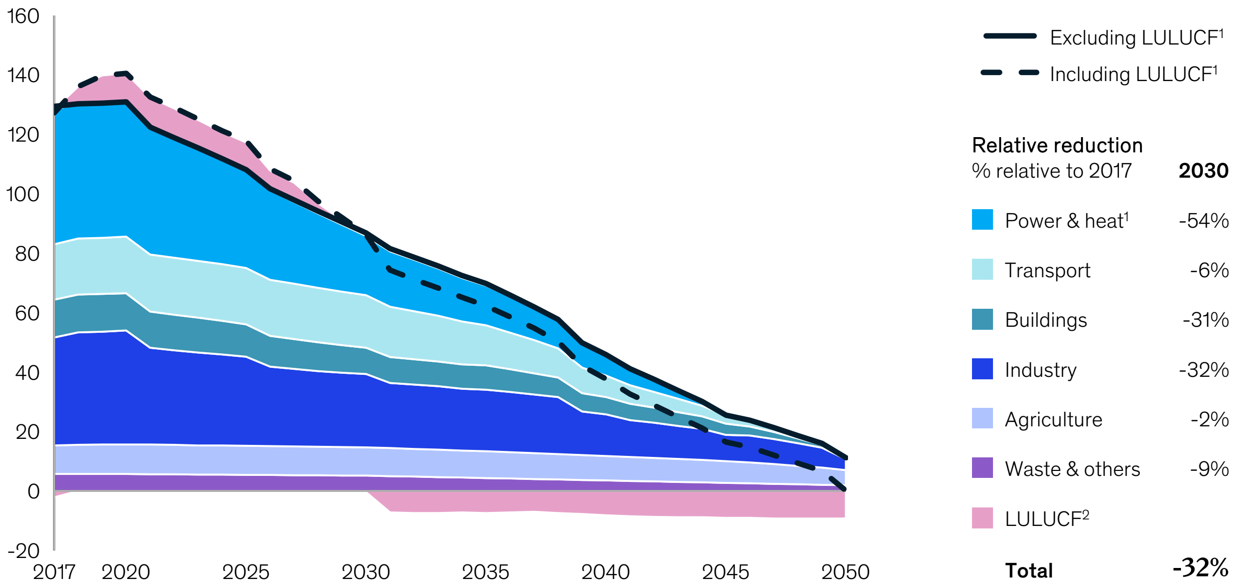
Following the cost-optimal pathway, for the Czech Republic to decrease the GHG emissions by 55 percent by 2030, it would need to sharply reduce coal mining and the use of coal for power and heat generation, improve insulation and replace decentralized coal heating boilers with lower-emission alternatives, significantly increase the percentage of electric vehicles on the roads, continue electrifying industrial processes and heat generation, and bring the Czech bark beetle outbreak under control by the second half of this decade.

To achieve the 2030 goals, all these efforts would need to begin immediately.

Achieving full decarbonization by 2050 would require far-reaching technological changes in every sector, as well as the deployment of natural and artificial carbon sinks to offset emissions in hard-to-abate sectors such as cement production and agriculture. On the cost-optimal pathway, the final 5 percent of GHG emissions would have to be abated through carbon capture, use, and storage (CCS). However, in the years before 2050, it is possible that new technologies or improvements in current technology economics may allow the Czech Republic to decarbonize fully without CCS.

Cost-optimal decarbonization path for the Czech Republic

$MtCO_2e$



Relative reduction % relative to 2017	2030	2050
Power & heat[1]	-54%	-105%
Transport	-6%	-100%
Buildings	-31%	-97%
Industry	-32%	-90%
Agriculture	-2%	-48%
Waste & others	-9%	-66%
LULUCF[2]		
Total	**-32%**	**-100%**

1. Reduction of more than 100% achieved by a combination of biomass and CCS technology
2. Land use, land use change, and forestry serves typically as a carbon sink thanks to carbon absorption in forests and land. Due to the current bark beetle outbreak, LULUCF is expected to be a net emitter for the next ~10 years.

Source: McKinsey analysis

Summary of the pathway and costs to reduce emissions by 2030

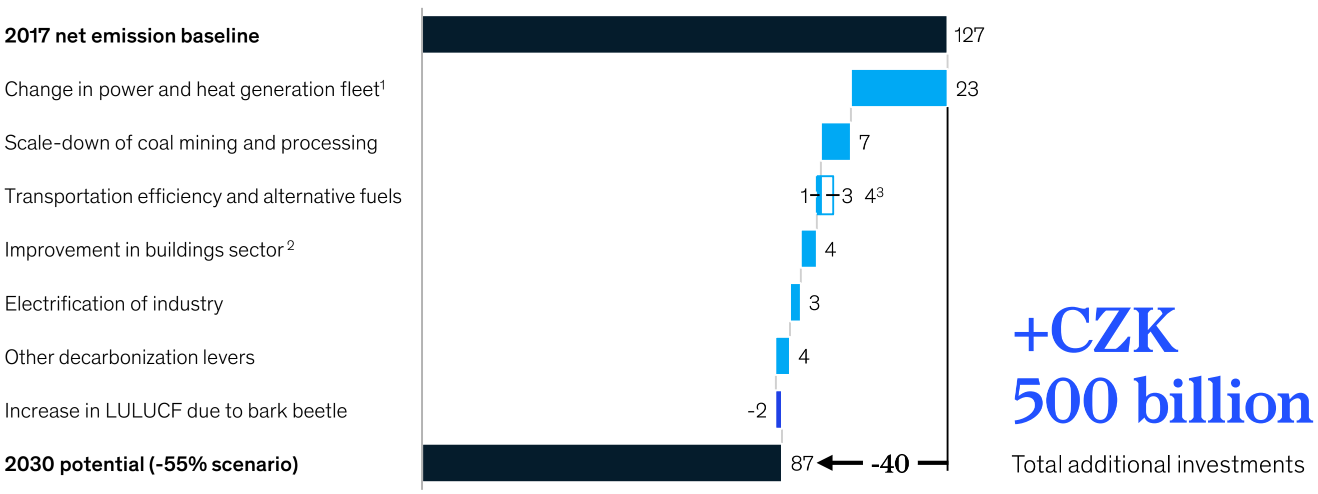
Our analysis shows that reducing emissions in the Czech Republic by 55 percent by 2030 could be realistic. It would require an additional investment of CZK 500 billion or 1 percent of the country's GDP over the next decade. The majority of these investments would generate a profit or fully pay for themselves through reduced operational costs achieved through new technologies.

Just reducing the country's dependence on coal for power and heat generation would get the Czech Republic 75 percent of the way toward reducing emissions by 55 percent by 2030. And the country has already begun to move away from coal mining and processing since the baseline year of 2017.

In addition to reducing coal dependence, four main actions would get the Czech Republic the rest of the way to 55% emissions reduction by 2030: electrifying transportation, increasing building insulation, switching space and water heating methods, and electrifying industry. These measures need to be implemented immediately. For example, our analysis shows that at least 49 percent of cars newly registered in the Czech Republic would have to be battery electric vehicles (BEV) or plug-in hybrid vehicles (PHEV) by 2030. Today, BEVs and PHEVs constitute less than 1 percent of registered vehicles.

The Czech Republic could lower GHG emissions by 55% with an additional investment of CZK 500 billion over the next decade

$MtCO_2e$; incl. LULUCF



1. Includes power generation and district heat generation (individual dwelling heating is included in buildings)
2. Switching heating methods away from coal; increased insulation levels
3. Scenario assumes an increase in emissions by 2030 by 3 Mt due to increased number of kilometers driven

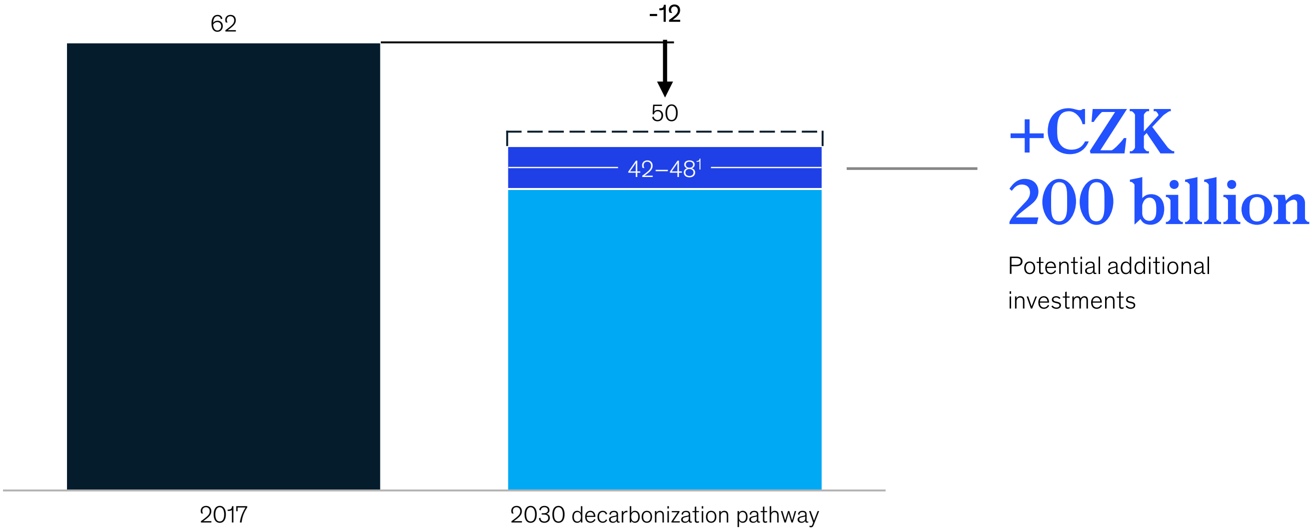
Source: McKinsey analysis

Most of the GHG reduction on the cost-optimal pathway comes from sources operating under the ETS regime. In our decarbonization scenario, non-ETS emissions would drop to 50 $MtCO_2e$, and the Czech Republic would meet the overall 55 percent reduction target. However, the non-ETS target for the Czech Republic could be more demanding, requiring a drop to 42–48 $MtCO_2e$ by 2030.[25] Our analysis shows that decreasing the Czech non-ETS emission to 45 $MtCO_2e$ (the middle of the possible range) could increase the required investment by up to CZK 200 billion as more costly decarbonization options would need to be used.

As noted before, achieving the 2030 target would require the Czech Republic to manage the current bark beetle outbreak that is causing mass deforestation throughout the country and turning forests from carbon sinks into significant sources of GHG emissions.

On the cost-optimal pathway, Czech emissions outside of EU ETS would decline to 50$MtCO_2e$ by 2030

$MtCO_2e$



1. AMO scenarios for increased commitments within the effort sharing regulation

Source: AMO; McKinsey analysis

To reach net-zero by 2050, the Czech Republic would need to change much of its capital stock, and use carbon sinks to capture the remaining hard-to abate emissions.

Summary of the pathway and costs to reach the 2050 target

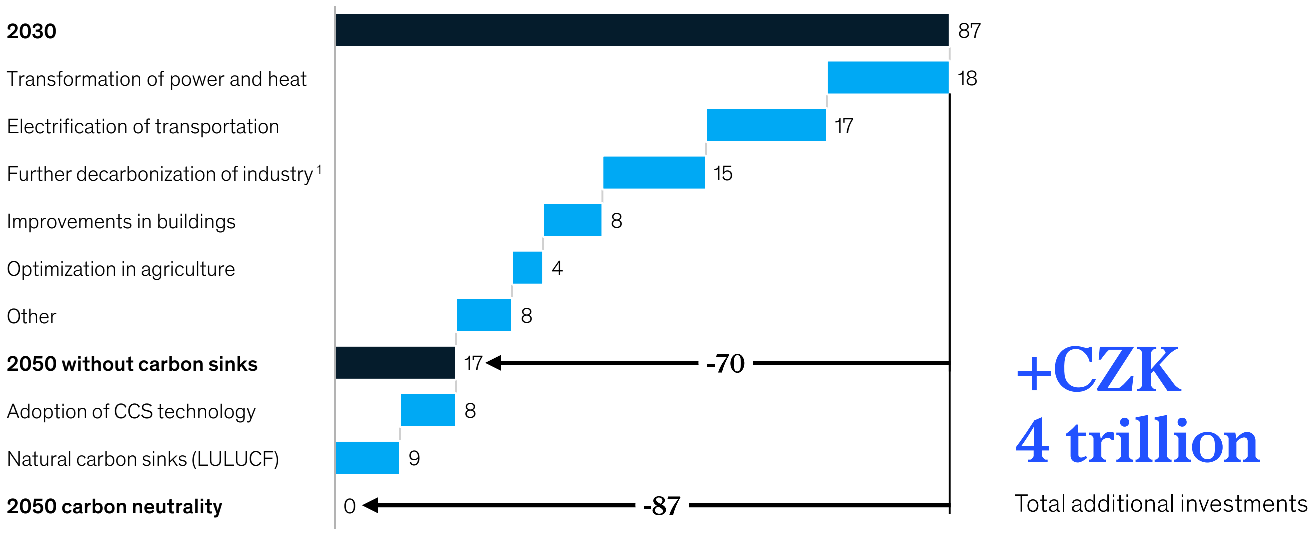
For any country, reaching net-zero emissions would require a significant overhaul of the economy. In some respects, the Czech Republic would face more challenges because of the relative size of hard-to-abate industries such as cement and lime production (4 $MtCO_2e$ combined) and agriculture (10 $MtCO_2e$).[26] The country also has a relatively limited amount of natural carbon sinkage both because it is relatively small compared with other EU members and because of the way its land is used. Plus, it's landlocked, eliminating offshore wind as a possible source of energy.

To reach net-zero by 2050, the Czech Republic would need to change much of its capital stock, including its energy-generation technology, industrial equipment, vehicle fleet, and buildings, and use the carbon sinks it has to capture the remaining hard-to-abate emissions. Our analysis shows the last 5 percent of emissions would need to be offset via carbon capture and storage, a technology that is not yet widely available at the required scale. Depending on technological progress, speed of innovation, and societal acceptance, alternative technologies allowing the Czech Republic to achieve net-zero could be small modular reactors or hydrogen energy storage. If these technologies do not become available, the Czech Republic would need to reduce output from hard-to-abate sectors.

However, there will be many opportunities in the coming years to replace or upgrade aging assets with greener ones.

Full decarbonization of the Czech economy between 2030 and 2050 would require CZK 4 trillion of additional investments

$MtCO_2e$ incl. LULUCF



1. Abatement in industry excludes CCS carbon sinks

Source: McKinsey analysis

Achieving net-zero would require the country to complete its shift from coal to renewables, nuclear, and CCS-equipped gas to generate heat and power. It would need to electrify the transportation and industry sectors to the greatest extent possible, increase the energy efficiency of buildings, switch heating to heat pumps, use biomass as a heating fuel in industry, and optimize animal feed and crop composition in agriculture.

Adopting these new technologies would enable the Czech Republic to reach 17 $MtCO_2e$ of annual gross emissions by 2050. To achieve net-zero, it would need to use natural carbon sinks to reduce those emissions by 9 $MtCO_2e$, and to adopt CCS technology to capture the remaining 8 $MtCO_2e$. Even if CCS turns out not to be feasible for the Czech Republic, the country still will have succeeded in reducing its emissions by 95 percent by 2050.

According to our analysis, it would require substantial additional investment for the Czech Republic to reach net-zero from 2030 to 2050: CZK 4 trillion at current prices, or 4 percent of Czech 2019 GDP each year.

Achieving net-zero would require the country to complete its shift from coal to renewables, nuclear, and CCS-equipped gas to generate heat and power.

Chapter 3

Decarbonization pathways for the major sectors of the economy

Power and heat

European context

For the EU as a whole, the power and heat sector accounts for 24 percent of total emissions, a lower share than in the Czech Republic.[27] Although the EU has been an early mover in decarbonizing power, with renewables accounting for 31 percent[28] of its total power supply today, it still has a long way to go to reach net-zero. Many countries—including Denmark, Greece, France, Hungary, and Germany—have already announced their intention to phase out coal.[29]

EU member states are all beginning at different points in their efforts to decarbonize their power sectors due to the differences in the types of power they currently use and the energy resources available to them. Along with Poland, Slovenia, and Bulgaria, the Czech Republic is among the EU member states that rely heavily on coal, including lignite (a low grade of coal) for power generation.[30] Finding ways to decarbonize the power sector is crucial to supporting the expected increased demand for electricity, which will nearly double when other sectors, such as transportation and industry, switch to electric power from fossil fuels as per the cost-optimal pathway.

Starting position of the Czech Republic

The power and heat sector accounts for 35 percent of the Czech Republic's GHG emissions, the highest of any sector. These emissions are primarily generated by coal power and combined heat and power generation (CHP) plants.

In 2017, the Czech Republic had a maximum power generation capacity of ~22 GW, and its peak power demand in 2017 was 11.8 GW. Coal made up 10.6 GW of the installed capacity,[31] which comes mostly from power plants commissioned in the 1970s and 1980s.[32] The most important exception is the Ledvice VI plant, which was commissioned in 2017.[33] The country's gas-fired power generation capacity is 2.3 GW, which comes from the large Počerady CCGT plant and many smaller ones.

35%

of the Czech Republic's GHG emissions come from the power and heat sector

The Czech Republic also has two nuclear power plants in Temelín and Dukovany that can generate up to 4.2 GW of electricity, providing the country's most significant source of emission-free energy.[34] Hydropower provides an additional 2.3 GW of zero-emission electric capacity.[35] This hydropower comprises pumped storage, run-of-river, and reservoir capacity that comes from several large sites, such as Orlík and Lipno, and numerous smaller plants.

Although the Czech Republic's hydropower capacity has remained flat, the volume of electricity generated at these plants has decreased since 2013 due to reduced rainfall and more frequent droughts.[36] The Solar PV installed capacity was 2.1 GW, and the country's installed wind capacity was 0.3 GW.

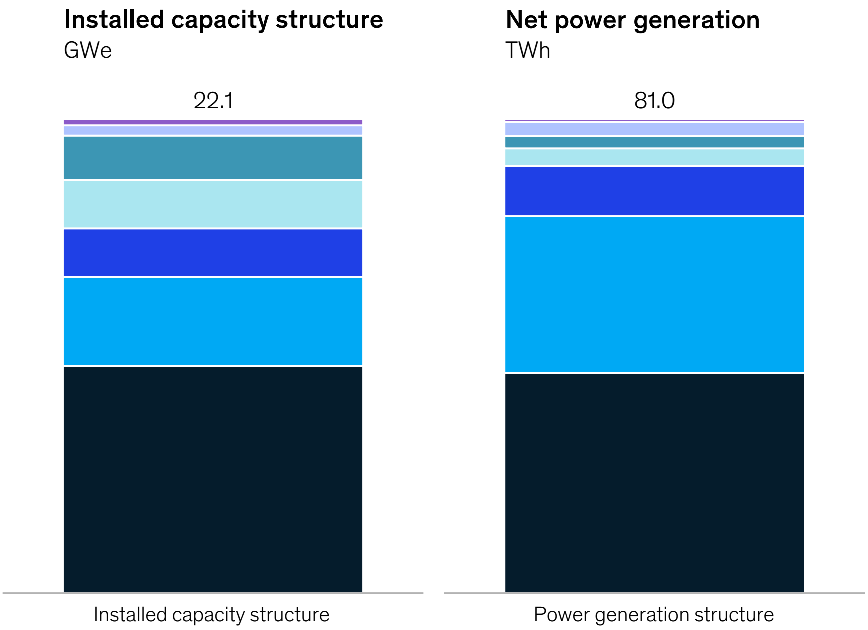
In 2017, the total net electric power production in the Czech Republic was 81 TWh, of which 68 TWh was consumed domestically,[37] and 13 TWh (or 16 percent) was exported. Coal plants produced 38 TWh, nuclear 27 TWh, and the rest came from other generation technologies.[38]

Large centralized plants also play an essential role in supplying Czech households and businesses with heat. In the Czech Republic, about 90 PJ of heat was supplied from centralized plants in 2017, of which roughly 50 percent was consumed by 1.6 million[39] Czech households connected to a district heating network. The remaining half was used by businesses and institutions such as hospitals and offices as well as by industry. Approximately 60 percent of this heat is generated using coal, often in CHP plants.[40]

We cover district heating emissions in this chapter and decentralized heating in the Buildings chapter.

Coal accounts for nearly half of installed capacity and net electric power production in the Czech Republic

2017



	Installed capacity	Net power generation profile
Wind onshore	0.3	0.6
Biomass & others	0.5	2.3
Solar	2.1	2.2
Hydro	2.3	3.0
Gas	2.3	8.5
Nuclear	4.2	26.8
Coal, incl. lignite	10.6	37.6

Source: ERÚ; OTE

Decarbonization options

In Europe, there are currently two proven ways to generate power that do not emit large amounts of GHGs: nuclear and renewables, which includes hydro, biomass, onshore and offshore wind, solar PV, and concentrated solar. Worldwide, the fastest growing ways to deliver renewable electricity are via wind and solar power. Installation costs for these technologies have fallen sharply in recent years. Consequently, solar and wind are the lowest-cost sources of new power generation capacity on a per MWh basis in many countries today.[41]

However, wind and solar can only provide power intermittently. Storing enough renewable energy to satisfy power demand throughout the year is far beyond the capabilities of current storage technologies; battery storage can cover a few days' demand at most. A plausible option for large-scale seasonal renewable energy storage is to convert excess wind and solar energy to hydrogen by electrolysis, store the hydrogen in salt caverns (such as those used today for gas), and later convert it back to electricity. Nuclear power and, to some extent, hydro are the only currently available large-scale GHG-free sources of electricity that are non-intermittent, although the availability of hydro depends on sufficient quantities of water in the rivers and reservoirs upon which the hydro plants are located.

Nuclear power is an essential part of the energy mix in several EU countries, including France, Sweden, and Slovakia. However, other countries, such as Austria and Italy,[42] have chosen not to make nuclear power part of their energy mix or have decided to phase out nuclear power due to a lack of public support for the technology. Germany[43] is set to decommission its entire nuclear reactor fleet by 2022. While several European countries are building or considering new nuclear plants, no plants of the latest ("third") generation have yet been commissioned in the EU, and the two most advanced projects (in Finland[44] and France[45]) are behind schedule and over budget.

Several companies are working to develop so-called Small Modular Reactors (SMRs). SMRs are designed to be assembled on the site from prefabricated modules, thus reducing total cost and construction time. At the time of writing, several SMR designs are under review by regulators. If successful, this could result in their deployment toward the end of the 2020s, with possible rollouts in the 2030s.

Plausible pathway for the Czech Republic—2030 horizon

For the power and heat sector to meet 2030 decarbonization targets, the most significant opportunity is to sharply reduce coal burning, especially of lignite, which is among the most GHG-intensive energy sources. Because it has an excess power generation capacity of nearly 50 percent[46, 47] over peak demand, the Czech Republic could retire a significant capacity of its lignite-fueled plants. The situation is more complicated for co-generation plants as heat from these is distributed through district heating networks. Those plants could either be switched from lignite to gas, biomass or waste, or their heat distribution system could be replaced by decentralizing the heating of buildings or blocks of buildings. Due to the importance of local conditions—for instance, topography and the state of the distribution network—the applicable solution will be specific to each district.

For the power and heat sector to meet 2030 decarbonization targets, the most significant opportunity is to reduce coal burning.

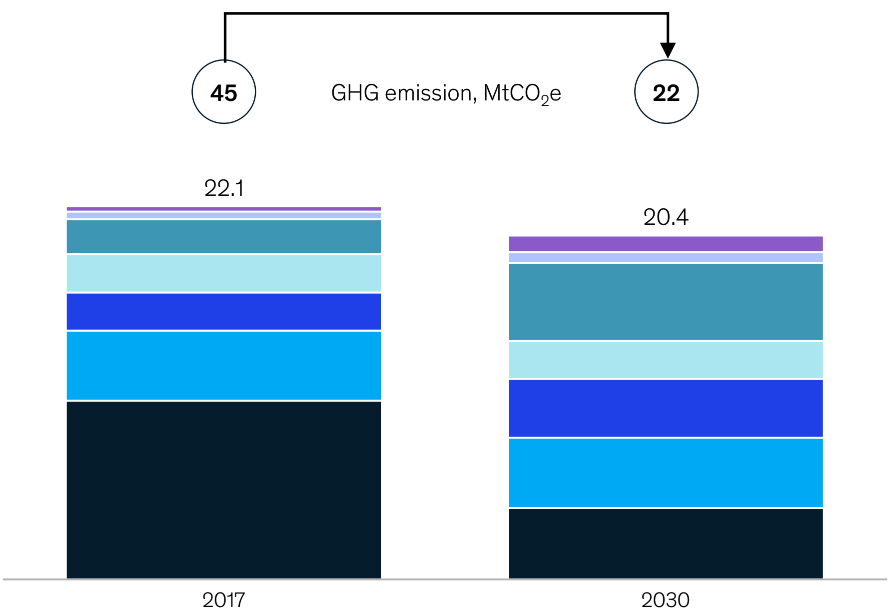
Of the Czech Republic's 10.6 GW of coal and lignite power generation capacity (which in 2017 emitted 42 $MtCO_2e$), about 3 GW have been decommissioned or slated for retirement by 2030. A further 0.7 GW of generation capacity could face feedstock supply constraints and would need to be retired in the mid-2020s. The two most important factors affecting the economics of coal and lignite power plants in the Czech Republic are EU ETS permit prices, which put coal at a cost disadvantage, and natural gas prices, which make coal uncompetitive when low. Our analysis shows that for a wide range of plausible scenarios combining these factors, coal-fueled power plants generating at least 1.5 GW could not operate economically. And, at least 1.2 GW of coal-fueled CHP plants could be economically replaced with a lower emission alternative.

Retiring all these plants would reduce the installed energy-generating coal capacity from 10.6 GW in 2017 to 4.2 GW by 2030, with a reduction in coal-related CO_2e emissions from 42 to 16 Mt.

Maintaining a sufficient reserve margin, and retaining the ability to meet Czech electric power and heat demand from fully dispatchable sources at all times, would require an additional 1.2 GW of gas CHP capacity. Also, it would demand 2.5 GW of solar PV and 0.7 GW of wind capacity to be added to our 2030 cost-optimal path. There are two reasons for this: the economics of these technologies will keep improving, and the expansion of renewables would need to be significantly upscaled by 2030 if the country is to meet its net-zero target for 2050. The renewable generation capacities would constitute less than 30 percent of the total installed capacity. Our analysis shows that the additional transmission and distribution investments to integrate this generation capacity into the Czech power supply system would be CZK 50 to 100 billion.

On the cost-optimal pathway, coal capacity for power and heat production falls and is partially replaced by increase in solar, gas, and wind capacity

GWe



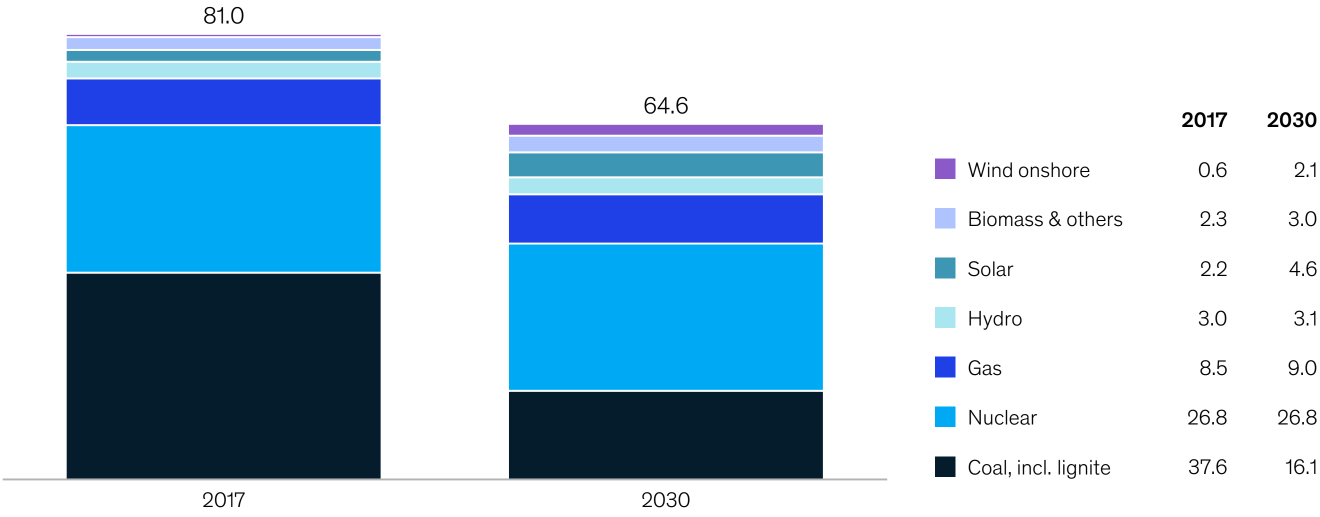
	2017	2030
Wind onshore	0.3	1.0
Biomass & others	0.5	0.6
Solar	2.1	4.6
Hydro	2.3	2.3
Gas	2.3	3.5
Nuclear	4.2	4.2
Coal, incl. lignite	10.6	4.2

Source: ERÚ; OTE; IAEA PRIS; McKinsey analysis

Given the expected growth of generation capacity in other countries, and assuming a plausible range of commodity prices, the Czech Republic could go from being a net exporter of electric power (to the tune of 13TWh in 2017) to a net importer of about 6 TWh in 2030. This pathway reflects the opportunity to import cheaper power for a part of the year, for example, when North Sea offshore wind production is strong. This evolution would not jeopardize Czech energy security as there is sufficient domestic capacity to fully cover demand in every scenario.

On the cost-optimal pathway, Czech power generation would decline by 20% by 2030

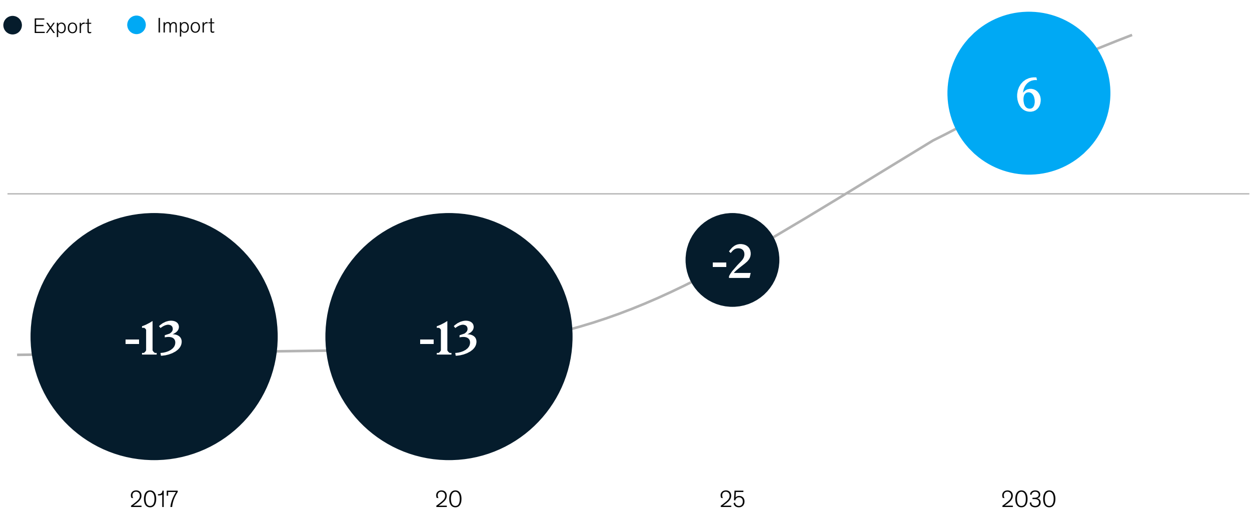
TWh



Source: ERÚ; McKinsey analysis

The Czech Republic would become a net power importer by 2030 on the cost-optimal pathway, driven by low import costs at times of high renewable production abroad

TWh



Source: ERÚ; McKinsey analysis

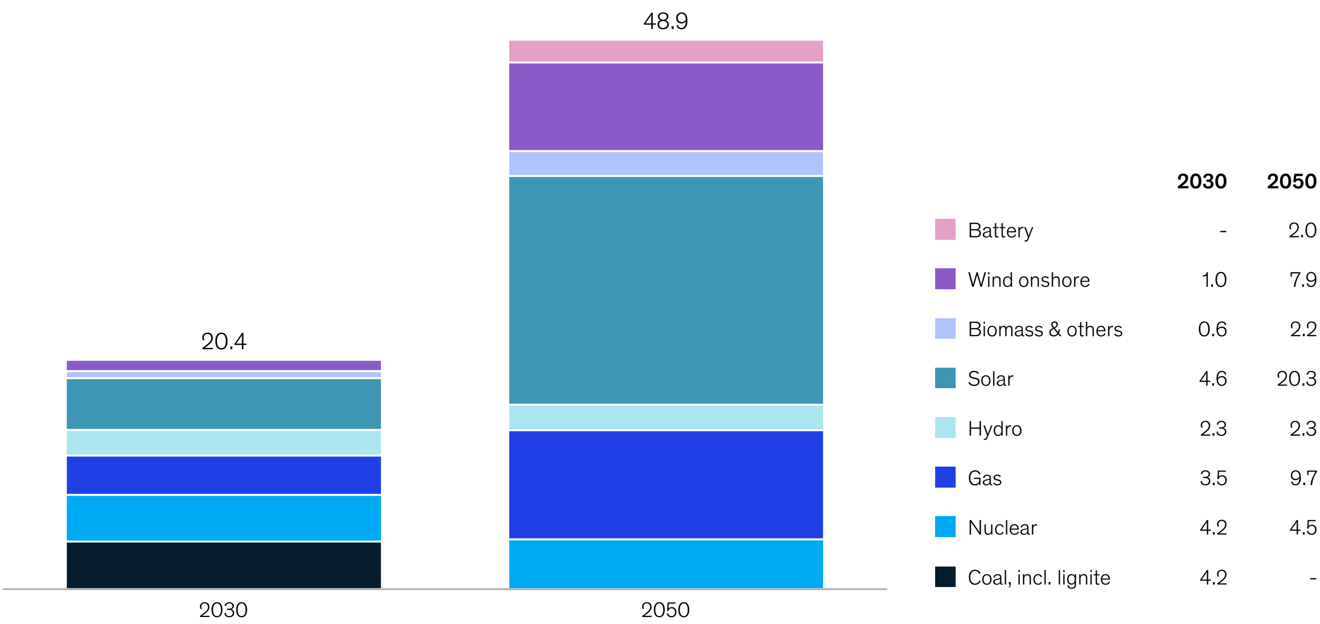
Plausible pathway for the Czech Republic—2050 horizon

On the cost-optimal pathway, electrification would be an essential lever for several sectors, including transport, industry, and buildings. As a result, electric power demand would increase from 71 TWh in 2030 to 125 TWh in 2050. Meeting peak demand without relying on energy imports will require significant additional generation capacities from zero-emission technologies. It would also require more power from GHG-generating sources such as natural gas, with emissions captured via CCS or offset through carbon sinks in LULUCF.

In 2030, the Czech Republic would still have 4.2 GW of coal-fueled generation capacity online, mostly in CHPs connected to central heating networks. Transitioning from coal would be crucial because of its deteriorating economics, its diminishing availability, and the necessity to fully decarbonize the power sector. A key precondition for discontinuing the use of coal for power and heat generation is ensuring an uninterrupted supply of heat to households and enterprises connected to coal-powered centralized heating systems.

On the cost-optimal pathway, the Czech Republic would add large capacities of solar, wind, and CCS-equipped gas by 2050

GWe



Source: McKinsey analysis

Being an importer of electric power would not jeopardize Czech energy security as there is sufficient domestic capacity to fully cover the local demand in every scenario.

Depending on local conditions such as housing density, topography, and the percentage of buildings connected to district heating systems, there are two principal ways to decarbonize heating—either decarbonize the centralized CHP sources through sustainable biomass and gas with CHP, or localize heating with alternative zero-emission sources such as direct electric heating, heat pumps, biomass, or solar thermal. A detailed city-level analysis would be required to determine where district heating systems should be dissolved or expanded. Our analysis assumes that the extent of district heating remains constant.

Following the cost-optimal pathway to net-zero emissions by 2050, the largest share of power generation capacity would be solar, with 20.3 GW capacity installed, and onshore wind with 7.9 GW. This renewable capacity would be complemented by 2 GW of batteries and 9.7 GW of gas generation to provide backup when the sun is not shining or the wind is not blowing, with the residual emissions from gas eliminated through CCS. In this report, we are assuming that the Czech Republic succeeds in commissioning 1.2 GW of new nuclear capacity in the 2030s, and a further 1.2 GW in the 2040s, which is broadly in line with the 2019 Czech national investment plan. Just as in our 2030 scenario, the Czech Republic would be a net importer of power, with guaranteed energy security. The resulting power generation mix would allow the country to accommodate more than 80 percent of an expected unregulated peak demand of 23 GW. That is without any contribution from intermittent renewable sources and with the largest power-producing block offline. The 20 percent gap between the power generation mix and peak demand could be closed with only limited production from renewables (about 10 percent of their capacity) and demand-side management or through a combination of both.

20.3 GW

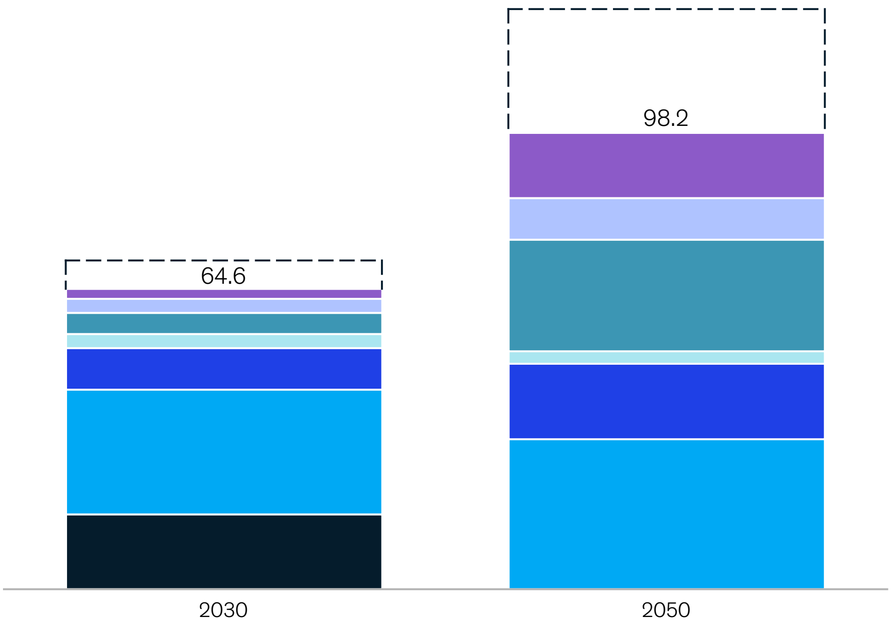
of solar capacity installed

Our analysis indicates a maximum feasible capacity for solar to be about 26 GW and around 11 GW for wind based on land availability. But while there is enough suitable land available for wind and solar, zoning changes and a relaxing of regulations regarding the minimum distance between dwellings and wind turbines could be considered to allow the installation of the capacity required. Power transmission and distribution networks also would need to be strengthened and equipped with more sensors and other active components to cope with a high proportion of intermittent generation and an almost doubling of expected peak demand between 2030 and 2050. Extrapolating from international studies, our analysis indicates that the cost of integrating this capacity into the power mix will exceed CZK 500 billion between 2030 and 2050.[48]

Given the physical constraints on renewables capacity, domestic green hydrogen production is likely to be relatively limited. Due to the large energy losses in converting electric power to hydrogen, Czech renewable power production would most likely be used directly as electricity. Moreover, due to capacity factors, as well as the load profile, hydrogen generation in the Czech Republic would most likely be more expensive than it would be in some other European countries. Should hydrogen be deployed in the Czech Republic at a greater scale, it would most likely have to be imported from countries more able to scale renewables, especially offshore wind.

On the cost-optimal pathway, Czech power imports would increase to 27 TWh per year while the country would retain the ability to cover peak demand independently

TWh



	2030	2050
Import	6.2	26.5
Wind onshore	2.1	14.1
Biomass & others	3.0	9.0
Solar	4.6	24.0
Hydro	3.1	2.7
Gas	9.0	16.3
Nuclear	26.8	32.3
Coal, incl. lignite	16.1	-

Source: McKinsey analysis

Behavioral changes and the circular economy

The decarbonization scenarios described in this report assume several technological and business changes leading to emission reductions. A similar or even greater contribution to the reduction of emissions may result from changes in consumer lifestyles and behaviors or the growth of a circular economy. Long-term climate strategies should also take into account the potential for behavioral changes to impact the environment and energy consumption.[49]

Some significant individual behavior changes could include:

Transportation

A reduction in the sector's carbon footprint could be achieved by reducing the use of fossil-fuel-powered vehicles, transferring cargo transport to rail, developing public transit, popularizing cycling, shifting to electric-powered personal transportation devices (such as electric scooters), carpooling and ridesharing, increasing investment in low-carbon infrastructure (i.e., cycle paths), and introducing congestion charges and tolls for vehicular access to city centers.

Diet

The prevailing diet in a society has a strong environmental impact. A person who eats a lot of meat could contribute more than twice the amount of GHGs to the environment as would a vegan. According to the Food and Agriculture Organization of the United Nations (FAO), animal husbandry accounts for 18 percent of global GHG emissions; plant production results in 20 to 30 times less GHG emissions than meat and dairy.[50]

Food production and logistics

When assessing the environmental impact of consumer diets, the entire supply chain should be taken into account: plant and animal production, product processing and storage, delivery to wholesalers and retailers, consumer transportation to food stores and back to their homes, processing and storage at home, and food-related waste. According to the FAO, approximately 1.3 billion tons of food are thrown away every year. That is one-third of all the food produced for human consumption.[51]

Goods and services

Protecting the integrity of the environment and mitigating climate change would also involve reducing the use of plastic in packaging. It would require promulgating regulations to encourage the development of a circular economy that discourages waste and encourages recycling and the reuse of previously owned items such as apparel, electronics, books, toys, and furniture.

Housing

Where we live, the household appliances we own, and how we use electricity and water also have environmental impacts.

Learning to value sustainable consumption, and developing a deeper respect for natural resources (and their limits) could reverse current consumer trends. A growing environmental awareness has given rise to a range of increasingly popular behaviors, such as a growing preference for local, regional, and seasonal products, respect for limited consumption, and a new emphasis on corporate social responsibility.

Industry

54%

is the reduction of industrial emission in the Czech Republic between 1990 and 2017

European context

The industry sector comprises numerous subsectors, including industrial materials such as cement and steel; chemicals such as ammonia and plastics; fuels like gasoline and coal; and consumer products like food, clothes, and paper. The key sources of industrial emissions are the combustion of fuel for manufacturing process heat (representing 52 percent of industrial emissions in the EU), and GHGs emitted while processing feedstocks (48 percent), such as CO_2 produced when natural gas is converted to hydrogen to make ammonia for fertilizers, or during the reduction of iron ore to make steel. Process emissions also include leakage of methane (and other GHGs).[52]

In 2017, industry emitted 1,010 $MtCO_2e$, accounting for 26 percent of total EU emissions. The highest-emitting industry segments are iron and steel (accounting for 15 percent of emissions), cement (11 percent), and oil refining (11 percent).[53]

Because industrial equipment often has a lifetime of more than 50 years, emission reduction efforts would need to focus on retrofitting existing sites in addition to building new sites. Changes would include those to production processes, such as replacing blast furnace systems with direct reduced iron coupled with electric arc furnaces (DRI-EAF) for steel.

Starting position of the Czech Republic

The Czech Republic lowered its industrial emissions by 54 percent between 1990 and 2017. However, the industrial sector still accounted for 28 percent of total emissions. The largest contributing subsectors were iron and steel (24 percent); industrial energy (16 percent); minerals (15 percent); chemicals (12 percent); and fugitive emissions (10 percent), mostly from coal mining.[54] The iron and steel industry is concentrated in two plants in the Moravia-Silesian region with a combined production capacity of 6.3 Mt of steel per year[55] and the majority of primary production in blast furnace and basic oxygen furnace (BF-BOF) technology. Minerals production in the Czech Republic comprises mostly cement and lime and is dispersed across the country in multiple facilities. Emissions from manufacturing solid fuels were primarily from one operation in the west of the Czech Republic that processed coal into coal gas and was decommissioned in 2020.

Decarbonization options

Decarbonizing industry is relatively difficult and, unlike in sectors such as transportation and power, is expected to increase costs. There are four technical barriers to reducing industrial GHG emissions:

1. Reducing emissions from feedstocks typically requires changing production processes.
2. Not all the technology for emissions-free high-temperature heat is commercially available yet. For example, in cement production, where kilns operate above 1,400°C, electric counterparts are not available at scale.
3. Industrial processes are deeply integrated and can rarely be changed in isolation.
4. There are few natural opportunities for large capital-intensive rebuilds or retrofits since asset lifetimes often exceed 50 years.

Adopting more costly low-carbon processes may put producers at a competitive disadvantage if others do not implement similar changes. Furthermore, many manufactured products in the Czech Republic are commodities competing for price in an international market where increased production costs cannot feasibly be passed onto customers.

However, there are six decarbonization levers that could be applied to reduce emissions in the industry sector:

1. Demand-side measures could lower emissions for commodities, for example, construction recycling and lightweighting to reduce steel consumption, and wood alternatives such as cross-laminated timber to replace cement.
2. Energy-efficiency improvements, such as lower-energy appliances and the deployment of the best available technology, could help decrease fuel consumption.
3. The electrification of heat (especially for lower temperatures) could be achieved by switching to electric furnaces, boilers, and heat pumps powered by zero-carbon electricity.
4. Hydrogen produced from zero-carbon electricity could replace hydrogen from steam methane reforming and open the door to new production processes such as using DRI-EAF in steelmaking.
5. Liquid or solid biomass such as bionaphtha could replace fuel and feedstock.
6. CCS could capture and productively reuse emissions at industrial facilities.

Plausible pathway for the Czech Republic—2030 horizon

On the cost-optimal pathway, GHG emissions from industry fall by 11.6 $MtCO_2e$ between the 2017 baseline and 2030. There are three main levers that could drive such a reduction:

— Decommissioning gasworks gas production (5.7 $MtCO_2e$).

— Decreasing coal mining and coal transportation (1.5 $MtCO_2e$).

— Electrification of processes (2.5 $MtCO_2e$).

Gasworks gas production has been decommissioned during 2020; meanwhile, coal mining and transportation emissions should decline in line with the demand for local coal from the power and heat sector. The electrification of industry could be led by the already announced plans of a major plant to switch from BF-BOF technology (using coal) to EAF powered by electricity, resulting in an abatement of 1.8 $MtCO_2e$.

Decarbonizing industry is relatively difficult and, unlike in sectors such as transportation and power, is expected to increase costs.

Plausible pathway for the Czech Republic—2050 horizon

Determining which decarbonization solution is most suitable for each plant depends largely on local conditions, such as the availability of infrastructure for storage and affordable, emission-free electricity and hydrogen. The cost-optimal pathway foresees the following technology shifts in the major industries that produce process-related GHG emissions:

— In steelmaking, a further shift towards EAF would be complemented by deploying DRI-EAF using mostly biogas and, to a smaller extent, natural gas with CCS or green hydrogen for the DRI step because EAF technology alone cannot produce steel of a high enough quality for some applications.

— Refining would be decarbonized about 40 percent by decreases in the demand for fuels in the overall economy, while the remaining reductions would depend on CCS.

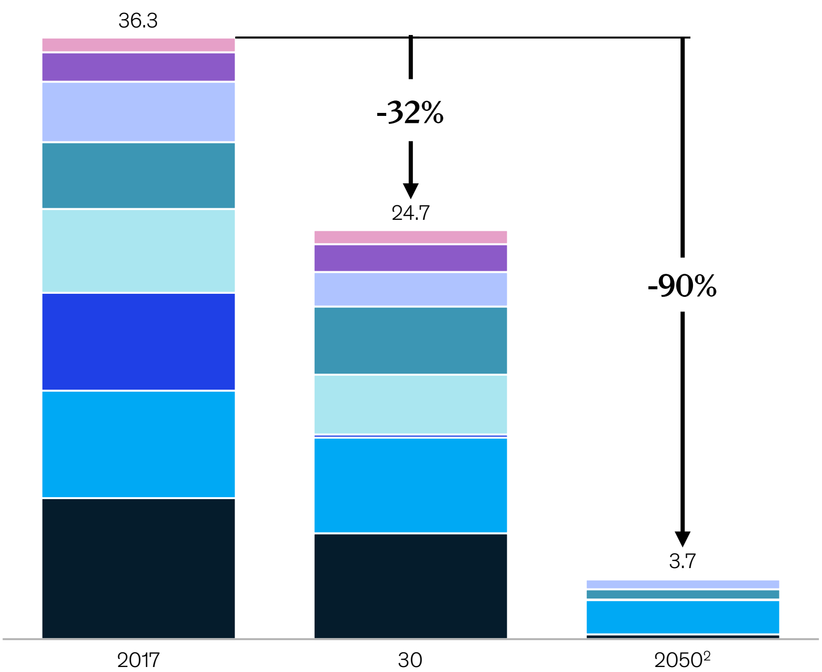
— Cement and lime production would be decarbonized through a combination of biomass for heating and, eventually, CCS.

— Ammonia production would fall to zero between 2040 and 2050, as it currently serves as a sink for excess hydrogen produced at refineries. If the price of hydrogen increases significantly before 2040 due to demand from other sectors, ammonia production might end earlier.

— In ethylene production, current naphtha crackers would be replaced by electric crackers by 2045.

Process improvements, CCS, and lower demand for refined fuels would allow the Czech industrial sector to achieve a 90% reduction in GHG emissions by 2050

$MtCO_2e$



	2017	2030	2050
Ammonia & ethylene	0.9	0.9	0.0
Other petrochemicals	1.8	1.7	0.1
Fugitive emissions	3.6	2.1	0.6
Cement & lime	4.0	4.1	0.6
Process heat[1]	5.1	3.6	0.0
Solid fuels	5.9	0.2	0.0
Other	6.5	5.8	2.1
Iron and steel	8.5	6.4	0.3

1. In the rest of the industrial sector
2. Abatement of emissions includes CCS technology

Source: Eurostat; McKinsey analysis

Agriculture

European context

In 2017, agricultural activities produced 470 $MtCO_2e$, accounting for 12 percent of EU total emissions. Raising animals for food generated nearly 55 percent of these emissions, followed by crop production (30 percent) and energy for farming activities (15 percent). In animal protein production, GHG emissions come from enteric fermentation, a natural part of animal digestive processes that produces methane (CH_4), and from manure management, which emits nitrous oxide (N_2O). Nearly 90 percent of emissions from animal protein production comes from dairy and non-dairy cattle.[56]

In crop production, 50 percent of GHG gases come from synthetic fertilizers[57]—exacerbated by the practice of applying fertilizer containing more nitrogen than crops need, with the excess nitrogen released into the atmosphere as N_2O. Other significant sources of GHG emissions come from the manure that farmers apply to the soil, organic soil cultivation, and crop residues.

Starting position of the Czech Republic

Agriculture accounts for 7 percent of total emissions in the Czech Republic, in which agricultural soils and related nitrous gas emissions represent 38 percent, while raising animals for food contributes an additional nearly 50 percent. The rest is emitted by agricultural equipment.[58]

While the production of animal meat has decreased significantly since 2000 (a 33 percent decline in beef production and 47 percent decline in pork meats[59]), the strategy of the Ministry of Agriculture assumes a reversal of this trend and growth in domestic meat production.[60] Based on this outlook, our analysis assumed a 3.5 percent annual growth rate of pork production between 2020–2030 and a 0.4 percent growth rate for beef. After 2030, production is assumed to remain constant at 2030 levels.

~50%

of emissions in agriculture are due to raising animals for food

Decarbonization options

Reducing agricultural emissions is more challenging than for most other sectors because they generally derive from natural processes that today's technology cannot solve. For example, there is currently no technology that can stop cows from emitting methane as part of their digestive process. Even the most advanced feed additives are only expected to reduce methane emissions by 30 percent.[61]

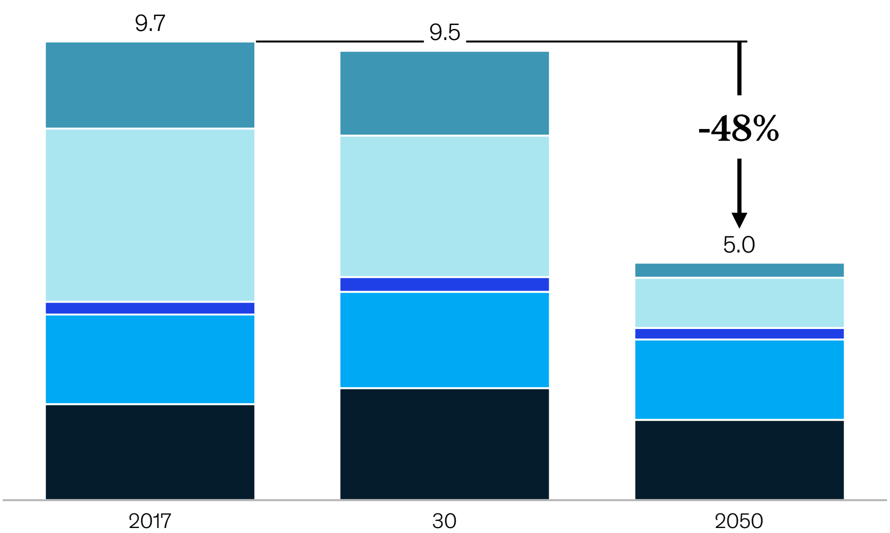
Because of these factors, the EU cannot reach net-zero agriculture emissions by 2050 while maintaining the current levels and structure of agricultural production. However, the long-lived gases (CO_2 and N_2O) can be eliminated or offset through a set of levers that include switching farm equipment and machinery to alternative fuels while biogenic methane can be significantly reduced by implementing anaerobic digestion systems for manure, improving animal feed to reduce methane emissions from cows, adopting genetic selection and breeding programs, using improved fertilizers, and deploying nitrification inhibitors on pastureland.

Plausible pathway for the Czech Republic

On the cost-optimal pathway, agriculture does not make a meaningful contribution to GHG abatement by the 2030 horizon. Agricultural GHG emissions remain nearly unchanged from 2017 (9.7 $MtCO_2e$) to 2030 (9.5 $MtCO_2e$). The only agricultural emissions that are eliminated by 2050 are those produced by equipment that can be fully electrified. The other major category that could be substantially decarbonized is crop production (71 percent reduction in emissions from 2017 to 2050), while emissions connected to meat and dairy production would decline by less than 20 percent. The remaining total agricultural emissions of 5 $MtCO_2e$ would need to be abated via carbon sinks in other sectors.

Carbon sinks in other sectors would be needed to offset the agricultural sector, which is unlikely to reach net-zero GHG emissions by 2050

$MtCO_2e$



	2017	2030	2050
Equipment & others	1.8	1.8	0.3
Crop production	3.6	3.0	1.1
Pork production	0.3	0.3	0.2
Dairy production	1.9	2.0	1.7
Beef production	2.0	2.4	1.7

Source: Eurostat; Czech Republic Ministry of Agriculture 2030 strategy; McKinsey analysis

Waste

Waste emissions mostly consisted of methane emitted from landfills and domestic and industrial wastewater. Methane capture has ramped up in the last ten years, with biogas stations located in approximately 33 percent of landfills, capturing ten to 15 percent of the generated methane.

Additional GHG abatement in waste by the 2050 horizon is expected to be driven by multiple smaller levers such as better recycling and less landfilling (1 $MtCO_2e$).

LULUCF

~30 mil. m^3

of timber expected to be salvaged yearly until 2025 due to bark beetle outbreak

European context

For most European countries, LULUCF serves as a sink for GHG emissions. Forested land can capture emissions as trees bind carbon as they grow. Currently, LULUCF absorbs 6.5 percent of the EU's total emissions, or 250 $MtCO_2$ per annum.[62] However, by 2050, this carbon-capture activity is projected to fall to 175 $MtCO_2$ per year due to forest lifecycles and factors such as changes in the types of trees. With a renewed focus on reforestation, this trend could be reversed, increasing CO_2 absorption to 375 $MtCO_2$ a year by 2050.[63]

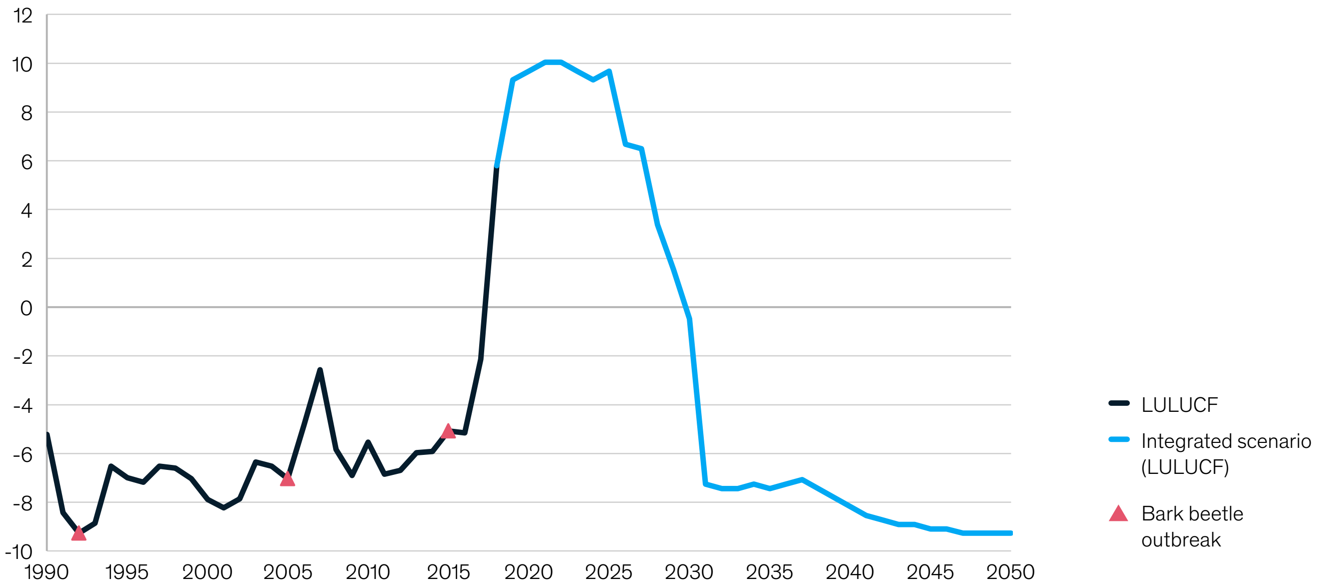
Until now, emissions and removals related to land-use and forestry have been excluded from reduction targets. But following recent regulatory changes, the removal of CO_2 through land-use will be accounted for in the EU's climate targets. This is critical to ensuring that current carbon stores are maintained and that there are sufficient incentives for member states to include land-use measures in national climate plans.[64]

Starting position of the Czech Republic

Between 1990 and 2015, the Czech LULUCF sector absorbed an average of 6.5 $MtCO_2e$ a year. Unfortunately, the 2015 bark beetle outbreak led to an annual increase in logging from 15.5 million cubic meters in 2014 to 32.6 million cubic meters in 2019.[65] This is turning Czech forests from a carbon sink to a source as the GHGs embedded in the wood are released, or are assumed to be released if the wood is exported. Based on expert interviews, the bark beetle outbreak and salvage logging levels of up to 30 million cubic meters of timber a year are likely to last at least through 2025. Together with the aging of these forests, which degrades their sink capacity, this might result in up to ten $MtCO_2e$ emissions a year by the middle of the 2020s. Other LULUCF components such as wetlands, cropland, grassland, and settlements are expected to remain constant over this time. A final component, harvested wood products, is modeled based on the development of logging levels and historical trends.

As bark beetle outbreaks and salvage logging abate, Czech forests could resume acting as a carbon sink by 2030

$MtCO_2e$



Source: National Greenhouse Gas Inventory Report Of The Czech Republic (2018); Expert interviews, Prognosis of Czech Forest Think Tank; National Forest Accounting Plan (2019) ; McKinsey analysis

Plausible decarbonization pathway

Managing the bark beetle outbreak and promoting a rebound in the total volume of living biomass in forests would be critical to achieving 2030 emissions targets. This would require rapid reforestation of previously logged areas and improved forest management practices to avoid a repeat of the outbreak. In our base case, the areas logged because of bark beetle could be reforested by 2030, resulting in a further expansion of the LULUCF carbon sink, capturing an estimated 9 $MtCO_2e$ a year in the 2040s as the young forests bind increasing volumes of CO_2. In addition to reforestation, the Czech Republic could also consider creating new forests on lands with low agricultural potential. This could help to manage droughts and other manifestations of climate change.

Managing the bark beetle outbreak and thereby promoting a rebound in the total volume of forest biomass is critical to achieving 2030 emissions targets.

Transport

European context

Domestic transportation emits 820 MtCO_2e a year, accounting for 21 percent of EU total emissions. Passenger cars account for 58 percent, followed by heavy-duty trucks and buses (26 percent), light-duty trucks (11 percent), and with the remaining contributions from railways, domestic aviation, and domestic marine vessels.[66, 67]

Despite rising interest in electric vehicles (EV), less than 0.5 percent of the cars, trucks, and buses now used in the EU are electric.[68] The rest have internal combustion engines (ICE) powered by diesel, gasoline, liquefied petroleum gas (LPG), or compressed natural gas (CNG). Biofuel accounts for just 5 percent of the energy used by road vehicles in the EU.[69] Nearly all airplanes and marine vessels also run on fossil fuels. Rail is the only sector that is already significantly electrified—80 to 90 percent of rail traffic is electric.[70]

Without intervention, the EU's transportation emissions would rise 30 percent by 2050. Transportation activity in the EU is projected to grow 1.5 percent per year until 2030, slowing to 0.7 percent a year from 2030 to 2050 as population growth stagnates.

Starting point for the Czech Republic

Transport accounted for 14 percent of total emissions in the Czech Republic in 2017. Passenger cars generated 64 percent of GHG emissions, trucks and buses 34 percent, and rail diesel combustion and other transportation accounted for 2 percent.[71]

The average age of passenger cars in the Czech Republic is 14.8 years, older than the EU average of 10.8 years.[72] Petrol is the most common fuel, used in 64 percent of passenger cars.[73]

14.8 years

is the average age of passanger car in the Czech Republic

The country's current share of electric vehicles is less than 1 percent, and, as of late 2019, there were only about 715 public charging points.[74] In the last decade, the Czech Republic's passenger fleet has increasingly adopted CNG as fuel—from 150 new registrations in 2010 to around 1,800 in 2019[75] while numbers of trucks fueled by liquefied natural gas (LNG) started rising in 2020, albeit from a small base.[76]

The number of passenger cars in the Czech Republic increased sharply from 2.4 million in 1990 to 6 million in 2020.[77] Based on current trends, and absent a meaningful change in technology, road transport emissions are expected to grow 20 percent by 2030, due to the longer average distances driven per each passenger car per year.[78]

Decarbonization options

Over the next decade, GHG emissions from road transport could be partially decreased by more efficient ICE technology (currently progressing at about 2 percent a year), increased use of biofuels, CNG and LNG, and broader adoption of plug-in hybrid vehicles (PHEVs). Behavioral changes—such as increased use of public transportation, ridesharing, cycling, or a reduction in non-essential trips—could further reduce GHG emissions due to a decline in the total number of kilometers driven. Further contribution to GHG emissions reduction could come from the transfer of freight transport from road to rail. A more substantial decrease in emissions would require a transition to battery-powered electric vehicles (BEVs) for passenger cars and, for a subsegment of trucks and buses, hydrogen-based alternatives such as fuel-cell electric vehicles (FCEVs).

With respect to the 2050 net-zero target, to achieve full decarbonization through BEVs, the power sector would have to produce the electricity to charge vehicles without generating GHGs and the automotive supply chain would itself have to be decarbonized—these topics are covered in the power and heat and industry sections of this report.

Plausible decarbonization pathway

In our decarbonization scenario for 2030, net emissions from transportation will fall by only 1 $MtCO_2e$ compared to 2017. Two counterbalancing factors explain this modest decline: the decrease in GHG emissions due to the electrification of road transport and higher efficiency of new ICEs (an expected reduction of 4 $MtCO_2e$) would be nearly offset by the predicted rise of 3 $MtCO_2e$ due to the increased distance driven by ICE vehicles.

The cost of batteries continues to fall sharply, accelerating the adoption of e-mobility by lowering the total cost of ownership (TCO) for EVs versus ICE vehicles. According to our calculations, EVs could become the favored alternative for every category of

According to our calculations, EVs could become the favored alternative for every category of passenger cars, short-haul trucks, and city buses during the 2020s.

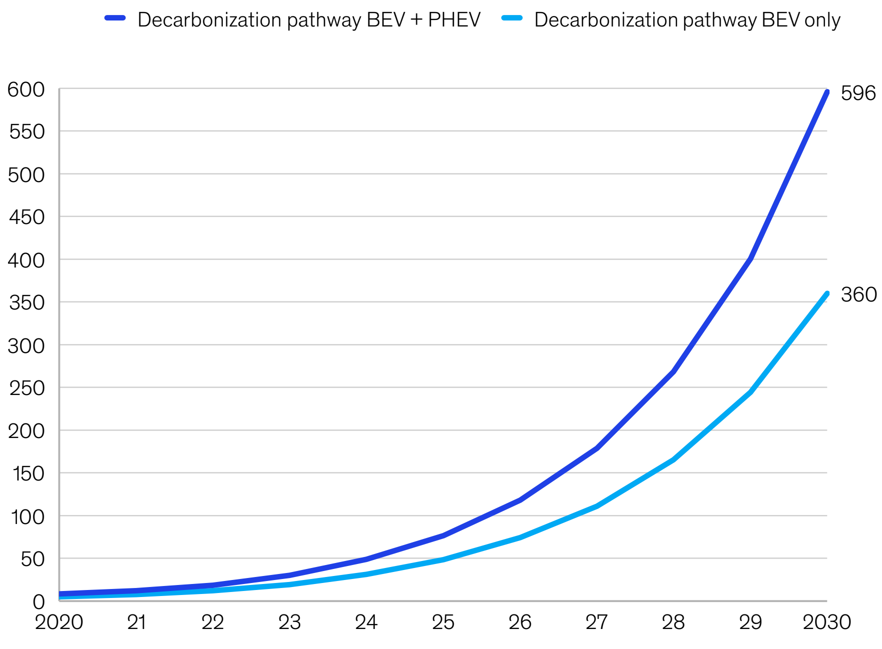
passenger cars, short-haul trucks, and city buses during the 2020s. Fuel cell electric vehicles (FCEVs) could reach TCO parity with ICE trucks by 2030, becoming the lowest cost option for long-haul trucks.

Given the relatively long average lifespan for these vehicles and the resulting slow turnover of the total vehicle stock, EV adoption would need to increase sharply during the 2020s to achieve even modest decreases in GHG emissions. On the cost-optimal pathway, EVs would account for close to 50 percent of total new registrations in 2030. That means there would be roughly 600,000 EVs operating in the Czech Republic. Even this rate of adoption of EVs will only partially contribute to meeting the targets of the European Renewable Energy Directive, which calls for 14 percent of the energy used in transportation to come from renewable sources. In 2016 the achieved share was 6.4 percent.[79] Introduction of 600,000 EVs until 2030 would contribute another 3.5 percent.[80] The rest might have to be covered by the increasing share of biofuels, a switch to next-generation biofuels, and the use of biogas for LNG.[81]

It would be possible for the Czech Republic to almost fully decarbonize transportation by 2050 through a complete transformation of its vehicle stock to BEVs and FCEVs and electrification of the remaining rail transport.

On the cost-optimal pathway, electric vehicles would account for nearly half of new Czech road vehicle registrations by 2030

Thousands of vehicles



Source: McKinsey analysis

49%

share of electric vehicles on new road vehicle registrations in 2030

There are economic and environmental cases for switching to EVs, including a reduction in non-GHG emissions such as SOx, NOx, and particulate matter, air pollutants with negative human health impacts. But transportation and mobility are a complex system, and the changeover to EVs would need to be coordinated and supported in the following areas:

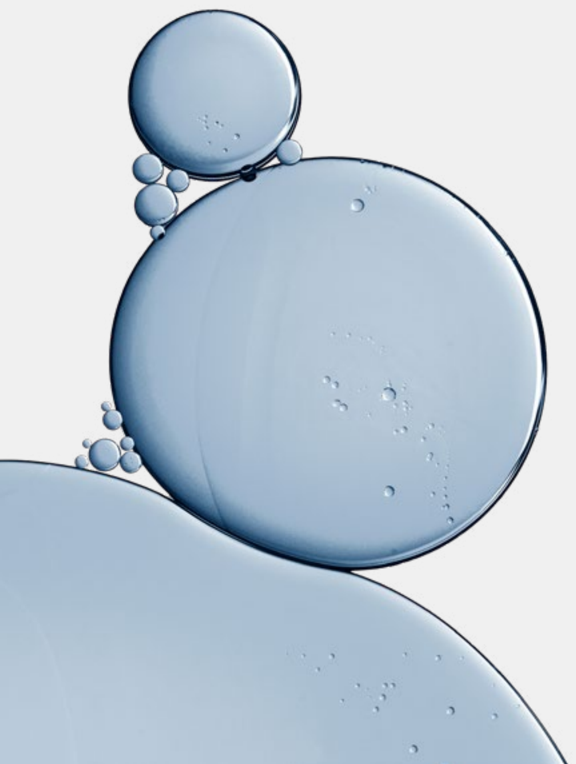
— Although the TCO is falling, throughout the 2020s, the initial capital costs of EVs and FCEVs will likely remain higher than for ICE vehicles. We expect this also to be true for used cars due to the need to refurbish their batteries. To encourage broad adoption of EVs, governments could consider helping households overcome those higher initial costs through a mix of financial incentives and non-monetary perks such as dedicating parking spots and limiting city center access to EVs.

— The development of widely accessible charging infrastructure needs to keep pace with the increasing number of EVs on the roads. As a rule of thumb, the required attach ratio—the number of EVs per publicly-available charging point—is between five and ten depending on local conditions and overall EV penetration.[82]

— The EV and battery supply chains need to be scaled up, including securing access to raw materials such as lithium, nickel, and cobalt for batteries. Manufacturers and suppliers of products for ICE vehicles may need help transitioning to the EV market.

— The power grid would need to be strengthened and digitized (for example, by deploying smart meters and sensors at the electric substation level) in areas with larger concentrations of EVs.

Key transportation uncertainties: Prices, technology advancements, and behaviors



Many uncertainties could change what today appears to be the most cost-effective pathway to decarbonizing transportation. For example, commodity and technology prices could negatively affect the road transport pathway as follows:

— **Low oil prices** (below EUR 40/ barrel) could delay progress toward EV TCO parity by up to five years. An 80 percent increase in electricity prices by 2030 would have a similar effect.

— **Rapid battery price declines** could alter the pathway for trucks and buses. An 80-percent decline in battery prices by 2030 (instead of 45 percent to 50 percent) would make BEVs more competitive than FCEVs. This would affect FCEV adoption in long-haul trucking (in the baseline outlook, FCEVs are cheaper.) Technological innovations such as high-density battery chemistries and a longer battery life could make BEVs even more attractive.

— **An accelerated hydrogen scenario** would make FCEVs more competitive in road transport. However, even if hydrogen production costs dropped to EUR 1/kg by 2030, FCEVs would only become competitive for cars by the end of the 2040s. However, if hydrogen prices declined to EUR 4/kg at the pump, and fuel cell stack costs fell to EUR 150/kW by 2030, FCEVs could become the lowest cost option for regional trucks and buses.

Buildings

2/3

of buildings in the EU are still heated by burning gas, coal, or oil

European context

In 2017, buildings emitted 490 $MtCO_2e$, accounting for 13 percent of the EU's total emissions. Residential buildings generated 70 percent of this total, while 30 percent came from commercial and public buildings.

Europe's building stock comprises more than 200 million structures.[83] By square meter, three-quarters of EU buildings are residential; the rest are shops, offices, schools, hotels, restaurants, and hospitals. In both residential and commercial buildings, the most energy is used for space and water heating (70 percent). The remaining 30 percent is consumed by appliances (15 percent), lighting (5 percent), cooking (5 percent), space cooling and other (5 percent).[84]

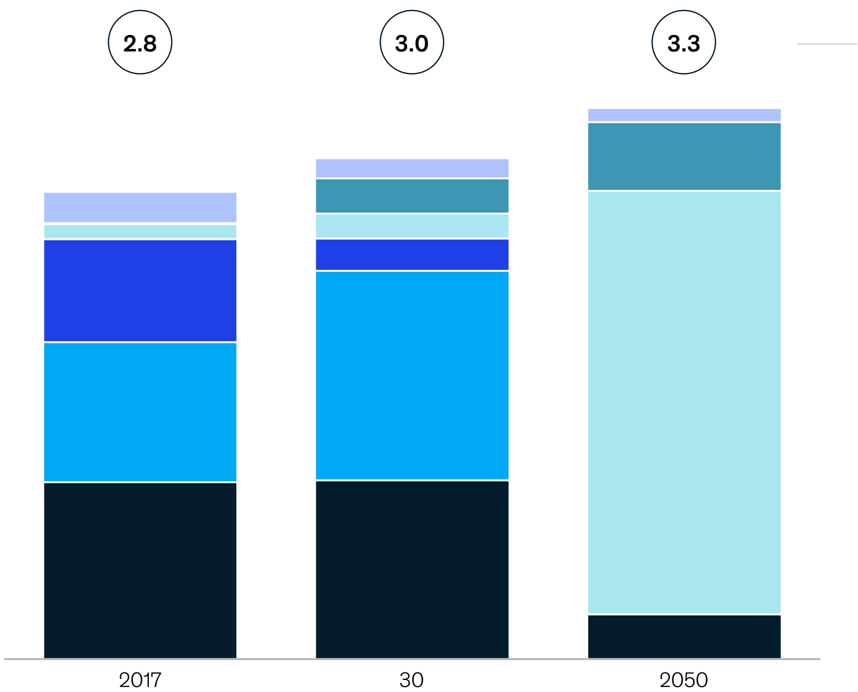
About two-thirds of buildings in the EU are still heated by burning gas, coal, or oil. Boilers are the dominant technology in the EU, but the mix and share of renewables vary by region. For example, gas boilers are common in Netherlands (84 percent), coal boilers are prevalent in Poland (36 percent), and electric heating is popular in France (19 percent).[85]

Starting point for the Czech Republic

In the Czech Republic, buildings generate ten percent of total emissions. These are primarily from heating space and water in residential (77 percent) and non-residential (23 percent) buildings. There has been a significant effort,

Coal and gas boilers would need to be phased out by 2050 and replaced mainly by heat pumps to meet decarbonization goals in residential heating

Share of technologies on household heat consumption[1]



Number of residential buildings using selected technologies
Millions

	2017	2030	2050
Others	6.7%	4.0%	2.6%
Solar thermal	0.2%	7.0%	12.5%
Heat pumps[2]	3.2%	5.0%	76.9%
Coal boiler	22.0%	6.4%	0%
Gas boiler	30.0%	41.8%	0%
Biomass boiler	37.8%	35.7%	8.1%

1. Excludes district heating, which is covered in the power & heat section
2. Air-to-water heat pumps (75%) and ground-to-water heat pumps (25%)

Source: Eurostat; McKinsey analysis

including government subsidies, to encourage the insulation of buildings to reduce heating and cooling needs and to replace fuel technologies with those that emit less GHGs. However, the efficiency of approximately 70 percent of existing Czech buildings could still be improved significantly.

Heating technologies differ sharply between apartments, single-family houses, and non-residential buildings. District heating is the most common way apartments are heated, with about 60 percent of households connected to district-wide heating systems.[86] The other two major sources of heating for apartments are gas boilers and electric heating, while only a small share still use coal-fired boilers. For single-family homes, gas boilers and biomass are the dominant technologies, followed by coal boilers, which are used in nearly 30 percent of houses. In the commercial sector, gas boilers are the primary source of heating, supplying about 45 percent of buildings, followed by district heating.[87]

Decarbonization options

The most efficient way to decrease the volume of GHGs emitted from buildings is to reduce the demand for energy by improving insulation, installing intelligent heat control systems, and changing owners' behaviors. Heating could be switched to electricity (heat pumps or resistance heating), renewables such as sustainably produced wood pellets, or thermal solar heating or green hydrogen could be used to replace natural gas.

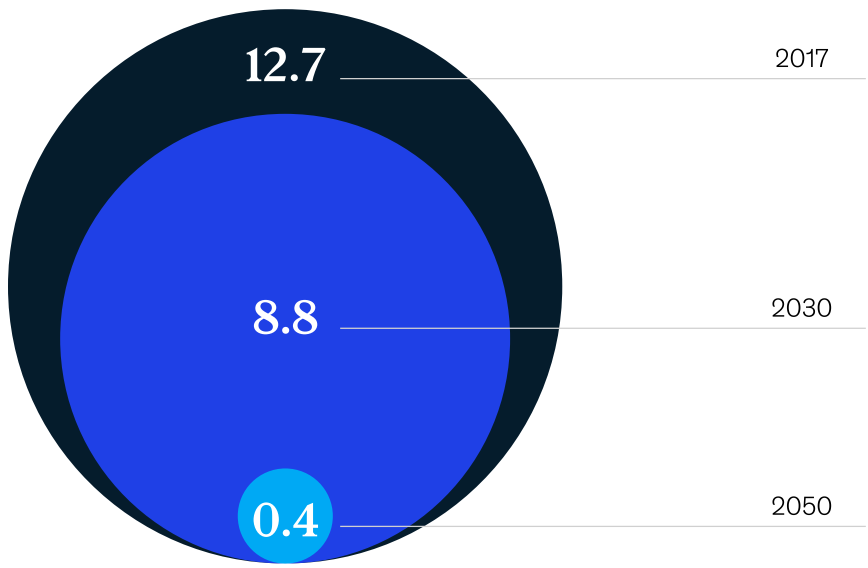
Plausible decarbonization pathway

By 2030, the buildings sector could be the main net contributor to the abatement of emissions not covered by the EU Emissions Trading Scheme. On the cost-optimal pathway, building emissions fall by 4 $MtCO_2e$ through a combination of improved insulation and energy use and replacing coal boilers for heating. Reducing energy use in buildings has a positive business case, for example saving EUR 35/ tCO_2 and EUR 5/tCO_2 for retrofitting a poorly insulated building with medium and high insulation, respectively. But replacing coal with gas could increase the size and volatility of heating bills in the residential sector and may need to be subsidized or mandated by the government. Solar thermal can be deployed in all three buildings sectors, but it can only play a partial role due to space constraints. Finally, heat pumps only play a relatively minor role prior to 2030 due to their comparatively high capital cost.

After 2030, decarbonization in all three sectors—apartments, single-family homes, and commercial buildings—would need to accelerate. Coal and gas boilers would have to be completely phased out by 2050 to achieve full decarbonization. This would require that 70 to 80 percent of buildings be well insulated, with a higher percentage in residential where there are currently fewer regulatory constraints. The key technologies to provide the majority of decentralized heat in 2050 would likely be heat pumps and biomass boilers.

GHG emissions of the Czech buildings sector on the cost-optimal pathway

$MtCO_2e$



Source: McKinsey analysis

Four decarbonization lever archetypes

Each sector and decarbonization lever has different underlying dynamics. Simply having a positive societal business case does not guarantee that the lever will be applied. In many cases, there are strong incentive, agency, and financing aspects that need to be considered by public policy-makers.

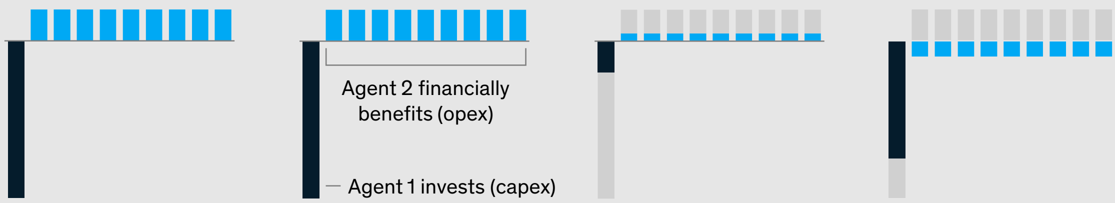
We have identified four decarbonization lever archetypes based on the return and payback profile of individual initiatives. From left to right, they would require increasing levels of legislative intervention to be successful. Type 1 levers offer attractive payback periods, sufficiently high internal rates of returns (IRRs), or both to motivate profit-seeking economic agents to act. Type 2 levers yield positive returns, but the profits accrue to different actors, and so require cross-agent collaboration to be encouraged, for example, by benefits-sharing. Type 3 have low absolute returns and IRRs, and, therefore, need public policy initiatives to stimulate agents to act on them. And Type 4 levers do not create any savings and thus give agents no economic incentive to act.

In addition to these decarbonization levers' financial characteristics, more relevant elements could make climate action complex. For instance, even with a sound economic rationale, a broad variety of barriers can limit progress, including political considerations (such as taxpayers' perspective), the regulatory landscape, infrastructure, supply chain, technology, and opposing business interests (for example, incumbents versus new industry).

Legislative action and public policy initiatives would be needed to encourage the implementation of certain decarbonization initiatives

Change in capex[a] Change in opex[a]

	1 Levers with stand-alone economic rationale	2 Levers with economic rationale but agent issues	3 Levers with limited financial incentives	4 Levers with no stand-alone economic rationale
Illustrative cash flow				
Logic of agent	Economic agent would invest in decarbonization lever because it results in opex savings with a sufficiently short payback period/high IRR	Economic agent doesn't invest in decarbonization lever because benefits are harvested by other economic agent	Economic agent would not invest in decarbonization lever because economic incentive is limited in absolute terms and/or IRR is too low	Economic agent would not invest in decarbonization as there are no savings
Climate action strategy	Promote/stimulate agents to act faster on decarbonization	Stimulate cross-agent collaboration (e.g., benefits sharing) and promote faster decarbonization	Promote/stimulate agents to act on decarbonization and seek ways to reduce efforts	Develop framework to support decarbonization for hard-to-abate/expensive activities with a level (international) playing field
Illustrative example	BEVs have higher upfront capital need but yield operational cost savings	Rental building insulation requires upfront investment by owner while tenant benefits from reduced costs	Heating technology fuel switch requires relatively limited investments with some ongoing operational costs	Industrial CCS requires both upfront investments and ongoing operational expenditures



a. Change in capex and opex vs business-as-usual technologies.
Source: Sustainability Practice McKinsey & Company

Conclusion

Actions to achieve net-zero

The fixed carbon budget consistent with keeping the rise in global temperature below 1.5°C means that the longer decarbonization actions are delayed, the steeper our future decarbonization path would need to be. Dealing with climate change is, therefore, the challenge of the next decade, as global GHG emissions need to be on a clear downward trajectory by the end of the 2020s to meet net-zero by 2050.

Reaching net-zero would require a joint effort by citizens, businesses, and governments. A significant portion of the Recovery and Resilience Facility, Europe's EUR 672.5 billion stimulus package, is earmarked for investments that contribute to the region's decarbonization objectives.[88] At the time of writing, 37 percent[89] of the stimulus has to be allocated to transformative green initiatives. If policy-makers chose to invest the Czech portion of this capital into accelerating decarbonization and building infrastructure to support a low-carbon economy it would be an important step, first toward meeting the 2030 targets and then toward net-zero emissions in 2050.

This type of financial incentive would be most effective if accompanied by economic, energy, and mobility strategies focused on green technologies, to ensure that the green transition mutually reinforces a migration of the economy towards products and services with higher added value. It could also help ensure that Czech businesses remain competitive in a world rapidly transitioning toward low-carbon technologies and help employees transition from legacy, GHG-emitting industries to new, green jobs.

Over the past 30 years, the Czech economy has transformed completely. A challenge on a similar scale—that of reaching net-zero emissions—lies ahead of the country for the next 30 years. The first step on the way is reaching the 2030 targets, and our analysis shows that this is achievable. However, in order to succeed, the Czech Republic would need to start taking decisive action now.

Appendix

Methodology of this report

To develop our pathway, we used McKinsey's Decarbonization Pathways Optimizer (DPO), a proprietary toolkit. This toolkit uses over 500 business cases covering every sector to find the cost-optimal way to meet the Green Deal targets while accounting for resources, supply chains, technology adoption, and constraints. We focus on proven technologies, or those likely to become workable in the near term.

Our model does not incorporate possible changes in behavioral patterns, such as a growing preference for public transportation or consumers choosing to reduce their demand for goods and services, though either could increase the speed or decrease the cost of decarbonization.

Our models use assumptions about commodity prices, EU ETS permit costs, and technology costs. Throughout the report, we use official forecasts or the latest McKinsey predictions where available. As an example, two crucial assumptions for the power and heat sector are the EU ETS permit price and the price of natural gas. We assume an EU ETS price of EUR 27 per ton for 2030 and a natural gas price of EUR 22/MWh.[90] Where multiple price scenarios are available, we choose the more conservative assumptions, that is, those that indicate higher decarbonization costs.

Our analysis focuses solely on GHG reductions. We do not include the potential impact of other initiatives, such as the European Renewable Energy Directive or the European Energy Efficiency Directive, which also need to be taken into account by policy-makers. Including the constraints imposed by these directives could change the optimal pathway and increase the required investment.

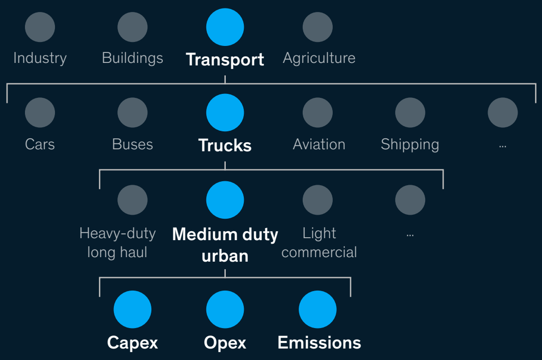
This report follows the convention used by the European Environmental Agency and uses GWP100 for reporting greenhouse gases in units of carbon dioxide equivalents (CO_2e). For convenience of reporting, all greenhouse gases can be converted into a single unit, called carbon dioxide equivalents (CO_2e). Using CO_2e allows non-CO_2 gases, such as methane and nitrous oxide, to be combined with carbon dioxide for analytical purposes, such as calculating marginal abatement costs or an emissions footprint. However, using CO_2e may oversimplify the unique warming dynamics of each individual greenhouse gas. The shortcoming of GWPs can be understood by looking at methane. The GWPs for all gases are derived by comparing the warming impact of a greenhouse gas relative to carbon dioxide over an explicit time period. The most common time periods are 20 years or 100 years, which create the commonly used GWP100 and GWP20 factors. For example, over a period of 20 years, methane absorbs 84 times more heat than carbon dioxide over 20 years, so the GWP20 factor for methane is 84. However, because methane exists for a shorter time in the atmosphere than carbon dioxide, its warming impact is less significant over a longer time period. Over 100 years, methane absorbs only 28 times more heat than carbon dioxide, so its GWP100 factor is 28. There is a factor of three difference between GWP20 and GWP100.[91]

Given the availability of data at the time of analysis the baseline year for analysis is 2017. The 2017 emission inventory data for the Czech Republic and the EU used in this report were retrieved from the Eurostat database in April 2020. These data are subject to change over time due to regular updates of national emission inventory reports and thus may differ.

Finally, all costs and benefits throughout the report are stated in 2020 real prices.

We modeled the full economy at technology level and optimized for minimal cost decarbonization pathways, subject to various constraints

McKinsey Decarbonization Pathways Optimizer (DPO)



>500

business cases considered across all sectors...

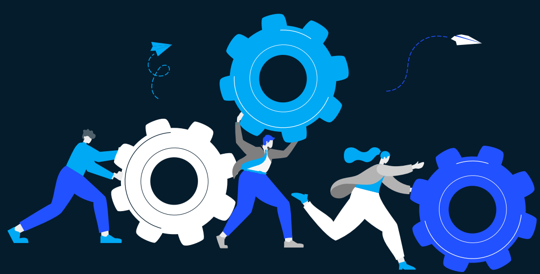
... that can supply continued activity levels in a country...

... minimizing the total system cost...

... while meeting a national and/or sectoral carbon reduction target...

... keeping track of maximum resource availability (e.g., biomass)...

... as well as supply-chain constraints for rolling out new technologies



Glossary and abbreviations

BECSS	bio-energy with carbon capture and storage
BEV	battery-powered electric vehicles
BF-BOF	blast-furnace - basic oxygen furnace
CCS	carbon capture and storage
CCUS	carbon capture, utilization and storage
CNG	compressed natural gas
CO_2	carbon dioxide
CO_2-e	carbon dioxide equivalent
DPO	Decarbonization Pathways Optimizer
DRI-EAF	direct reduced iron - electric arc furnace
ETS	emissions trading system
FCEV	fuel-cell electric vehicle
GHD	greenhouse gasses
GWP	"Global Warming Potential" (how much energy the emissions of one ton of gas will absorb during a given period compared to the emissions of one ton of carbon dioxide)
ICE	internal combustion engine
LNG	liquefied natural gas
LULUCF	land use, land-use change, and forestry
MaaS	mobility-as-a-service
$MtCO_2e$	mega tons of carbon dioxide equivalent
MWe	Megawatts electric
N_2O	nitrous oxide
PHEV	plug-in hybrid vehicles
PJ	petajoule (0.278 TWh)
SMR	small modular reactor
TCO	total cost of ownership

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