bp Energy Outlook
2024 edition

Energy Outlook 2024 explores the key trends and uncertainties surrounding the energy transition.

This year's *Energy Outlook* is focused on two main scenarios: *Current Trajectory* and *Net Zero*. These scenarios are not predictions of what is likely to happen or what bp would like to happen. Rather they explore the possible implications of different judgements and assumptions concerning the nature of the energy transition. The scenarios are based on existing technologies and do not consider the possible impact of entirely new or unknown technologies.

The many uncertainties surrounding the possible speed and nature of the energy transition means the probability of any one of these scenarios materialising exactly as described is negligible. Moreover, the two scenarios do not provide a comprehensive description of all possible outcomes. They do, however, span a wide range of possible outcomes and so might help to illustrate the key trends and uncertainties surrounding the possible development of energy markets out to 2050.

The *Energy Outlook* is produced to inform bp's views of the risks and opportunities posed by the energy transition and is published as a contribution to the wider debate about the factors shaping the future path of the global energy system. But the *Outlook* is only one source among many when considering the prospects for global energy markets and bp considers a wide range of other external scenarios, analysis and information when forming its long-term strategy.

Contents

Introduction to *Energy Outlook 2024*

Welcome to the 2024 edition of bp's *Energy Outlook.*

Global developments and events in recent years have highlighted the considerable challenges facing the global energy system and those of us who work within it.

Despite marked increases in government climate ambitions and actions, and rapid growth in investment in low carbon energy, carbon emissions continue to rise. Indeed, other than the Covid-induced fall of 2020, carbon emissions have risen every year since the Paris climate goals were agreed in 2015. The carbon budget is running out.

The world is in an 'energy addition' phase of the energy transition in which it is consuming increasing amounts of both low carbon energy and fossil fuels. The history of energy has seen several past phases of 'energy additions', for example the rapid increase in coal as the world shifted from the use of wood as its primary energy source to coal, and later the sharp increases in oil as it displaced coal as the dominant energy form. But in each of these cases, the world continued to consume similar or greater amounts of all types of energy.

The challenge is to move – for the first time in history – from the current energy addition phase of the energy transition to an 'energy substitution' phase, in which low carbon energy increases sufficiently quickly to more than match the increase in global energy demand, allowing the consumption of fossil fuels, and with that carbon emissions, to decline.

The longer it takes for the world to move to a rapid and sustained energy transition, the greater the risk of a costly and disorderly adjustment pathway in the future.

The challenge posed by the energy transition is further complicated by the repercussions of the energy disruptions and shortages caused by the war in Ukraine. These disruptions, and the economic and social costs they entailed, served as a reminder to us all that the transition also needs to consider the security and affordability of energy.

I realise that the concept of the energy trilemma – the importance of energy systems providing energy which is secure and affordable as well as sustainable – has been discussed and used for many years. But its relevance has never been greater: any successful and enduring transition needs to address all three elements of the trilemma.

These challenges, together with the broader implications of the shifts and trends underway in the global energy system, are explored in this year's *Outlook* using two main scenarios: *Current Trajectory* and *Net Zero*. Together these scenarios span a wide range of the possible outcomes for the global energy system over the next 25 years. It is possible to use these scenarios to identify energy trends that are common across both scenarios and those that are more dependent on the pace of the transition. This can help inform judgements of how the energy system may evolve over coming decades.

The two scenarios can also be compared to give a clearer sense of what needs to be done to shift the world from its current unsustainable emissions trajectory to a pathway consistent with the Paris climate goals. Spoiler alert: amongst other things, this suggests a need for greater electrification fuelled by even faster growth in wind and solar power, a significant acceleration in energy efficiency improvements, together with increasing use of a whole range of other low carbon energy sources and technologies, including biofuels, low carbon hydrogen, and carbon capture, use and storage (CCUS).

I hope this year's *Energy Outlook* is useful to everyone trying to tackle the challenges facing the global energy system and accelerate the transition to global net zero.

As always, any feedback of the *Outlook* and how it can be improved would be most welcome.

Spencer Dale
Chief economist

Recent developments and emerging trends

The *Energy Outlook* scenarios are informed by recent trends and developments in the global energy system.

- Carbon emissions have continued to increase, growing at an average rate of 0.8% per year over the past four years (2019-23). If CO_2 emissions were maintained at close to recent levels, the carbon budget estimated by the Intergovernmental Panel on Climate Change (IPCC) to be consistent with a high probability of limiting average global temperature increases to 2°C would be exhausted by the early 2040s.
- The war in Ukraine increased the attention on ensuring energy security and affordability as well as achieving the Paris climate goals. The recent disruptions in the Middle East have reinforced the importance of energy security.
- The increased focus on energy security could support greater emphasis on improving energy efficiency and growing domestic energy production. It may also prompt greater government involvement in the design and operation of energy markets, as illustrated by the growing role of green industrial policies, increasing attention on the security of energy supply chains and, where relevant, on the utilization of local fossil fuel resources.
- Global energy demand has continued to grow, averaging around 1% per year between 2019 and 2023, weaker than its average rate of a little below 2% over the 10 years to 2019, driven by increasing prosperity and growth in emerging economies.
- Progress on improving energy efficiency has been disappointing. The amount of energy used per unit of economic activity has fallen by a little over 1% per year over the past four years on average. That is slower than the previous 10 years and much weaker than the 4% annual rate targeted in the energy efficiency pledge at COP28.
- Investment in low carbon energy is estimated to have grown very rapidly in recent years, up around 50% since 2019 at approximately $1.9 trillion in 2023. This investment is heavily concentrated in developed economies and China, with far lower investment levels in emerging economies where costs of capital are typically higher.
- Much of this investment has been deployed in renewable power, with wind and solar power generation almost doubling between 2019 and 2023. This growth has been driven in particular by solar, supported by continuing falls in cost – the costs of solar modules have fallen by around 60% over the past four years.
- The energy additions from low carbon sources have not, however, been sufficient to meet the growth in total global energy demand, meaning the use of fossil fuels has continued to increase. Fossil fuel consumption reached a new high in 2023, driven primarily by rising oil consumption.
- Oil and gas upstream investment totalled $550 billion in 2023. Although upstream investment remains below its peak in the early 2010s, production has continued to grow steadily, supported by improving productivity of investment.

- Growth in oil demand since 2019 – which has averaged around 0.5 Mb/d per year – has been largely driven by increasing consumption in emerging economies and increased demand for petrochemical feedstocks. Oil consumption in developed economies continued to fall over much of the past two decades. In 2022 oil demand in developed economies was around 2 Mb/d lower than it was before the Covid-19 pandemic, and 5.5 Mb/d (around 10%) below its historic peak in 2005.
- Strong growth in natural gas demand in emerging Asian economies, combined with disruptions to Russian pipeline exports to Europe, has increased the importance of liquified natural gas (LNG) within global gas markets. LNG demand has grown around eight times the rate of overall natural gas consumption over the past five years.
- Growth in electricity has continued to outpace total energy demand growth in recent years as the energy system has increasingly electrified. This has been driven by continued rapid growth in electricity use in emerging economies, spurred by improved accessibility and affordability. Nascent but growing demand from data centres to support the increasing adoption of generative AI applications looks set to increase electricity demand materially in some markets in the coming years.
- The rapid growth in low carbon generation is putting increased pressure on the infrastructure and governance process supporting power markets, including planning and permitting and grids. For example, in the US the average time between a request for grid connection and commercial operation increased from less than two years for projects built in 2000-07 to nearly five years for projects built in 2023.
- The number of electric vehicles has risen rapidly, with sales increasing from two million vehicles in 2019 to around 14 million in 2023. This growth has been underpinned by vehicle emissions regulations, especially in China, the EU and the US.
- Sales of heat pumps also grew steadily, particularly in the EU and North America. Annual sales increased by around 75% in the EU between 2019 and 2023 to reach 2.6 million units per year.
- Growth in less mature, higher cost, low carbon energy vectors and technologies – including low carbon hydrogen, synthetic biofuels, and carbon capture and storage – remains at a very early stage. As an example, at the beginning of 2024 less than 5 Mtpa low carbon hydrogen projects were operational or under construction – a small fraction of the existing use of unabated fossil-fuel-based hydrogen.
- Investment in critical minerals mining and exploration has increased in recent years in response to prospective increases in demand as the energy system transitions, but would need to accelerate further to meet the needs of a rapid energy transition.

Key insights

The scenarios in this year's *Energy Outlook* can be used to help inform some key insights about how the energy system may evolve over the next 25 years. Some of these insights stem from factors affecting the global environment and energy markets that are common across both scenarios and so may suggest an increased likelihood that they may also be apparent in pathways lying 'between' these scenarios. Other insights are more dependent on the pace of transition.

Global environment

- The carbon budget is running out. The longer the delay in taking decisive action to reduce emissions on a rapid and sustained basis, the greater the risk of a costly and disruptive adjustment pathway later. Government ambitions and provisions in support of the energy transition have grown in recent years, but further global policy action is needed to achieve a Paris-consistent pathway.
- The disruptions to global energy supplies associated with the war in Ukraine have increased the importance attached to ensuring secure and affordable energy while also achieving the Paris climate goals. This greater focus on safeguarding energy security includes many countries placing more weight on ensuring the security of their key low carbon energy value chains.

Trends common across both scenarios

- Energy demand grows more strongly in emerging economies, driven by rising prosperity and living standards. But the magnitude and persistence of the growth in energy consumption depends critically on actions taken globally to accelerate improvements in energy efficiency.
- The structure of energy demand changes, with the importance of fossil fuels declining, replaced by a growing share of low carbon energy, led by wind and solar power. The world moves from the 'energy addition' phase of the transition, in which more of both low carbon energy and fossil fuels are consumed, to an 'energy substitution' phase, with declining consumption of fossil fuels.
- Wind and solar grow rapidly, supported by falling costs and a steadily increasing electrification of the energy system. The rising share of variable renewable energy in power generation requires global power systems to bolster their resilience to fluctuations in generation, by upgrading grids, and increasing system flexibility, storage, and reliable spare (dispatchable) capacity.
- Oil demand declines over the outlook but continues to play a significant role in the global energy system for the next 10-15 years. This requires continuing investment in upstream oil (and natural gas).

- The decline in oil demand stems at first largely from the improving efficiency of the internal combustion engine (ICE) vehicle fleet, but then over time increasingly from the electrification of road transport. The number of electric vehicles grows rapidly, underpinned by regulatory standards and increasing cost competitiveness.

Transition-dependent trends

- Whether the demand for natural gas increases or falls over the next 25 years depends on the speed of the energy transition. Natural gas consumption rises in emerging economies as they grow and industrialize. But in accelerated transition pathways this is offset by shifts away from natural gas to lower carbon energy.
- The use of biofuels and biomethane grows over the next 25 years. But the pace of that expansion in key sectors such as aviation is highly dependent on the extent of government policies and mandates supporting their use.
- Low carbon hydrogen helps to decarbonize the energy system through its use in industry and transport for activities that are hard to electrify, and, to a lesser extent, in providing resilience in power systems. The high cost of low carbon hydrogen relative to incumbent unabated fossil fuels, however, means that its significance depends on the scale of policy support. Even in a faster transition pathway, much of the growth of low carbon hydrogen occurs after 2035.
- CCUS plays a critical role in enabling the transition to a low carbon energy system, but it requires government support and incentives to compensate for the additional costs its use involves. The deployment of CCUS complements a transition away from fossil fuels – it does not act as an alternative.

Overview

Two scenarios to explore the speed and shape of the energy transition out to 2050

Net Zero is in line with 'Paris consistent' IPCC scenarios, while *Current Trajectory* suggests a significant temperature overshoot

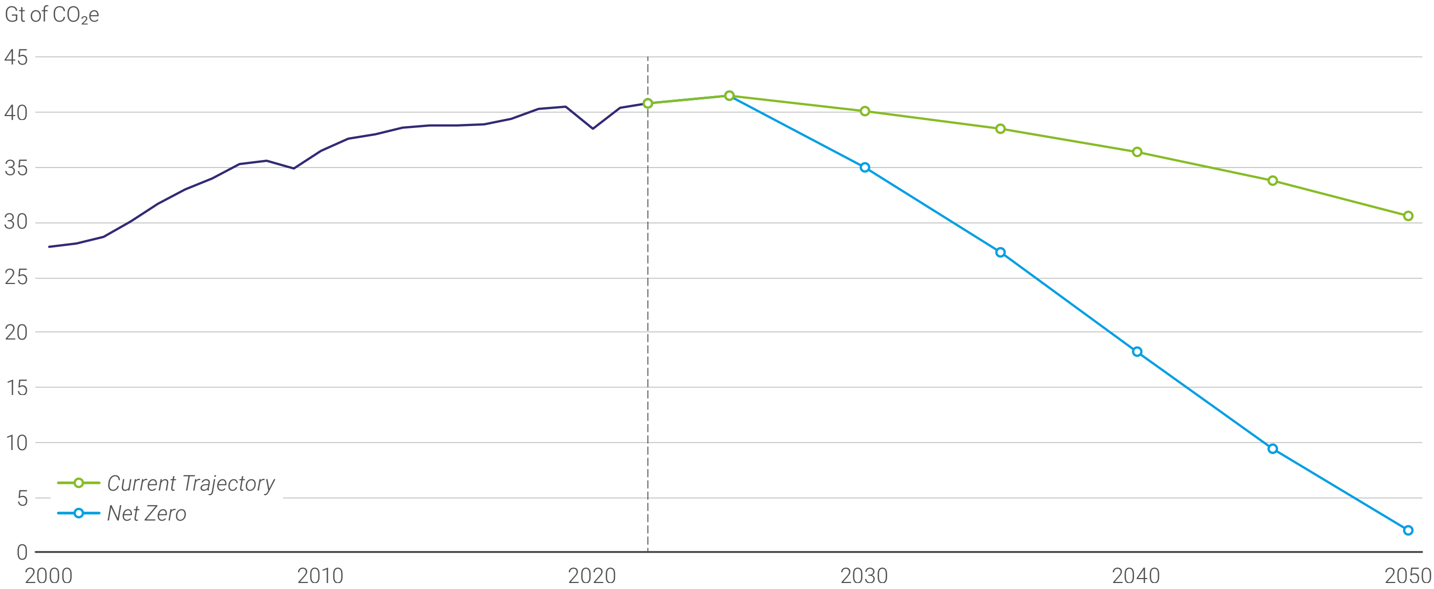
Progressing the energy transition: from energy addition to energy substitution

The pathway along which the global energy system is currently travelling, if continued, is not consistent with a 2°C carbon budget

Delaying the energy transition could lead to a costly and disorderly adjustment pathway

Two scenarios to explore the speed and shape of the energy transition out to 2050

Carbon emissions



Carbon emissions include CO_2 emissions from energy use, industrial processes, natural gas flaring and methane emissions from energy production.

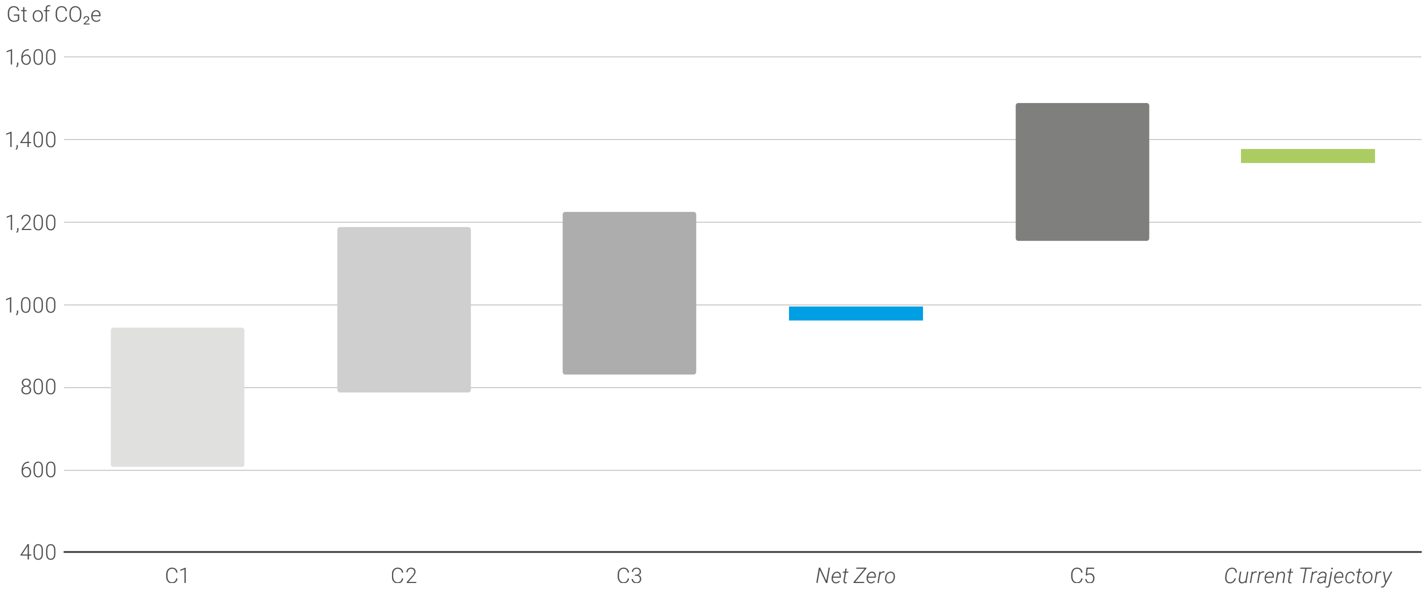
Key points

bp's *Energy Outlook 2024* uses two scenarios – *Current Trajectory* and *Net Zero* – to explore a range of possible outcomes for the global energy system out to 2050.

- The wide range of factors that are likely to shape the transition of the global energy system over the next 25 years – for example, policy, technology, societal pressures, financing and geopolitics – mean it is not possible to make meaningful predictions of how the energy system will evolve.
- Instead, the *Energy Outlook* uses scenarios that span a wide range of possible outcomes out to 2050. In doing so, the scenarios inform an understanding of which trends in the energy system are more likely to occur across most plausible outcomes and which ones are more dependent on the speed and shape of the energy transition. That understanding can help shape strategic choices that are more resilient to the many uncertainties surrounding the future of the energy system.
- The scenarios consider carbon emissions from energy production and use, most non-energy related industrial processes, and natural gas flaring and methane emissions from the production, transportation, and distribution of fossil fuels and the incomplete combustion of traditional bioenergy (see pages 102-103 of the Annex for more details). The scenarios use data from 2022 as the base year. The considerable inertia in the energy system means that its evolution over the next few years is unlikely to vary significantly across scenarios.
- *Current Trajectory* is designed to capture the broad pathway along which the global energy system is currently travelling. It places weight on climate policies already in force and on global aims and pledges for future decarbonization. At the same time, it also recognizes the myriad challenges associated with meeting these aims. CO_2 equivalent (CO_2e) emissions in *Current Trajectory* peak in the mid-2020s and by 2050 are around 25% below 2022 levels.
- *Net Zero* explores how different elements of the energy system might change to achieve a substantial reduction in carbon emissions. In that sense, *Net Zero* can be viewed as a 'what if' scenario: what elements of the energy system might change, and how, if the world collectively acts for CO_2e emissions to fall by around 95% by 2050.
- *Net Zero* assumes that there is a significant tightening in climate policies. It also embodies shifts in societal behaviour and preferences which further support gains in energy efficiency and the adoption of low carbon energy.
- The carbon emissions remaining in *Net Zero* in 2050 could be eliminated by either additional changes to the energy system (including CCUS-enabled carbon dioxide removals (CDR) (see pages 68-69) or by the deployment of natural climate solutions (NCS). The use of NCS to offset emissions from the energy system would depend on a range of factors including the costs of both NCS and the relative costs of abating greenhouse gas emissions inside and outside of the energy system. These costs are not explicitly considered in the *Outlook*.

Net Zero is in line with 'Paris consistent' IPCC scenarios, while *Current Trajectory* suggests a significant temperature overshoot

Cumulative carbon emissions in IPCC scenarios in 2015-2050



C1-C5 represent the categories of IPCC scenarios using the 10%-90% percentile range for various temperature outcomes as described in this section.
See the Annex for an additional explanation on how cumulative emissions are calculated.

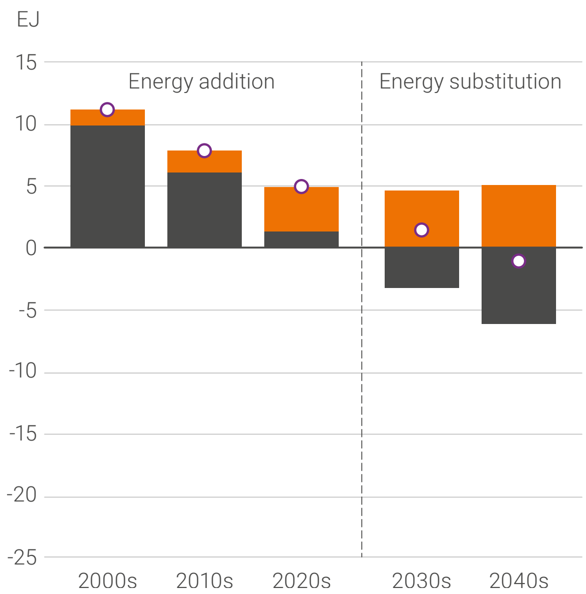
Key points

The pace and extent of decarbonization in *Net Zero* is broadly aligned with a range of IPCC scenarios consistent with meeting the Paris climate goals. In contrast, the emissions profile of *Current Trajectory* suggests a much greater likelihood of a significant overshoot relative to those climate goals.

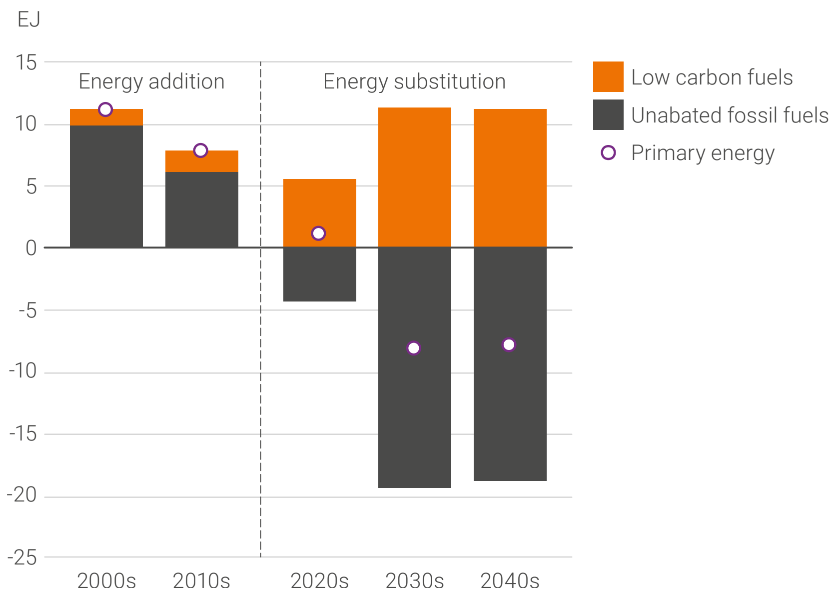
- The *Energy Outlook* scenarios extend only to 2050 and do not model all forms of greenhouse gases or all sectors of the economy. As such, it is not possible to directly infer the increase in global average temperatures in 2100 implied by *Current Trajectory* and *Net Zero*.
- However, it is possible to make an indirect inference by comparing the cumulative carbon emissions in the two scenarios for the period 2015-50 with the ranges of corresponding carbon trajectories taken from the scenarios included in the IPCC Sixth Assessment Report (Climate Change 2022: Impacts, Adaptation and Vulnerability). See pages 92-93 in the Annex for more details.
- It is not straightforward to compare *Net Zero* with the Paris climate goals. Cumulative CO_2e emissions in *Net Zero* are broadly in the middle of the ranges of two categories of IPCC scenarios – C2 and C3. IPCC C2 scenarios are consistent with a greater than 50% probability of returning global warming to 1.5°C after a high overshoot, and IPCC C3 scenarios are consistent with a greater than 67% probability of limiting average global temperature rises to 2°C. On that basis, *Net Zero* might be considered to be broadly consistent with the Paris climate goals.
- In contrast, cumulative carbon emissions in *Current Trajectory* are above the mid-point of the range of emissions from IPCC C5 scenarios, which are consistent with a greater than 50% probability of limiting average global temperature rises to 2.5°C. This suggests *Current Trajectory* is not consistent with meeting the Paris climate goals.

Progressing the energy transition: from energy addition to energy substitution

Average annual change in primary energy in *Current Trajectory*



Average annual change in primary energy in *Net Zero*



Calculation does not include 2020 due to impact of Covid-19.

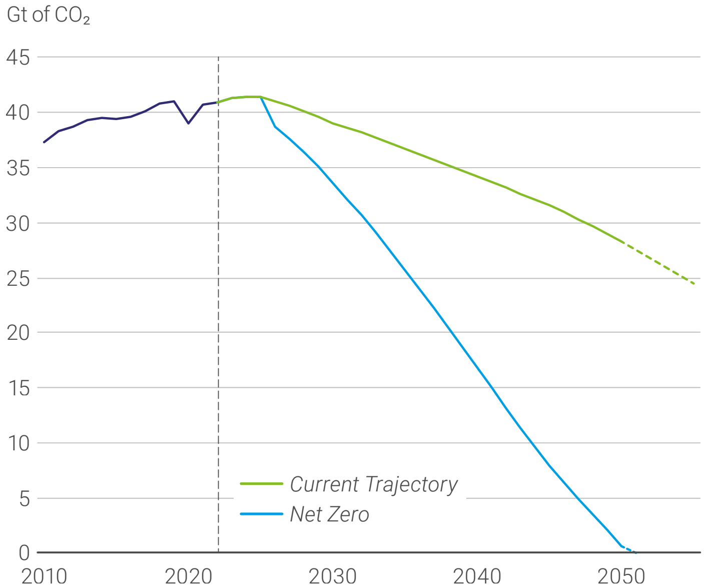
Key points

The global energy system faces the challenge of moving from the current phase of the energy transition, in which low carbon energy is accelerating, to a second phase in which it is growing sufficiently quickly to reduce the need for fossil fuels.

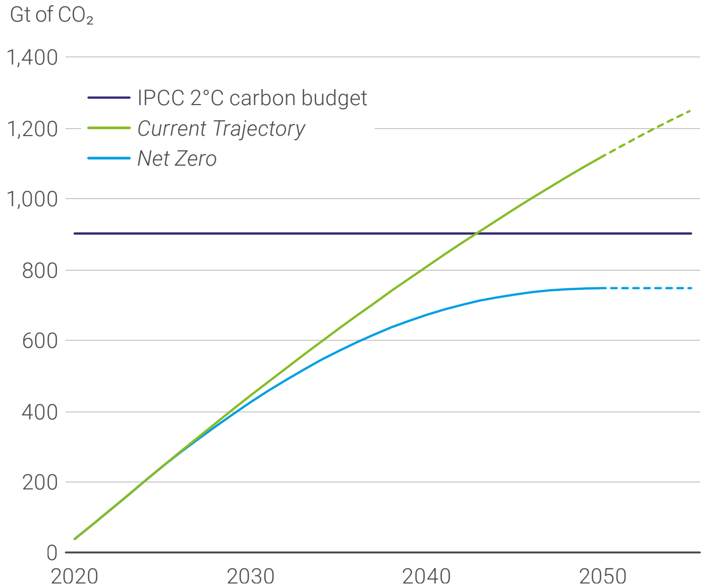
- Low carbon energy has increased significantly in recent years, boosted in particular by growth in wind and solar power generation, which has more than doubled since 2018. This accounted for a third of the growth in primary energy over that period.
- Despite this rapid growth, the global energy system remains in an 'energy addition' phase of the transition. Low carbon energy is growing rapidly, increasing its share of the energy mix and helping to slow the pace at which emissions are rising. But it is not increasing quickly enough to keep pace with the growth in total global energy demand. As a result, the absolute consumption of fossil fuels (and their associated carbon emissions) continues to increase, alongside the growth in low carbon energy.
- This energy addition phase has occurred in previous structural transitions of the energy system. For example, during the rapid growth in the use of coal as it displaced traditional biomass (including wood) to become the world's primary energy source. And later, during the increases in oil demand, as it displaced coal as the dominant energy form.
- It is striking that in both these previous energy transitions, the world continued to consume similar or growing amounts of the 'old' form of energy (in these cases traditional biomass and, later, coal) even as it also adopted the 'new'. The global energy system remained persistently in the energy addition phase.
- The challenge for the global energy system is, for the first time in history during an energy transition, to move from energy addition to energy substitution. This occurs only when the growth of the 'new' energy – this time low carbon energy – exceeds the increase in total global energy demand, so that the use of the 'old' energy – in this case unabated fossil fuels – declines in absolute terms.
- In *Current Trajectory*, the 2020s as a whole is another decade of energy addition. Low carbon energy increases by 40%, but fossil fuel consumption also grows. A combination of larger increases in low carbon energy and slower growth in energy demand, aided by quickening gains in energy efficiency, causes a shift to the 'substitution' phase of the energy transition in the 2030s and 2040s in *Current Trajectory*. But the extent of this transition is relatively limited: unabated fossil fuels still account for two-thirds of primary energy in 2050 in *Current Trajectory*.
- In *Net Zero*, however, larger increases in low carbon energy combined with an acceleration in energy efficiency cause the energy system to move into the energy substitution phase of the energy transition over the 2020s. This transition gathers pace in the 2030s and 2040s, such that the share of unabated fossil fuels in primary energy declines to less than 20% by 2050 and net carbon emissions from the energy system are close to zero.
- The quicker pace of energy transition in *Net Zero* is driven both by larger increases in low carbon energy, enabling more rapid substitution away from unabated fossil fuels, and by faster gains in energy efficiency, which cause total primary energy to peak in the second half of this decade and decline through the 2030s and 2040s. By 2050 primary energy in *Net Zero* is around a third lower than in *Current Trajectory*.
- The key drivers needed to move the energy system from *Current Trajectory* to *Net Zero* – to an earlier and quicker energy transition – are explored in pages 76-87.

The pathway along which the global energy system is currently travelling, if continued, is not consistent with a 2°C carbon budget

CO_2 emissions



Cumulative CO_2 emissions, 2020 onwards



Key points

The longer the global energy system remains on its current pathway, the harder it will be to remain within a 2°C carbon budget, or indeed to meet the Paris climate goals.

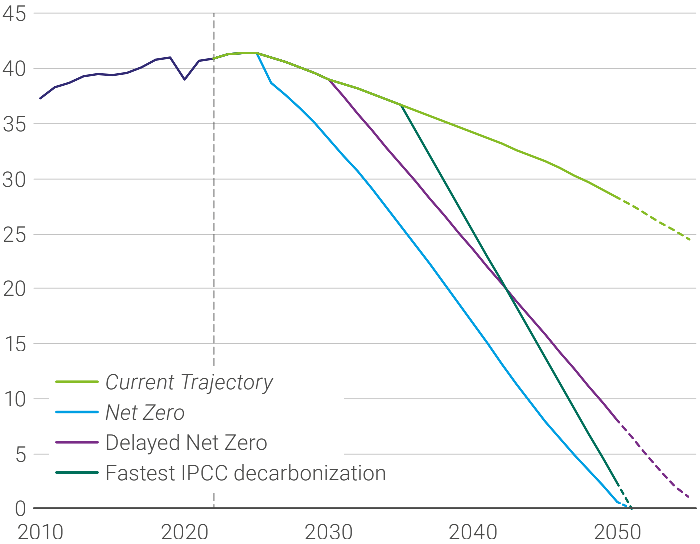
- Climate science suggests that average global temperature rises depend on the cumulative amount of greenhouse gases that have been emitted. In that context, the IPCC provides estimates of carbon budgets consistent with limiting average global temperature rises to different levels.
- The Paris climate goals are to limit average global temperature rises to well below 2°C and pursue efforts to limit temperature rises to 1.5°C.
- The IPCC does not produce estimates of carbon budgets which equate specifically to limiting average global temperature rises to 'well below 2°C'. But it does provide an estimate for a carbon budget consistent with there being a high probability (83%) of limiting temperature rises to 2°C. For that reason, the remainder of this analysis is based around this 2°C carbon budget.
- The IPCC estimates that the remaining 2°C carbon budget is around 900 Gt CO_2 (measured from the beginning of 2020)[a]. This budget estimate includes anthropogenic CO_2 emissions from agriculture, farming and other land use (AFOLU), but excludes the global warming effects from non-CO_2 emissions (such as methane) whose global warming effects are accounted for separately when estimating the CO_2 budget[b].
- To compare the carbon emissions implied by *Current Trajectory* and *Net Zero* with the IPCC 2°C carbon budget, the emissions pathways implied by the scenarios are adjusted to include IPCC estimates of AFOLU-related emissions and to exclude estimates of methane emissions associated with the production, transportation, and distribution of fossil fuels and from incomplete combustion of traditional biomass (see pages 96-97 in the Annex).
- These adjusted emissions pathways suggest that the emissions implied by *Net Zero* are within a 2°C budget, whereas in *Current Trajectory* cumulative emissions exceed the budget in the early 2040s.
- The longer the world remains on a pathway like *Current Trajectory*, the harder it would be to stay within a 2°C carbon budget. This raises the risk that an extended period of delay could increase the economic and social costs of remaining within a 2°C budget.
- This risk is explored in an alternative *Delayed and Disorderly* scenario.

[a] The IPCC estimates that if the probability of the carbon budget being consistent with 2°C is reduced from 83% to 67%, the budget increases to 1150 $GtCO_2$ (since 2020).
[b] See Table SPM.2 | Estimates of historical carbon dioxide (CO_2) emissions and remaining carbon budgets. IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

Delaying the energy transition could lead to a costly and disorderly adjustment pathway

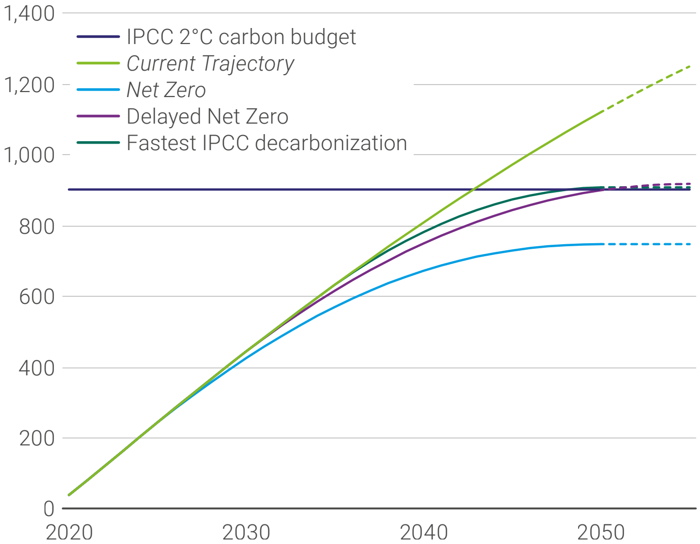
CO_2 emissions

Gt of CO_2



Cumulative CO_2 emissions, 2020 onwards

Gt of CO_2



For more details, see the Annex on our modelling approach to *Delayed Net Zero* and the fastest IPCC decarbonization scenario.

Key points

Beyond a certain point, the cost and disruption associated with meeting a 2°C carbon budget is likely to increase the longer the shift to a faster decarbonization pathway is delayed.

- The *Delayed and Disorderly* scenario assumes that the global energy system moves in line with *Current Trajectory* for a period, after which sufficient policies and actions are undertaken to begin an accelerated fall in carbon emissions, consistent with meeting a 2°C carbon budget.
- It also assumes that there are limits to the pace at which it is possible to decarbonize the global energy system in an 'orderly' manner, i.e. without having to resort to policies and actions that have outsized economic and social costs. This maximum pace of 'orderly' transition is uncertain and would depend on the specific triggers leading to the decision to pursue a faster transition pathway and on the technologies available to reduce emissions at the time that decision has been taken.
- There are different ways in which this maximum pace of 'orderly' transition could be approximated:
  - One possibility would be to assume that this fastest pace is broadly in line with the rate achieved in *Net Zero*. This stylised assumption would imply that the latest date the energy system could continue along the *Current Trajectory* pathway before then moving to a rapid decarbonization while still achieving an 'orderly' transition consistent with remaining within a 2°C budget, would be around the beginning of the next decade. This '*delayed Net Zero*' pathway gets to net zero emissions by the mid-2050s and cumulative carbon emissions remain just within the 2°C carbon budget.
  - An alternative approximation would be to base it on the fastest pace of modelled decarbonization in the IPCC scenarios, which is somewhat more rapid than in *Net Zero*. This would imply a shift away from the *Current Trajectory* pathway to a rapid decarbonization pathway by the mid-2030s to remain within a 2°C budget.
- These approximations suggest that, if the move to an accelerated transition pathway is delayed much beyond the early-to-mid 2030s, there would be an increasing likelihood that costly – or 'disorderly' – measures would be needed to keep emissions within a 2°C carbon budget. These measures could take many different forms, with the aim of reducing or curtailing the use of unabated fossil fuels and higher-emitting activities and so achieving an even more rapid pace of decarbonization than in *Net Zero* or the fastest decarbonization scenarios considered by the IPCC.
- If the world was still following the *Current Trajectory* pathway in the early 2040s it would have exceeded a 2°C carbon budget.
- The *Delayed and Disorderly* scenario is highly stylised, and other assumptions, for example in which the world moved away from *Current Trajectory* onto a decarbonization pathway that accelerated over time, would imply a different timeframe.

Energy demand

Growth in energy demand is led by increasing prosperity in emerging economies, offset by quickening gains in energy efficiency

Primary energy demand gradually decarbonizes, driven by rapid growth in renewable energy

Oil demand falls over the outlook driven by falling use in road transport

Oil is increasingly replaced by electricity as the main energy source for road transport

Aviation and marine transportation are increasingly decarbonized through a combination of hydrogen-derived fuels and biofuels

Falls in oil demand are reflected in shifting patterns of product demand and refining activity

The pattern of global oil supplies shifts as oil demand declines

The outlook for natural gas demand depends on the speed of the energy transition

LNG demand depends on gas consumption in Europe and Asia, which are reliant on LNG imports for supplies of gas

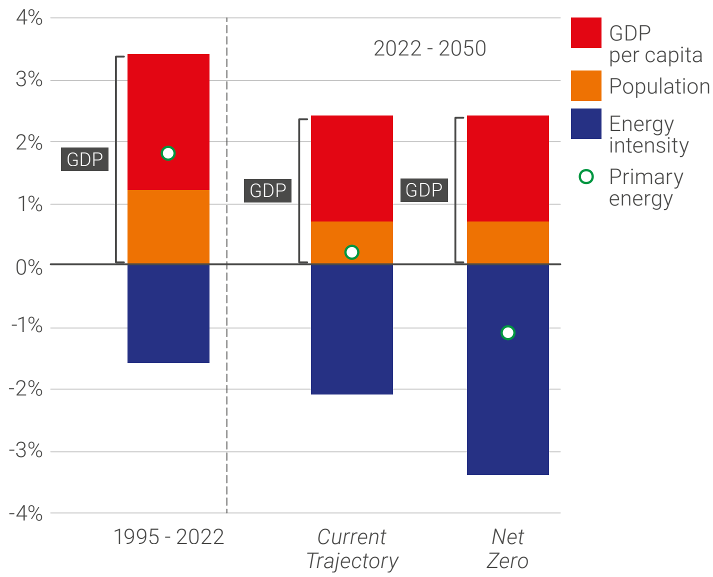
The global pattern of natural gas production is increasingly driven by developments in LNG trade

The role of coal in the global energy system declines, driven by China

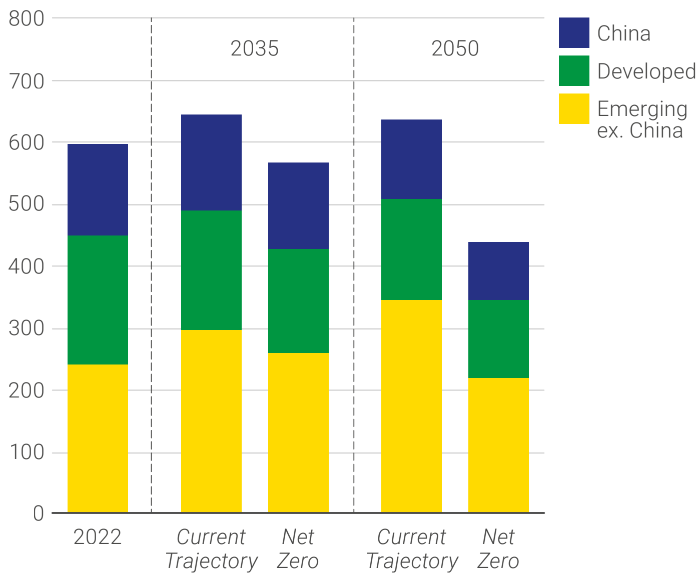
Modern bioenergy increases rapidly, helping to decarbonize sectors and processes which are hard to electrify

Growth in energy demand is led by increasing prosperity in emerging economies, offset by quickening gains in energy efficiency

Average annual growth of primary energy demand



Primary energy by region



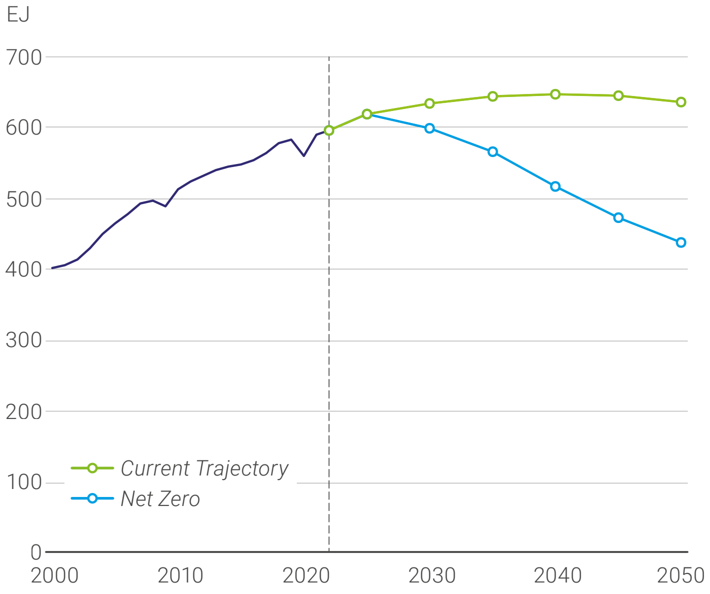
Key points

Growth in global energy demand is underpinned by increasing levels of prosperity in emerging economies. The extent and persistence of this growth depends on the pace of energy efficiency improvements.

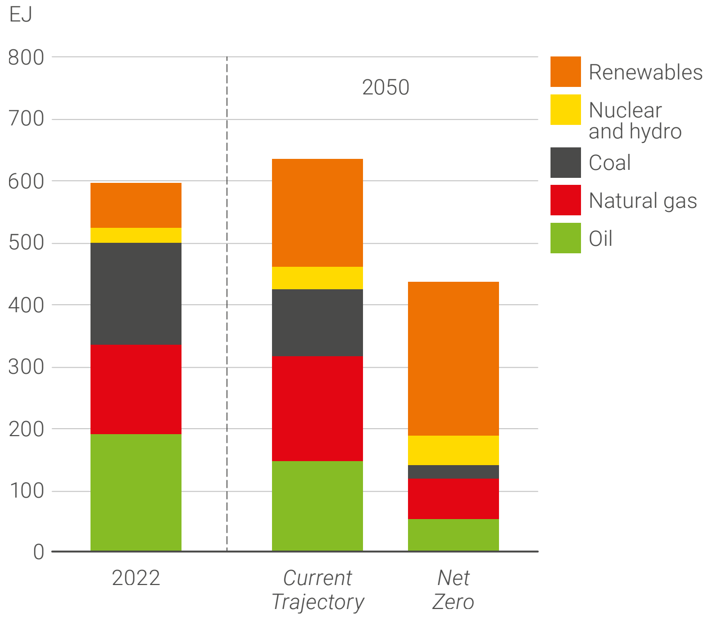
- Annual GDP growth averages 2.4% over the outlook in the two scenarios. This is slower than the average growth of almost 3.5% per year seen over the previous 25 years, reflecting both slower population growth and weaker gains in GDP per capita. Even so, the size of the world economy doubles by 2050. The main driver of this increase is rising levels of prosperity in emerging economies, which account for around 70% of the increase in global activity.
- As in recent *Energy Outlooks*, the assumed trajectory for global GDP includes an estimate of the impact of climate change on economic growth. This impact includes the effects of both increasing temperatures on economic activity and the upfront costs associated with mitigation and adaptation. More details of the approach and its limitations can be found on pages 98-99.
- The extent to which increasing economic activity results in higher energy demand depends on improvements in energy efficiency. Annual gains in energy efficiency average 2.1% in *Current Trajectory* and 3.4% in *Net Zero*, compared with 1.6% over the previous 25 years. These faster efficiency gains are supported by the increasing shift towards wind and solar power generation, which reduces the energy losses associated with converting thermal energy into electricity, as well as by the broader pressures to decarbonize the energy system and enhance energy security.
- The combination of slower economic growth and faster gains in energy efficiency means the growth of global primary energy demand is much weaker than in the past, and demand actually falls over the outlook in *Net Zero*. Over the past 25 years, primary energy has grown at an average annual rate of 1.8%: that compares to growth of 0.2% in *Current Trajectory* and an average annual decline of 1.1% in *Net Zero*.
- The main sources of increase in energy demand are emerging economies (excluding China), where demand grows over the first half of the outlook in both scenarios. After that, energy demand in these emerging economies depends on the pace of decarbonization. It continues to grow in *Current Trajectory*, increasing by around 45% over the outlook. In contrast, in *Net Zero*, energy demand in emerging economies peaks in the early 2030s and falls thereafter, such that by 2050 it is around 10% below 2022 levels.
- Growth in energy consumption in China and developed economies is more muted, reflecting both slower economic growth and greater gains in energy efficiency. Demand in China peaks in the mid-to-late 2020s in both scenarios, before falling to around 15% and 35% below 2022 levels by 2050 in *Current Trajectory* and *Net Zero* respectively. Energy demand in developed economies continues the decline seen over much of the past 20 years, falling between 20-40% over the outlook in *Current Trajectory* and *Net Zero* respectively.

Primary energy demand gradually decarbonizes, driven by rapid growth in renewable energy

Primary energy



Primary energy by energy type



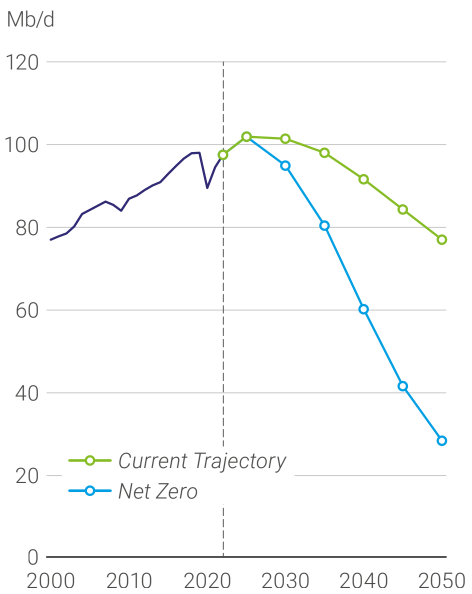
Key points

Primary energy demand increases in the near term before plateauing or falling thereafter, with the fuel mix becoming increasingly decarbonized.

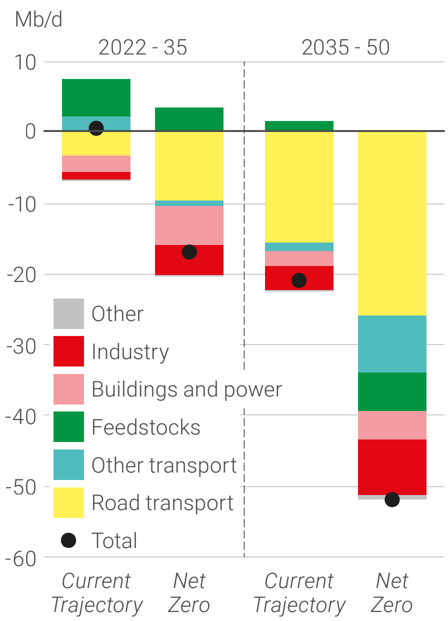
- Primary energy demand in *Current Trajectory* increases out to the mid-2030s before broadly plateauing, as continuing increases in energy consumption in emerging economies (excluding China) are broadly offset by declines in developed economies and, eventually, in China.
- In contrast, energy demand peaks in the middle of the current decade in *Net Zero* before declining thereafter, as increasing efforts to decarbonize the energy system drive faster gains in energy efficiency.
- By 2050 primary energy demand in *Current Trajectory* is around 5% higher than in 2022 but is a little over 25% lower than 2022 levels in *Net Zero*.
- The fastest growing source of primary energy is renewable energy, which includes wind and solar power, bioenergy and geothermal (but excludes hydropower). Renewable energy more than doubles by 2050 in *Current Trajectory* and increases more than three-fold in *Net Zero*. The share of renewables in primary energy increases from a little over 10% in 2022 to more than a quarter by 2050 in *Current Trajectory*, and to more than half of all primary energy in *Net Zero*.
- The increasing importance of renewables is reflected in the declining share of fossil fuels, which falls from around 85% of primary energy in 2022 to around two-thirds by 2050 in *Current Trajectory* and only a third in *Net Zero*.
- The largest falls occur in the share of coal, as the world shifts towards lower carbon fuels in industry and power. By 2050 coal consumption is between 35-85% lower in the two scenarios (see pages 46-47).
- Oil demand also declines in both scenarios, driven primarily by the falling use of oil in road transport (see pages 30-31). The share of oil in primary energy decreases from around a third in 2022 to around a quarter by 2050 in *Current Trajectory* and to a little over 10% in *Net Zero*.
- Whether demand for natural gas rises or falls from its current level depends on the pace of decarbonization. In *Current Trajectory*, natural gas demand increases by close to a fifth as emerging economies increase their reliance on it. In contrast, the greater shift towards electrification and lower carbon energy sources in *Net Zero* means natural gas demand plateaus in the second half of this decade and by the end of the outlook is around half of its 2022 level (see pages 40-41).
- The definition of primary energy used in the *2024 Energy Outlook* is based on the 'direct equivalent method', which is the approach used by the IPCC. See pages 104-105 in the Annex for more detail.

Oil demand falls over the outlook driven by falling use in road transport

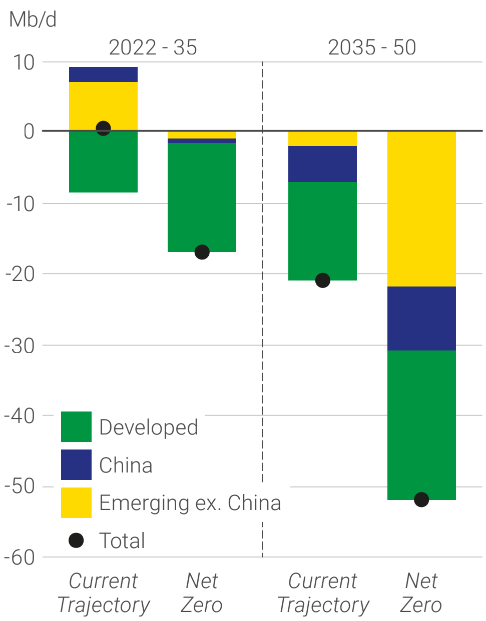
Oil demand



Change in oil demand by sector



Change in oil demand by region



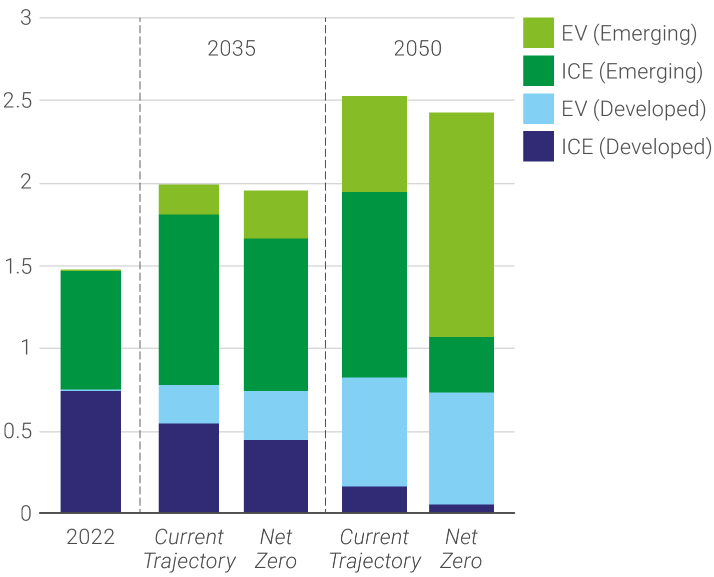
Key points

Global oil demand plateaus over the remainder of this decade before declining over the rest of the outlook, led by the falling use of oil in road transport.

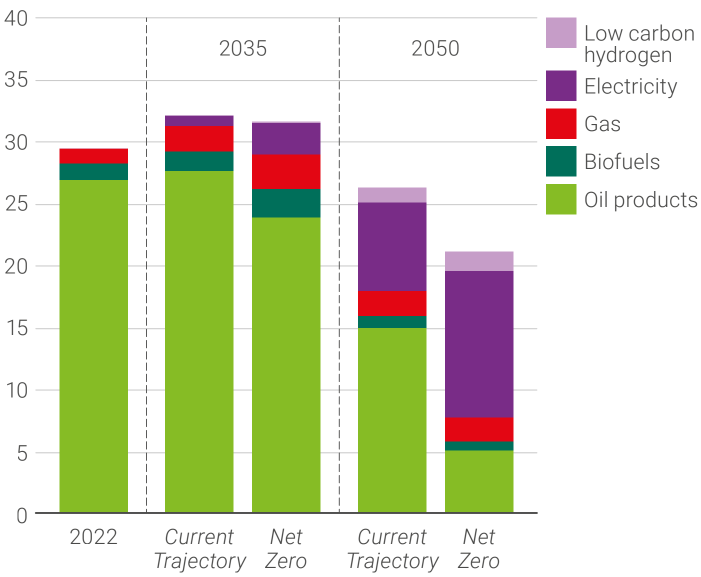
- Oil continues to play a major role in the global energy system over the first half of the outlook, with the world consuming between 100-80 Mb/d of oil in 2035 in *Current Trajectory* and *Net Zero* respectively.
- In *Current Trajectory*, oil consumption gradually declines over the second half of the outlook to around 75 Mb/d in 2050. The contraction in oil use is more pronounced in *Net Zero*, with demand falling to between 25-30 Mb/d by 2050 – around 70% below its 2022 level.
- The single biggest driver of the reduction in oil consumption is the declining use of oil in road transport as the efficiency of the vehicle fleet improves and alternative fuels are increasingly used, led by the electrification of cars and trucks (see pages 32-33).
- In *Current Trajectory*, the declining use of oil in road transport over the first half of the outlook is offset by the increasing use of oil as a feedstock, especially in the petrochemicals sector as rising prosperity boosts consumption of plastics, textiles, and other oil-based materials. Further out, broad-based declines in oil across all forms of transport dominate the continuing small increases in the use of oil as a feedstock, which plateaus at around 25 Mb/d in the 2040s.
- In *Net Zero*, the falls in oil demand across all forms of transport are more pronounced and the use of oil as a feedstock peaks in the mid-2030s as the world limits the use of single-use plastic and encourages greater levels of recycling.
- The falling use of oil in industry seen in both scenarios by 2050 also reflects the decreasing use of diesel generators and the increasing use of alternative fuels in off-road industrial vehicles.
- The falls in oil demand are concentrated in developed economies, continuing the long-term decline seen in these markets since the early 2000s. Oil consumption in developed economies falls from around 45 Mb/d in 2022 to between 20 and 7 Mb/d by 2050 in the two scenarios.
- In China, oil demand edges slightly higher over the next few years before declining post-2030, driven in large part by the increasing electrification of road transport.
- In the other emerging economies, increasing levels of prosperity and rising living standards support more resilient oil demand. In *Current Trajectory*, emerging economies' demand increases until the mid-2030s after which it broadly plateaus. The increased electrification of road transport in *Net Zero* leads to more pronounced falls in oil consumption across emerging economies in the second half of the outlook.

Oil is increasingly replaced by electricity as the main energy source for road transport

Light duty vehicles by technology and region



Medium and heavy duty vehicles: energy use by fuel



Gas includes biomethane.

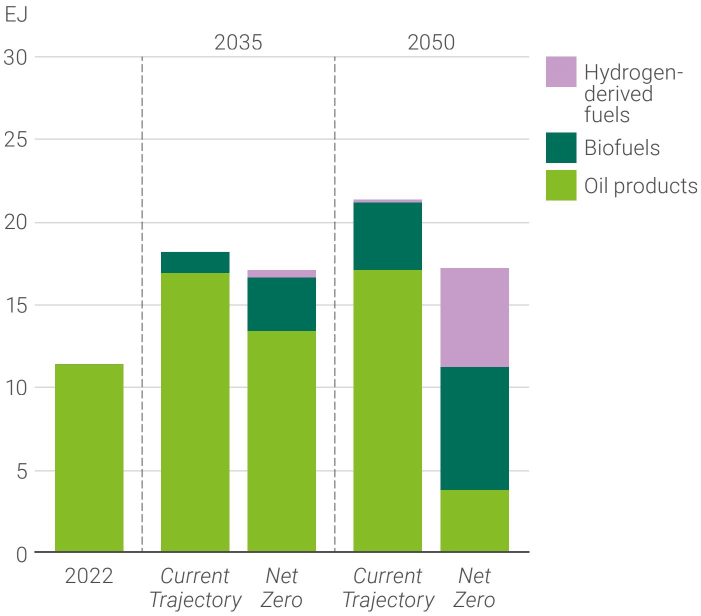
Key points

Demand for road transportation grows as prosperity and living standards in emerging markets improve, with the use of oil in road transport increasingly displaced by electricity.

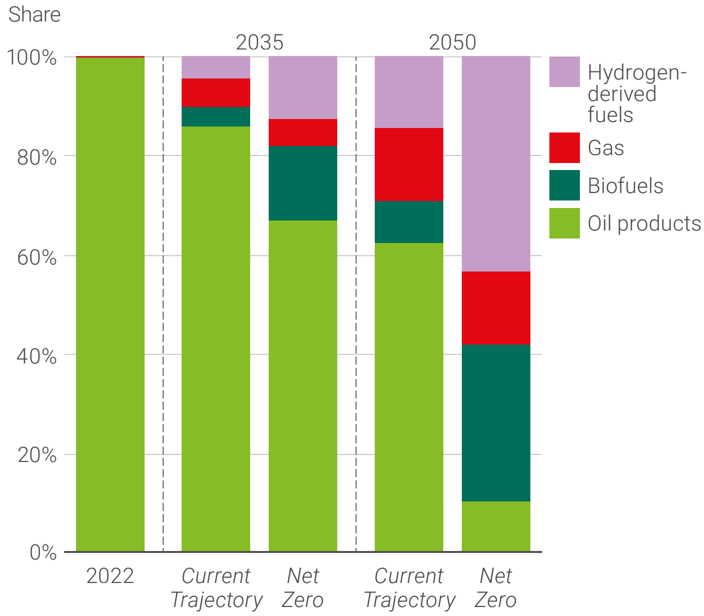
- The global light duty vehicle parc increases from around 1.5 billion vehicles in 2022 to around 2.0 billion vehicles in 2035 and 2.5 billion in 2050 in both scenarios.
- This expansion in light duty vehicles is almost entirely accounted for by a growing number of light vehicles in emerging economies, as rising levels of prosperity facilitate increased levels of car ownership, and those vehicles are driven greater distances.
- In contrast, the market for light vehicles in developed economies is largely satiated, with the number of such vehicles stable at around 0.7-0.8 billion vehicles over the entire outlook.
- The fleet of light-duty vehicles is increasingly electrified over the outlook, led by changes in developed economies. This increasing electrification is driven by tightening policy and regulation standards, supported by increasing cost competitiveness of electric vehicles as battery costs continue to fall and the manufacturing of such vehicles is progressively scaled up.
- The share of electric vehicles in the global light vehicle parc increases from less than 2% in 2022 to between 20-30% by 2035 in *Current Trajectory* and *Net Zero*, growing to between 50 and 85% respectively by 2050.
- The global fleet of internal combustion engine (ICE) light vehicles is relatively unchanged in size over the first half of the outlook, with declining numbers in developed economies offset by growth in emerging economies. But by 2050 the number of ICE vehicles is around 10% lower than 2022 levels in *Current Trajectory* and 75% lower in *Net Zero*. The smaller number of ICE vehicles, combined with their improving efficiency, means the amount of oil used in light vehicles falls from around 30 Mb/d in 2022 to 16 and four Mb/d by 2050 in *Current Trajectory* and *Net Zero* respectively.
- Similar trends are apparent in medium and heavy-duty (MHD) trucks, with the global fleet of MHD trucks increasing from around 65 million in 2022 to around 110 million by 2050 in the two scenarios. Around 80% of the growth in demand for MHD trucking services stems from increasing transportation needs in emerging economies.
- As with light-duty vehicles, tightening regulation standards drive a shift away from the use of oil-based products towards lower carbon fuels. Increasing electrification of trucks accounts for most of this shift, with hydrogen playing a supporting role, especially for long-distance heavy-duty trucks in *Net Zero*. Natural gas, including biomethane, also accounts for an increasing share, with its use concentrated in China and developing economies including India.
- The share of oil-based products in MHD trucks' energy consumption falls from over 90% in 2022 to 60% by 2050 in *Current Trajectory* and 25% in *Net Zero*, causing oil consumption in MHD trucks to fall from 13 Mb/d in 2022 to 7 Mb/d in *Current Trajectory* and 2 Mb/d by 2050 in *Net Zero*.

Aviation and marine transportation are increasingly decarbonized through a combination of hydrogen-derived fuels and biofuels

Aviation: energy use by fuel



Marine sector energy mix



Gas includes biomethane.

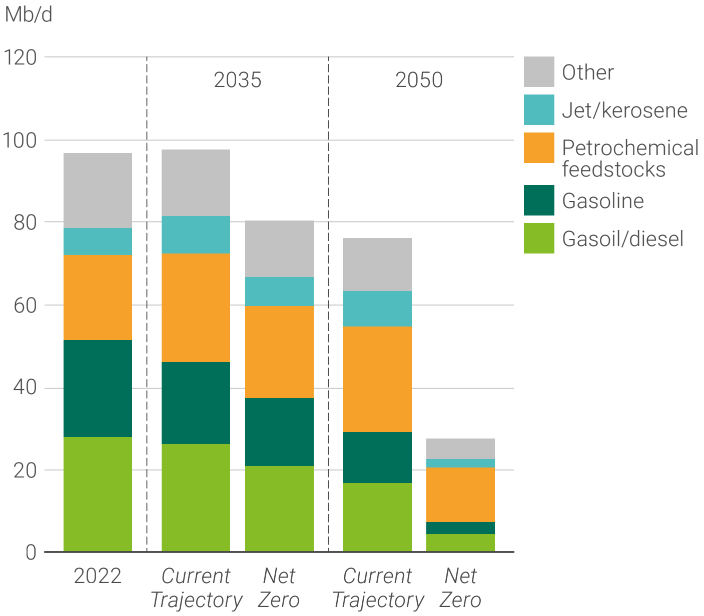
Key points

Aviation and marine transportation both increase over the outlook as global economic activity rises, with the use of oil-based products increasingly displaced by lower carbon alternatives.

- The growth in global activity, combined with the speed and convenience of flying, means the demand for air travel grows strongly over the outlook, increasing by 75% between 2025 and 2050 in *Current Trajectory*. Tightening conservation measures and changing consumer behaviour dampen this growth in *Net Zero*, although passenger air kilometres still increase by 40% over that period.
- Continuing efficiency improvements in air travel mean that this increasing demand does not fully translate into increased energy demand, which grows by 35% between 2025 and 2050 in *Current Trajectory* and by only 10% in *Net Zero*.
- The incumbent aviation fleet and long-haul range requirements mean that liquid fuels remain the dominant energy source, with the decarbonization of aviation driven by the increasing use of liquid sustainable aviation fuel (SAF).
- In *Current Trajectory*, virtually all of this SAF is derived from bio-feedstocks, and this low carbon fuel accounts for between 5-10% of total aviation fuel by 2035 and close to 20% by 2050. Bio-derived SAF also provides most of the SAF used in the first half of the outlook in *Net Zero*. But the increased use of SAF in that scenario, combined with limitations on the availability of bio-feedstocks, means there is a growing role for hydrogen-derived SAF by 2050 in *Net Zero*.
- The growing role played by SAF is underpinned by a significant increase in production capacity, with between 15 and 30 world-scale facilities coming online every year between the 2030s and mid-2040s.
- Seaborne trade also increases over the outlook, as growth in the world economy increases the need for the shipping of goods and raw materials. Seaborne-based travel increases by 70% in *Current Trajectory* and 30% in *Net Zero* over the outlook. Total energy use grows much less quickly due to significant efficiency gains, with energy demand broadly unchanged in *Current Trajectory* and 20% lower in *Net Zero*.
- The decarbonization of the marine sector requires the transition of the fleet away from oil-based fuels to lower carbon alternatives. Over the first half of the outlook, this transition is spread across liquefied natural gas (LNG), biofuels (bio-methanol and biodiesel), and hydrogen-derived fuels (ammonia and methanol).
- Further out, the marine sector transition accelerates in both scenarios as new ships come online and the existing fleet is retrofitted, allowing alternative fuels to be adopted more quickly. Hydrogen-derived fuels and biofuels take an increasingly large share of the marine energy mix. By 2050 in *Net Zero*, the share of oil products declines to around 10%, with hydrogen-derived fuels accounting for 40% of marine energy and biofuels a further 30%.
- The growth in the use of alternative marine fuels is supported by significant development of bunkering facilities, including fuel storage and refuelling barges.

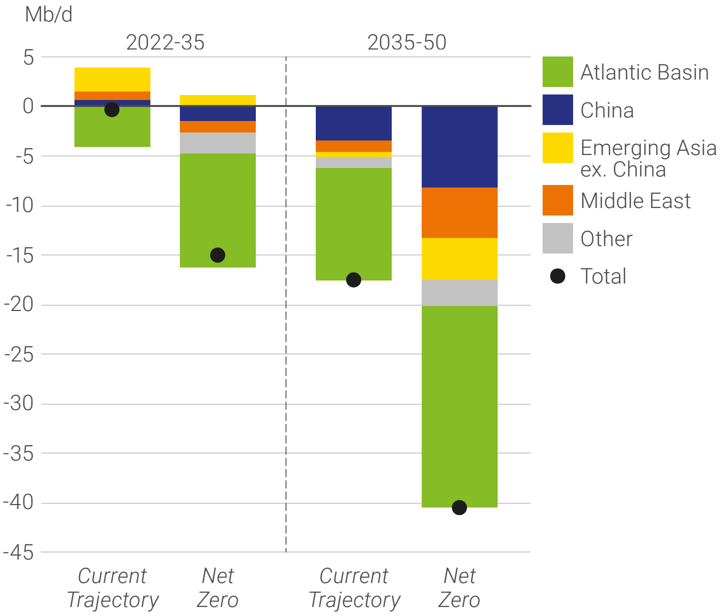
Falls in oil demand are reflected in shifting patterns of product demand and refining activity

Product demand



Product demand includes NGLs but excludes biofuels.
Petrochemical feedstocks include naphtha, LPG and ethane.

Change in refining throughput by region



Atlantic Basin includes North America, the Caribbean, Central America, South America, Europe and Eurasia.

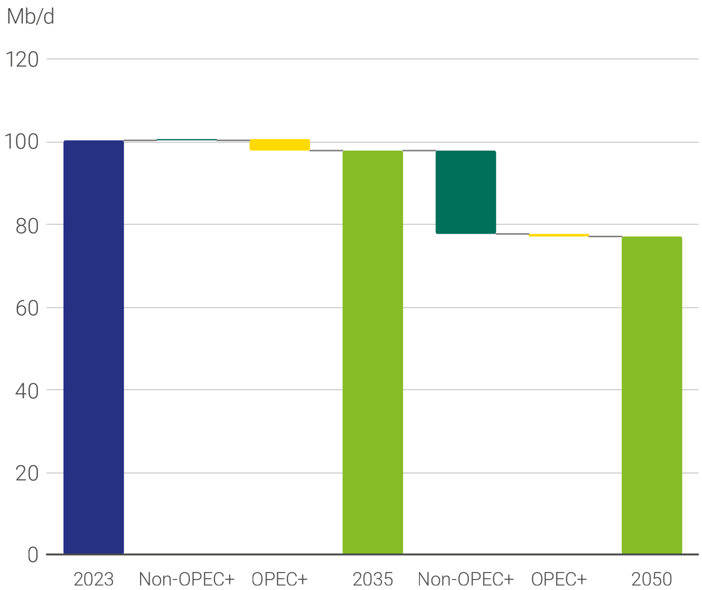
Key points

The changing level and composition of oil product demand leads to a marked rationalization in refining activity, with its global composition shifting over time.

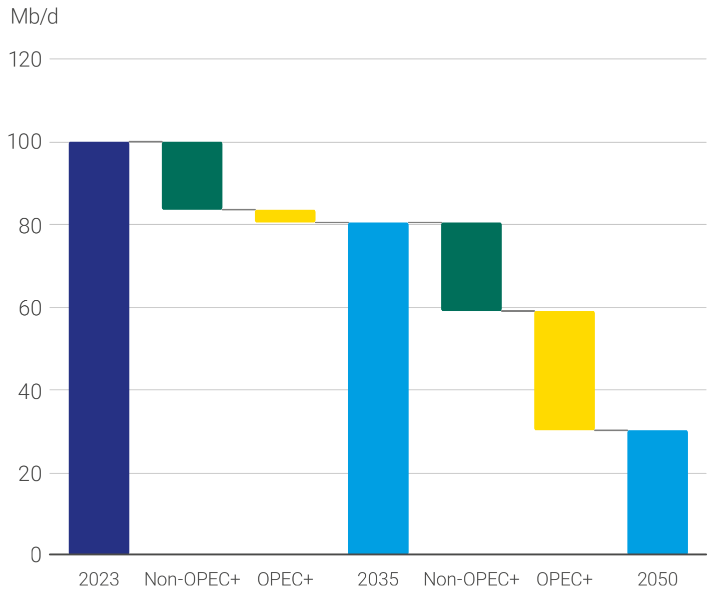
- In *Current Trajectory*, even though overall oil demand is relatively unchanged over the first half of the outlook, gasoline and diesel demand both decline as the use of oil in road transport falls. This is offset by increasing demand for petrochemical feedstocks (naphtha, ethane and LPG) and jet fuel.
- The fall in oil consumption in the second half of the outlook continues to be driven by gasoline and diesel, both of which decline by more than a third post-2035, with these falls centred in North America, the EU and China.
- Similar to *Current Trajectory*, the large and sustained falls in oil demand in *Net Zero* are most pronounced in diesel and gasoline, both of which decline by over 20 Mb/d over the outlook. But the demand for petrochemical feedstocks also declines as the world limits its use of plastics and other manufactured materials. The falls in product demand are spread more evenly across the globe than in *Current Trajectory*, with declines in all of the main regional demand centres.
- The pressure on the refining sector is compounded by the increasing use of natural gas liquids (NGLs) and biofuels. This is especially the case in *Net Zero*, where the share of these non-refined products in total liquids consumption increases to almost 30%, from around 15% in 2022.
- The falls in aggregate product demand, together with the shifting mix of products and changing geographical composition, lead to marked changes in the level and geographical spread of refining activity.
- Refineries adapt in different ways to increase their resilience to the changing scale and mix of product demand, including enhancing their yield flexibility, co-processing bio feedstocks, and reducing the carbon intensity of their process heat and hydrogen inputs. The ability of refineries to adapt successfully depends on their geographical exposure to the falls in demand, their existing configurations, and the local conditions and policies in which they operate.
- In *Current Trajectory*, the 20% fall in refining throughput over the outlook is concentrated in the Atlantic Basin, where combined throughput declines by 40%, as the weight of refining activity shifts to the more resilient centres of product demand in emerging Asian economies, including China, India, and the Middle East. Rationalization of refining activity in the Atlantic Basin roughly offsets growth in the Eastern hemisphere in the first half of the outlook in *Current Trajectory*, and accounts for almost two-thirds of the decline post-2035.
- The sharper falls in refining throughput are more geographically dispersed in *Net Zero*, mirroring the broader-based declines in product demand. The Atlantic Basin still accounts for around 60% of the fall in global refining runs over the outlook, with notable falls also in China, other parts of emerging Asia and the Middle East.

The pattern of global oil supplies shifts as oil demand declines

Change in oil supply in *Current Trajectory*



Change in oil supply in *Net Zero*



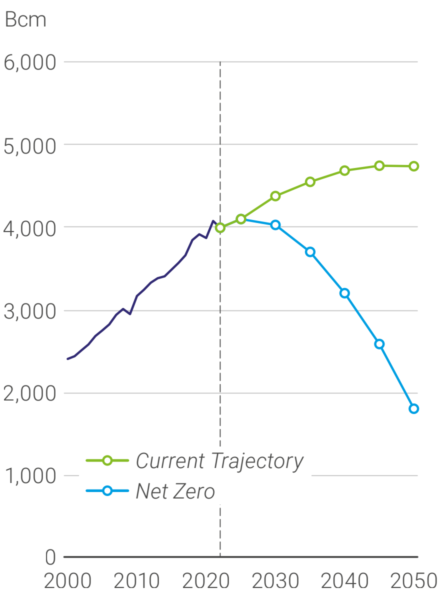
Key points

The composition of global oil production changes over time, with the impact of falling oil demand borne largely by non-OPEC+ producers.

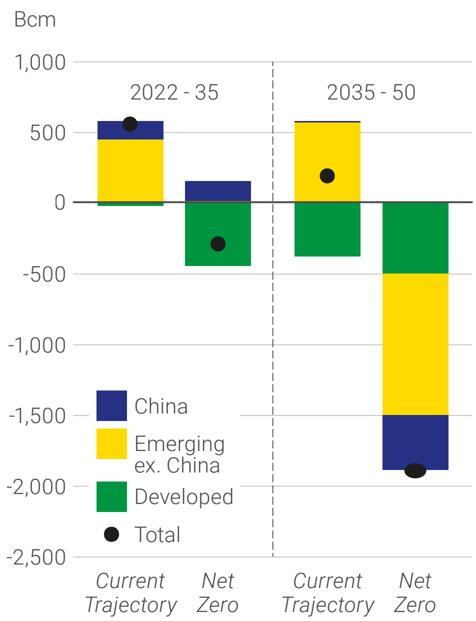
- In *Current Trajectory*, aggregate oil demand and production are little changed over the first half of the outlook. That is also largely the case for the mix between non-OPEC+ and OPEC+ supplies, with OPEC+'s share of global oil supplies remaining around 50%.
- The makeup of non-OPEC+ output, however, does change out to 2035. US tight oil increases further in the near term, before peaking towards the end of this decade at around 16 Mb/d and gradually declining thereafter as the most advantaged sites begin to be exhausted. As the growth in US tight oil slows over the next decade, non-OPEC+ supply is augmented by robust production in Brazil and Guyana, where output reaches around 5 Mb/d and 1.5 Mb/d respectively during the mid-2030s.
- The combination of relatively flat demand and resilient non-OPEC+ output means there is little scope for OPEC+ to increase its levels of production over the first half of the outlook in *Current Trajectory*.
- The decline in oil demand in the second half of the outlook in *Current Trajectory* is assumed to prompt OPEC+ to increase its share to a little over 60% by 2050. As a result, almost all of the decline in oil demand post-2035 in *Current Trajectory* is borne by non-OPEC+ producers, with US tight oil halving from its peak level to around 8 Mb/d by 2050.
- The earlier and deeper fall in oil demand in *Net Zero* leads to sustained falls in both non-OPEC+ and OPEC+ output. The higher cost structure of non-OPEC+ production, together with the assumption that OPEC+ competes to maximise its share of diminishing global oil production, means that lower non-OPEC+ production accounts for around 55% of the total reduction in global oil supplies.

The outlook for natural gas demand depends on the speed of the energy transition

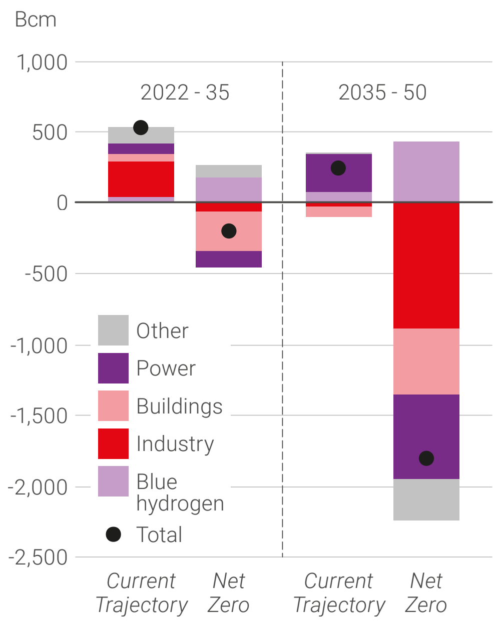
Natural gas demand



Change in natural gas demand by region



Change in natural gas demand by sector



Key points

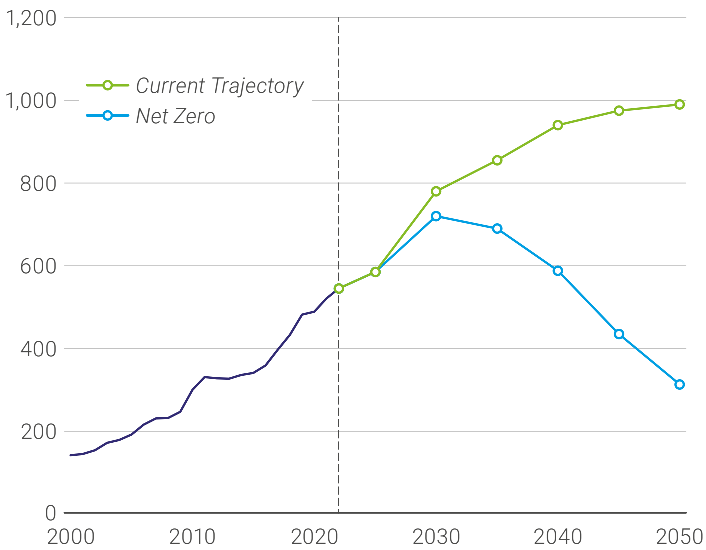
The prospects for natural gas are shaped by two significant but opposing trends: increasing demand in emerging economies as they grow and industrialize, offset by a shift away from natural gas to greater electrification and lower carbon fuels as the world decarbonizes. The net impact of these two opposing forces depends on the speed of the energy transition.

- In *Current Trajectory*, natural gas demand grows throughout the outlook, expanding by around a fifth by 2050, with its share of primary energy increasing to a little over 25%. In contrast, natural gas demand peaks around the turn of this decade in *Net Zero* and by 2050 is around half of its 2022 level.
- These contrasting outlooks reflect the impact of two competing trends.
- The dominant trend in *Current Trajectory* is the increasing use of natural gas in emerging economies (excluding China) which rises by a little over 50% by 2050, more than accounting for the entire growth in global gas demand over the outlook. The rise in emerging economies' gas consumption is driven by increasing use in the power and industrial sectors as these economies grow and industrialize.
- Growth in global gas demand is also boosted by increasing consumption in China, again driven largely by increasing use within the industrial and power sectors. Chinese gas demand broadly plateaus in the 2040s, and by 2050 is around a third higher than its level in 2022.
- Natural gas demand in developed economies is broadly unchanged over the first part of the outlook in *Current Trajectory*, as declining use in buildings is offset by gains in transport, industry and its use as a feedstock to produce blue hydrogen. Natural gas used in the power sector declines only marginally as it supports the continued displacement of coal generation alongside growth in renewables.
- However, in the second half of the outlook, the use of natural gas in developed economies falls by over 20%, reflecting a pronounced shift towards electrification and lower carbon energy sources in the power, industrial and buildings sectors.
- In contrast, in *Net Zero* this shift to alternative energy sources in developed economies happens earlier and with greater force. Natural gas demand in these markets peaks during the 2020s and by 2050 is over 55% below its 2022 level. These falls are driven by a combination of greater energy efficiency, increased electrification of buildings and light industry (supported by the increasing use of heat pumps), and the growing use of other low carbon energy sources in heavy industry.
- Natural gas demand in emerging economies continues to rise over the first part of the outlook. But the shift to greater electrification and lower carbon fuels subsequently drives a broad-based decline in gas usage, with demand peaking in the early-2030s. By 2050 gas consumption in emerging economies is down over 50% from 2022 levels.
- In *Net Zero* around 80% of natural gas consumption is abated with CCUS by 2050, mainly in the industrial and power sectors and in the production of blue hydrogen (see pages 68-69).

LNG demand depends on gas consumption in Europe and Asia, which are reliant on LNG imports for supplies of gas

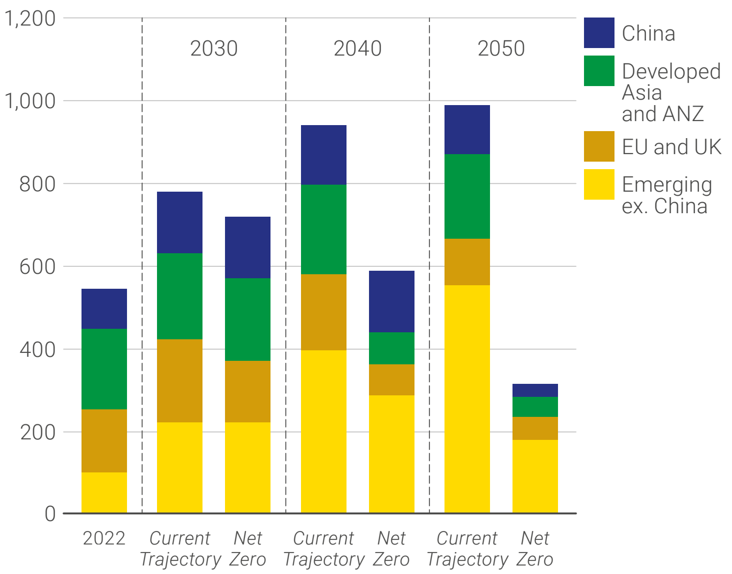
LNG traded volume

Bcm



LNG imports by region

Bcm



Includes all global LNG imports. Developed Asia comprises developed economies in Asia, and is dominated by Japan, South Korea and Singapore.

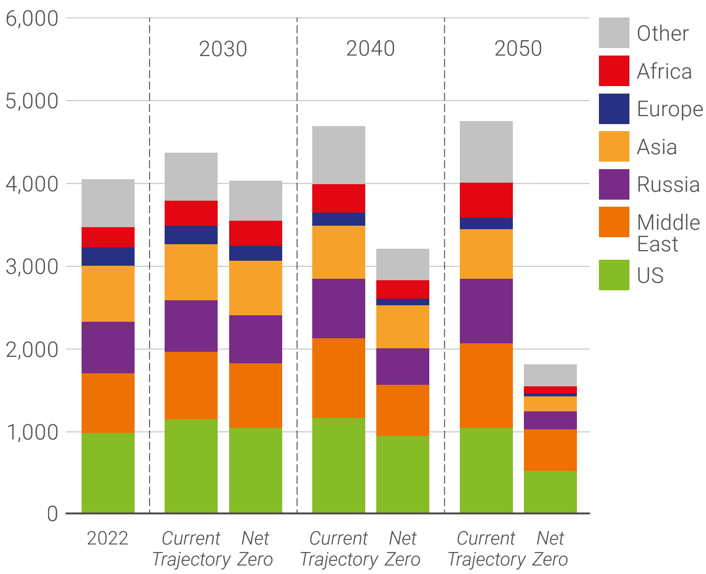
Key points

LNG demand increases rapidly in the near term, but the outlook post-2030 becomes increasingly dependent on the pace of the transition, especially in Europe and Asia, which rely on LNG imports to meet their incremental natural gas demand.

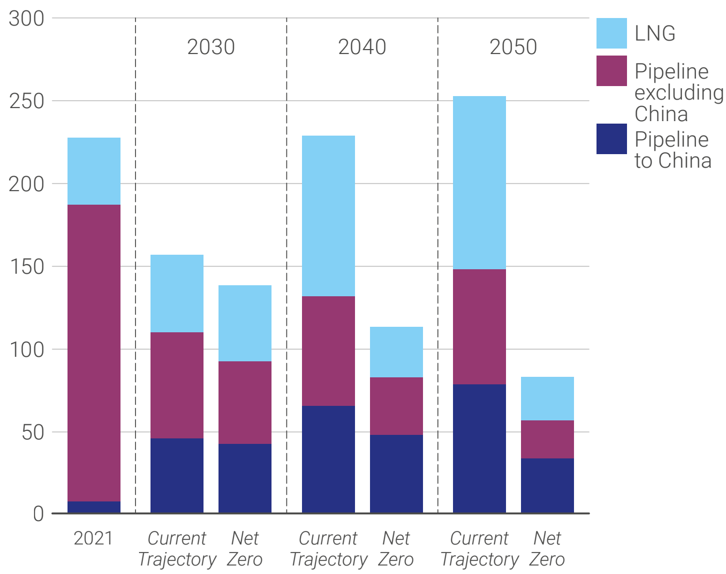
- LNG demand grows robustly in the first part of the outlook, driven by increasing demand in emerging economies including China, as the increasing use of natural gas in these economies is largely met by imported LNG. By 2030, LNG demand is 40% and 30% above 2022 levels in *Current Trajectory* and *Net Zero* respectively.
- The main difference between the two scenarios out to 2030 reflects contrasting trends in the EU and UK. In *Current Trajectory*, LNG demand in the EU and UK increases out to 2030 as they continue to adjust to the loss of Russian pipeline imports. In contrast, in *Net Zero* a greater shift to alternative energy sources combined with faster gains in energy efficiency means that by 2030, EU and UK LNG demand is below 2022 levels, although still above levels in 2021 prior to the war in Ukraine.
- The range of outcomes for LNG trade widens post-2030. In *Current Trajectory*, LNG demand increases by more than 25% over the subsequent 20 years. This demand growth requires 300 Bcma of additional liquefaction capacity to come online post-2030. In contrast, the gains in LNG demand out to 2030 in *Net Zero* are reversed over the following decade, and by 2050 global trade in LNG is around 40% below its 2022 level, implying that no additional liquefaction capacity beyond that already under construction is required.
- This widening range of outcomes adds to the uncertainty associated with investments in LNG facilities, which typically have an economic life of 15-20 years.
- The growth of LNG demand after 2030 in *Current Trajectory* is driven entirely by continuing strong growth in emerging economies (excluding China), with India accounting for a third of this increase. The overall growth in global LNG trade is tempered by falling demand in Europe as the region transitions away from natural gas, and in China where growth in pipeline supplies from Russia reduces the need for LNG imports.
- LNG demand in emerging economies in *Net Zero* also continues to grow during the 2030s before peaking towards the end of the decade, but this growth is more than offset by sharp falls across the main demand centres in Europe and developed Asian economies, as the use of gas in these economies is crowded out by increasing electrification and a shift towards lower carbon energy sources.

The global pattern of natural gas production is increasingly driven by developments in LNG trade

Natural gas production by region



Russian natural gas exports

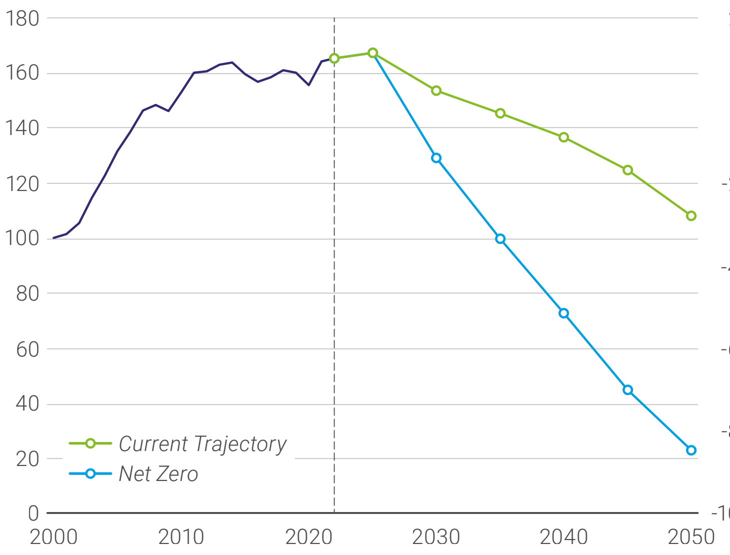


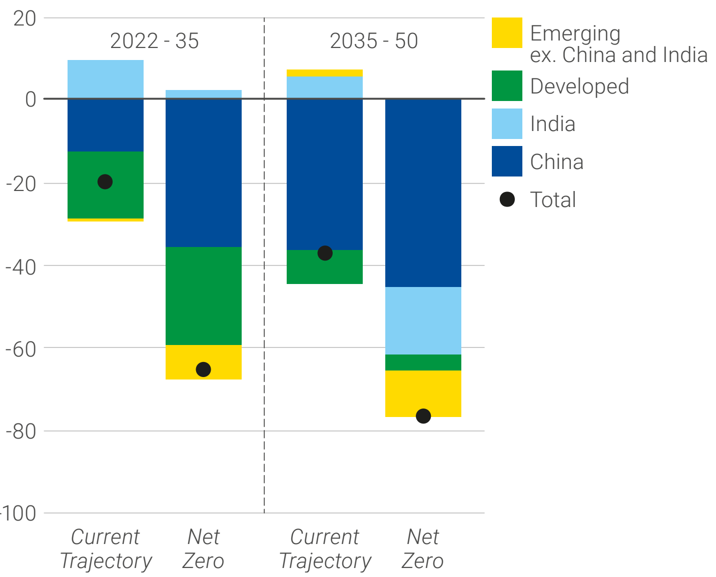
Key points

Global natural gas production is driven initially by the need to support increasing demand for LNG exports, with the US and the Middle East gaining share relative to Russia. Further out, the pattern of global supply increasingly depends on the speed of the energy transition.

- The growth in US and Middle East gas production seen in recent years continues over the remainder of the 2020s, mainly due to its pivotal role in LNG exports. In *Current Trajectory*, 80% of the growth in global natural gas production comes from these two regions, with about three-quarters of this production growth used for LNG exports. In *Net Zero*, production grows in these two regions even as it declines in the rest of the world, mainly due to growth in LNG exports offsetting declines in domestic consumption. In contrast, Russian production largely stagnates as the impact of the war in Ukraine and continuing international sanctions limit growth in domestic demand and stall any expansion in LNG exports.
- The outlook for global gas production post-2030 depends on the speed of the energy transition.
- In *Current Trajectory*, global gas supplies continue to grow post-2030, meeting the increasing demand in emerging economies. The growth in gas production is led by the Middle East, Africa and Russia as the impact of international sanctions gradually fades. US gas production peaks in the mid-2030s and declines modestly thereafter as reductions in domestic demand outweigh continued growth of LNG exports.
- In contrast, in *Net Zero* global gas production declines by around 55% in the final 20 years of the outlook as demand in the world's major gas consuming centres declines. The majority of the reduction in gas demand is borne by the US, the Middle East and Russia, which account for almost half of the decline in global gas production. Gas production in Asia declines by almost three-quarters, driven by falling production in China and Southeast Asia.
- In 2030 Russian gas exports are between 30-40% below pre-war levels in *Current Trajectory* and *Net Zero*. The sharp drop in pipeline exports to Europe following the outbreak of the war in Ukraine is sustained and international sanctions limit any expansion in LNG exports. The loss of exports to Europe is only partially offset by increases in pipeline exports to China via the existing Power of Siberia pipeline and a new Far East line commencing later this decade.
- The scope for Russian gas exports to recover post-2030 depends on the speed of the transition. In *Current Trajectory*, the gradual expansion of LNG exports as the impact of international sanctions fades, combined with the growth of pipeline exports to countries outside of Europe, especially China following the commissioning of Power of Siberia 2 from the mid-2030s, means Russian gas exports grow to a little above pre-Ukraine war levels by 2050. In contrast, the accelerating shift away from natural gas as the energy transition gathers pace in *Net Zero* means Russian gas exports never recover, with further declines in both pipeline and LNG exports.

The role of coal in the global energy system declines, driven by China





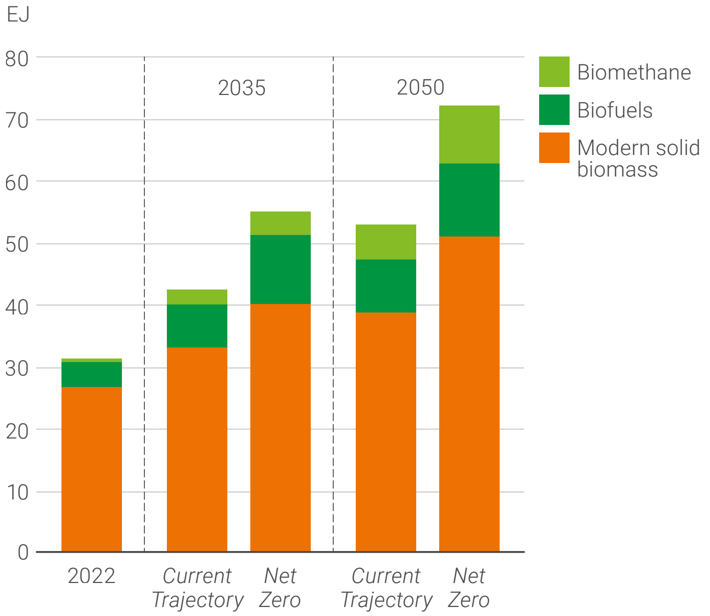
Key points

Global coal consumption peaks in the mid-2020s and then declines steadily throughout the remainder of the outlook.

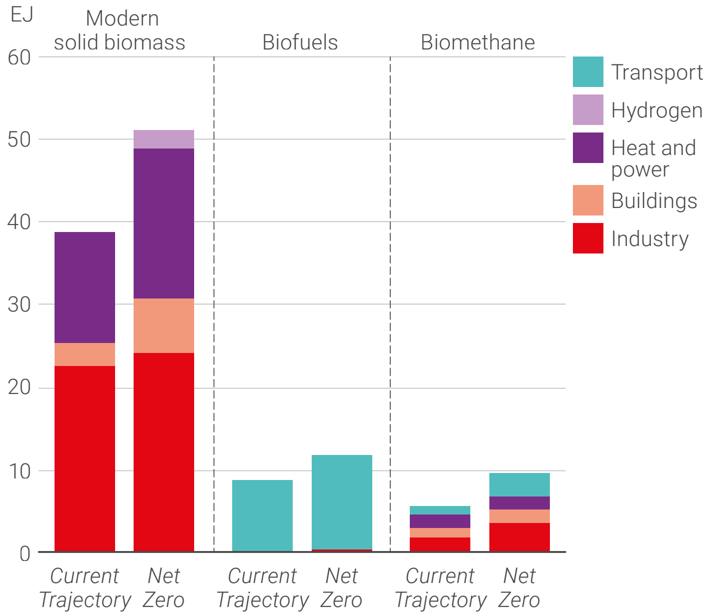
- The diminishing role of coal in global energy is most pronounced in *Net Zero*, with consumption falling by around 85% by 2050 and the share of coal in primary energy declining from 28% in 2022 to only around 5%. The decline in coal use is less pronounced in *Current Trajectory*, with consumption declining by a little over a third and still providing around 17% of the world's energy needs in 2050.
- The global fall in coal consumption is dominated by China as its economic growth slows and it transitions to a lower carbon fuel mix. Chinese coal consumption peaks before 2030 and falls thereafter: this decline accounts for almost 90% of the reduction in global coal consumption by 2050 in *Current Trajectory*, and around 60% in *Net Zero*.
- The smaller fall in coal consumption in *Current Trajectory* partly reflects continued increases in coal consumption in India and other emerging economies to help meet the rapid expansion of domestic energy demands, especially for electricity use. Despite India's wind and solar power generation increasing 15-fold in *Current Trajectory*, coal consumption nonetheless increases by 75% to help meet rising energy demands, with two-thirds of that increase deployed in the power sector.
- The declining use of coal globally is concentrated in the power sector as coal is displaced by rapid growth in wind and solar power. The use of coal within industry also declines, especially in *Net Zero*, as industrial processes increasingly electrify or switch to other lower carbon alternatives such as low carbon hydrogen (see pages 60-61).
- In *Net Zero*, around three-quarters of the remaining use of coal in 2050 is used in conjunction with CCUS, concentrated in industry and the power sector.

Modern bioenergy increases rapidly, helping to decarbonize sectors and processes which are hard to electrify

Modern bioenergy by type



Modern bioenergy demand in 2050



Key points

The use of modern bioenergy – modern solid biomass, biofuels and biomethane – increases significantly over the outlook, providing a source of low carbon energy to help decarbonize sectors and processes that are hard to electrify.

- Modern bioenergy use increases by around two-thirds by 2050 in *Current Trajectory* and more than doubles in *Net Zero* to a little over 70 EJ by 2050. This expansion is achieved without any increase in land use, with most of the modern bioenergy sourced regionally from residues and wastes.
- In *Net Zero*, the increase in the total use of bioenergy is partially offset by the declining role of traditional biomass, which is currently predominantly used for cooking and heating in Africa and some parts of Asia. The use of traditional biomass is almost eliminated by 2050 in *Net Zero*. Less progress is made in reducing reliance on traditional biomass in *Current Trajectory* – total consumption falls by only around 5%, as the impact of rising populations offsets average per person use falling by around a quarter.
- The largest source of growth of modern bioenergy is solid biomass (such as wood pellets, and forest and agricultural residues), which increases from a little over 25 EJ in 2022 to between 40 and 50 EJ by 2050 in the two scenarios, used mainly in the industrial and power sectors.
- In industry, solid biomass is used as a low carbon alternative to coal and natural gas to fuel high-temperature heat processes, especially in cement and steel manufacturing. It is also used in a range of other industrial sectors where the source of the biomass is closely connected to the industrial process, such as in food or paper production.
- In the power sector, biomass is used as an alternative to traditional forms of thermal power, especially coal and natural gas. Within emerging economies, biomass is predominantly used in new biomass cogeneration plants that produce heat and power, and in co-firing plants together with coal. The use of biomass in the power sector can be combined with CCS to provide a source of carbon dioxide removal (BECCS) (see pages 68-69). The use of BECCS is most pronounced in *Net Zero*, reaching around 1 $GtCO_2e$ in 2050, of which around 50% is deployed in the power sector.
- The demand for biofuels expands rapidly over the first half of the outlook, increasing by around 60% in *Current Trajectory* and almost tripling in *Net Zero*. This growth is driven by increasing use in transport in China and emerging economies as well as in the EU and US, supported by government policies to boost biofuel use. The pace of growth slows in the second half of the outlook as increasing electrification of road transport reduces the role of biofuels, with much of the additional growth in the second half of the outlook coming from use in aviation and marine (see pages 34-35).
- Biomethane grows rapidly over the outlook, blended into the natural gas grid or fed into industrial sites as a direct substitute for natural gas. By 2050 biomethane comprises around 3% of total gas volumes in *Current Trajectory* and around 15% in *Net Zero*, compared with less than 1% in 2022. This growth is supported by increasing blending mandates, especially in *Net Zero*, where average blending rates are above 35% in many regions, including the US and EU.

Power sector

Electricity demand grows significantly, as prosperity in emerging economies rises and the world increasingly electrifies

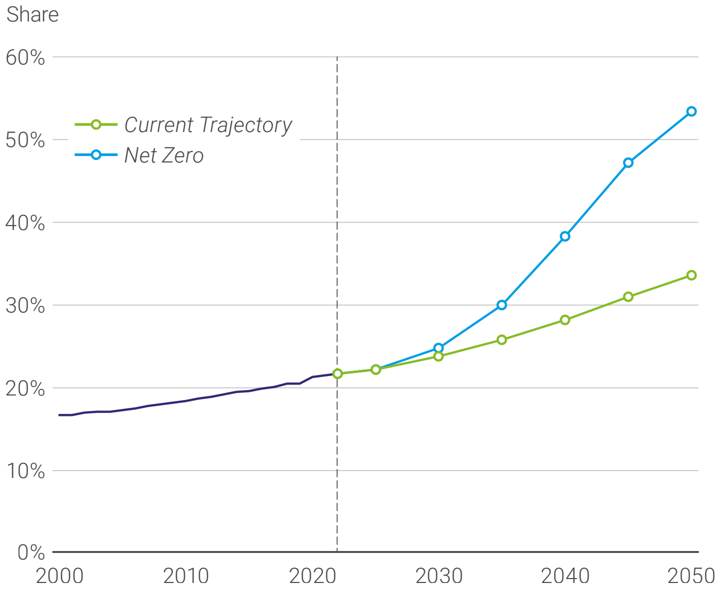
Growth in power generation is dominated by a massive expansion of wind and solar power

Rapid growth in wind and solar power is underpinned by further cost reductions and an acceleration in the deployment of new capacity

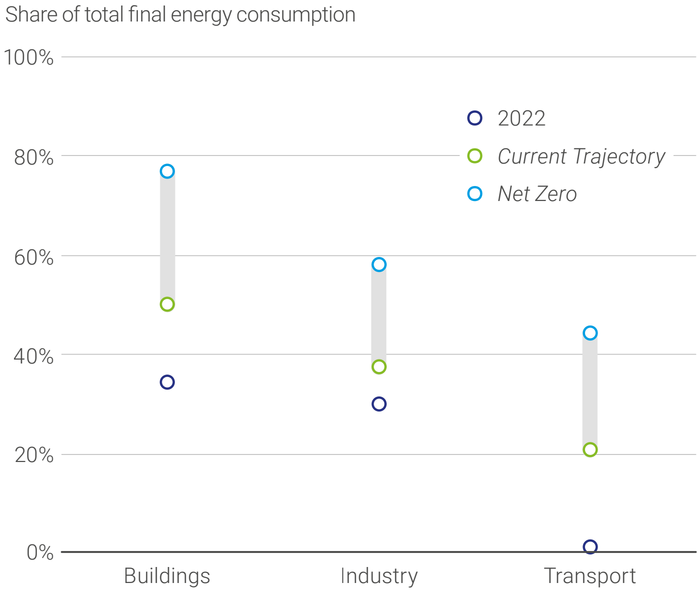
Power systems need to be resilient to the increasing variability associated with the growing dominance of wind and solar

Electricity demand grows significantly, as prosperity in emerging economies rises and the world increasingly electrifies

Electricity as a share of total final energy consumption



Range of electrification across end-use sectors in 2050



Key points

Electricity demand grows robustly over the outlook, driven by improving living standards in emerging economies and by increasing electrification of the global energy system.

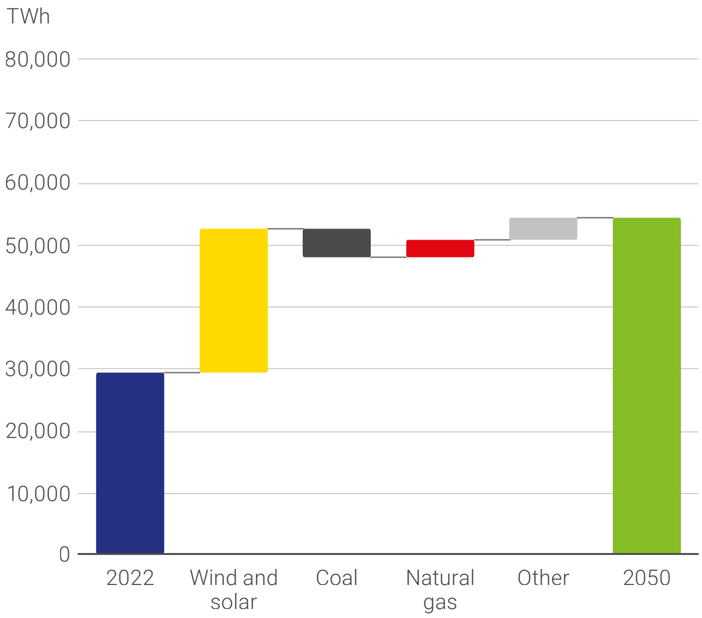
- Final electricity demand increases by around 75% by 2050 in *Current Trajectory* and by 90% in *Net Zero*. Most of this growth – around four-fifths in each scenario – is driven by increasing demand in emerging economies, as rising prosperity improves access to electricity and enables the growing adoption of electrical appliances.
- India is the fastest-growing electricity market over the outlook, with electricity consumption roughly doubling by 2035 and more than tripling by 2050 in both scenarios. In doing so, India overtakes the EU as the third largest power market globally by 2035 in *Net Zero* and 2040 in *Current Trajectory*, behind only China and the US. Despite that, electricity consumption per capita in India in 2050 in both scenarios is still less than half of that in the EU.
- Electricity consumption in developed economies accelerates, growing at an annual average rate of around 1.5% in the two scenarios, around three times faster than that seen over the past 20 years. This acceleration is underpinned by the increasing electrification of existing uses of energy and by the growing importance of new sources of demand, including rising demand from data centres to support the growing use of artificial intelligence applications.

Even so, the average pace of growth of electricity in developed economies in *Net Zero* is roughly half that in emerging economies.

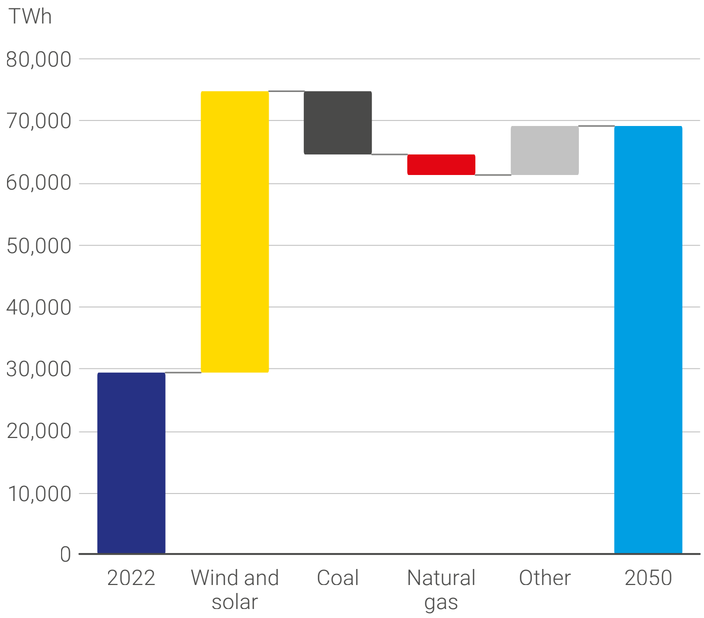
- The share of electricity in the world's total final consumption (TFC) of energy increases from a little over 20% in 2022 to around 35% by 2050 in *Current Trajectory* and to more than 50% in *Net Zero*.
- The increasing electrification of the energy system is apparent across all end-use sectors.
- The greatest scope for electrification is in buildings, where between half and three-quarters of final energy demand is electrified by 2050, up from around a third of energy use in 2022. The higher level of electrification in *Net Zero* is driven by the greater adoption of heat pumps for space heating and more extensive phaseout of inefficient traditional biomass in emerging economies.
- Considerable scope exists to further electrify the industrial sector. The range of outcomes in 2050 – with 40% and 60% of the industrial sector electrified in *Current Trajectory* and *Net Zero* respectively – largely reflects differences in the degree of policy pressure and incentives to decarbonize industrial processes rather than technical constraints.
- The transport sector has the largest increase in the share of electrification relative to its current low level, as road transportation is increasingly electrified. However, the difficulty of electrifying long-distance transportation, including in aviation and marine, means the degree of electrification of transport in 2050 is less than in other end-use sectors.

Growth in power generation is dominated by a massive expansion of wind and solar power

Electricity generation by source in *Current Trajectory*



Electricity generation by source in *Net Zero*



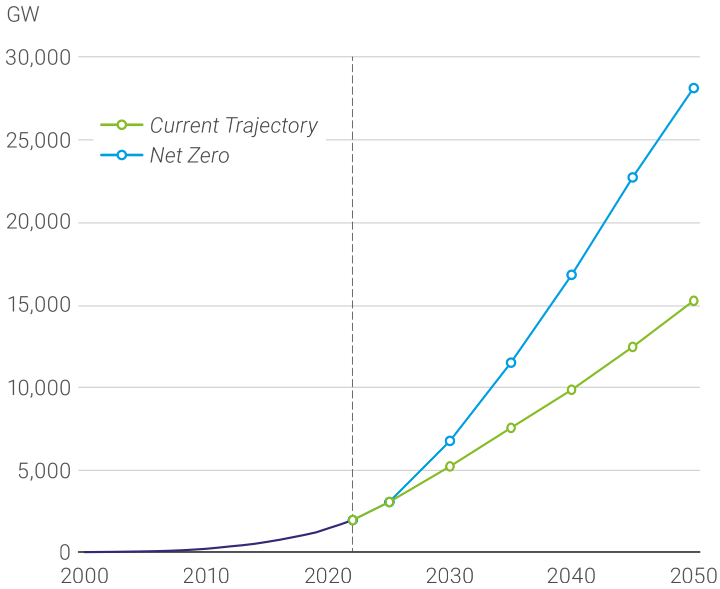
Key points

The increase in power generation is broadly matched by a surge in wind and solar power, helping to decarbonize the global power system.

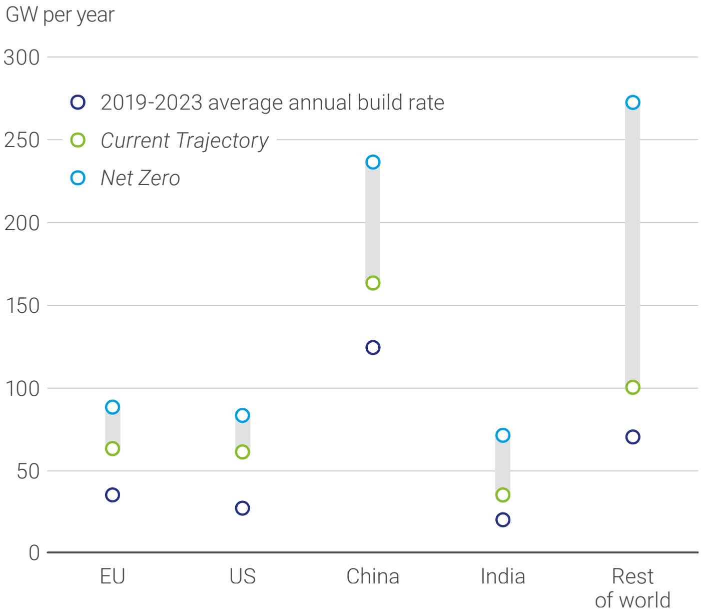
- In *Current Trajectory*, the increase in total power generation of almost 25,000 TWh is largely matched by a roughly eight-fold increase in wind and solar power of 23,000 TWh (see pages 56-57 for more details on the growth in wind and solar power).
- Global coal-fired generation falls by around 40% out to 2050 in *Current Trajectory*, reflecting a broad-based decline across most regions of the world, the main exceptions being India and emerging Asia. Coal generation in India increases by over 90% by 2050, driven by the need to meet rapid growth in electricity demand.
- In contrast to the decline in global coal generation, gas-fired generation increases by more than 40% by 2050 in *Current Trajectory*, led by strong growth in emerging Asia, where it roughly triples by 2050.
- By 2050, coal and natural gas combined account for close to a third of global power generation in *Current Trajectory*.
- Other sources of low carbon power generation continue to play a significant role in *Current Trajectory*. The share of global power generation from nuclear and hydropower increases slightly to reach 20% by 2050. Meanwhile, generation from bioenergy and geothermal power gradually grows in scale, while remaining a very small proportion of total power generation.
- The increase in total power generation is even greater in *Net Zero*, with a rise of almost 40,000 TWh out to 2050, of which around 30% (11,500 TWh) is used to produce green hydrogen (see pages 62-63). The total growth in generation is more than matched by a huge expansion in wind and solar power, which increases by around 45,000 TWh – a 14-fold increase relative to 2022 levels.
- The surge in wind and solar power pushes out coal and natural gas from the global power sector. Coal generation is the biggest casualty, falling by over 90% by 2050, with its share in global power declining from close to 40% in 2022 to around 1% in 2050.
- Gas-fired generation is a little more resilient, but its share in global power markets nonetheless falls by around 18 percentage points over the outlook, to close to 5% by 2050. The somewhat greater resilience of natural gas is helped by three quarters of gas-fired generation by 2050 being produced in conjunction with CCUS. The technologies helping to balance the power sector as it increasingly decarbonizes over the outlook are discussed in pages 58-59.
- Other sources of low carbon power also grow significantly, with nuclear energy more than doubling by 2050 and hydropower growing by around three-quarters. The growth of new nuclear power takes place almost entirely in emerging economies – led by China – with developed economies mainly extending the life of existing reactors or replacing decommissioned capacity. By 2050, nuclear and hydropower together account for close to 20% of total power generation in *Net Zero*.
- The massive expansion in wind and solar power, supported by increases in other sources of low carbon power, leads to a significant decarbonization of the power sector. The average carbon intensity of power generation in *Current Trajectory* declines by just over 60% over the outlook. In *Net Zero*, the almost complete elimination of unabated fossil fuel emissions combined with the deployment of bioenergy used with CCUS (BECCS) results in the power sector being a source of negative emissions by 2050.

Rapid growth in wind and solar power is underpinned by further cost reductions and an acceleration in the deployment of new capacity

Installed wind and solar capacity



Wind and solar capacity: average annual build rates (2024-2035)



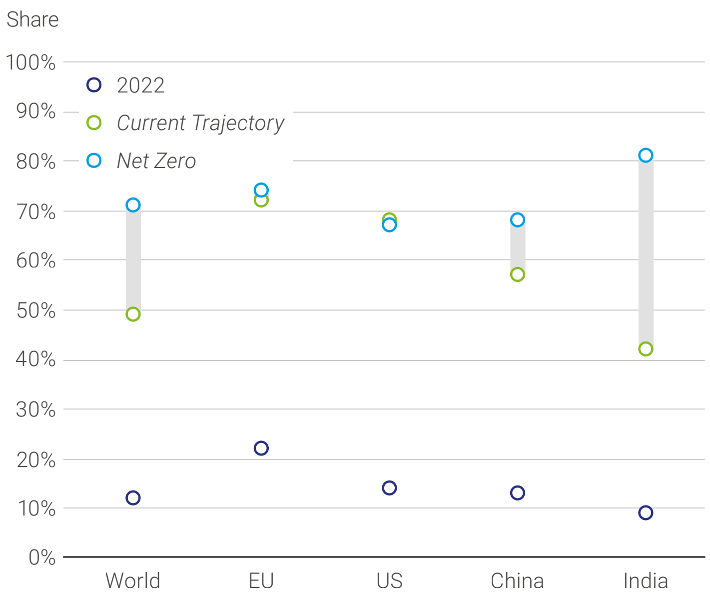
Key points

The rapid growth in wind and solar power is underpinned by further gains in cost competitiveness and by the successful scaling of a number of enabling factors that enable a sharp acceleration in the deployment of new wind and solar capacity.

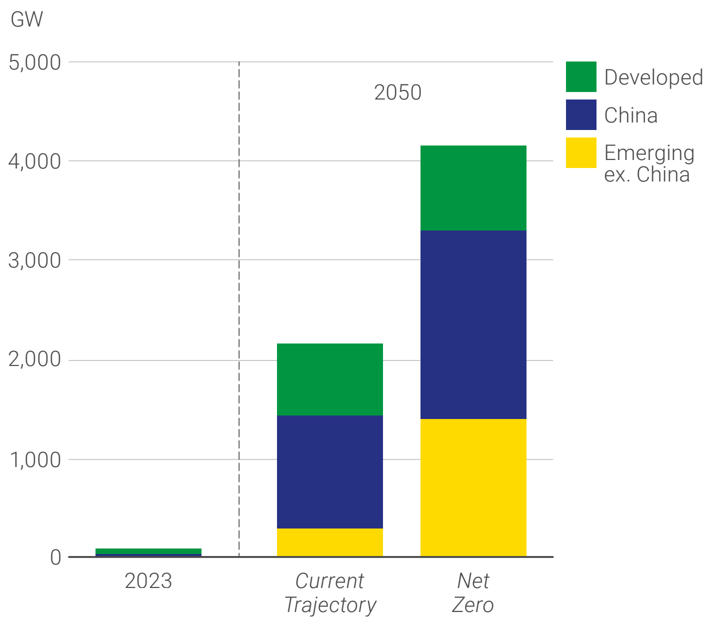
- Wind and solar capacity increases around eight-fold by 2050 in *Current Trajectory* and by a factor of 14 in *Net Zero*.
- Over the first half of the outlook, this buildout of new capacity is concentrated in China and developed economies, each of which account for around 30-45% of the increase in new capacity across the two scenarios.
- Emerging economies other than China play an increasing role in the second half of the outlook, helped by improving access to finance, increased investment in transmission and distribution networks, and more robust regulatory frameworks. Beyond 2035, these economies account for close to a third of the total buildout of new wind and solar capacity in *Current Trajectory* and over 60% in *Net Zero*, with China accounting for an additional 35% and 25% in the two scenarios respectively.
- The rapid expansion in wind and solar power is underpinned by further cost declines as technology and energy production costs continue to benefit from ever-increasing deployment levels. Solar costs are further reduced by increasing module efficiency, load factors and project scales. Likewise, the declines in wind power costs are helped by increasingly large turbines and lower operating costs.
- These cost reductions are most pronounced over the first 10-15 years of the outlook. Further out, the pace of reductions slows and costs eventually plateau as falling generation costs are offset by the growing expense of balancing systems with increasing shares of variable energy sources (see page 56-57).
- The expansion in installed capacity requires a significant increase in the pace at which new capacity is financed and built. The annual additions of installed wind and solar capacity out to 2035 average between 400-800 GW per year in *Current Trajectory* and *Net Zero*, which is around 1.5-3 times faster than the average pace of additions seen in recent years, respectively.
- In addition to a significant increase in investment (see pages 72-73), the rapid acceleration in the deployment of wind and solar capacity in both scenarios depends on a number of enabling factors scaling at a corresponding pace. These include the upgrade and expansion of transmission and distribution infrastructure, higher social acceptance, expanding supply- and demand-side flexibility, and increasing the speed of planning and permitting. Challenges around these enabling factors are a drag on even faster growth of solar and wind power in *Current Trajectory*.
- The expansion of wind and solar capacity also requires that supply chains develop and expand, safeguarding energy security by avoiding excessive dependence on individual countries and regions.

Power systems need to be resilient to the increasing variability associated with the growing dominance of wind and solar

Share of wind and solar in power generation in 2050



Stationary battery storage: installed capacity



Key points

The huge expansion in wind and solar power means power systems need to adapt to ensure they are resilient to the increasing variability of power generation.

- The share of wind and solar in global power generation increases from a little over 10% in 2022 to between 50-70% by 2050 in *Current Trajectory* and *Net Zero*. The penetration of wind and solar varies across different markets, reaching levels as high as 75-80% in the EU and India in *Net Zero*, which rely less on other forms of low carbon energy and abatement technologies such as nuclear, hydropower, and CCUS.
- The increasing penetration of wind and solar means power systems need to be resilient to the fluctuations in generation as the prevalence of wind and sunshine varies. These fluctuations can range in timescale, from the very short term (seconds to hours) to much longer (decades).
- The resilience of power systems to these types of fluctuations depends on four key elements:
- **Overbuild of wind and solar capacity:** The power generated by wind and solar capacity varies depending on the available wind and sunshine. For wind and solar to meet, on average, say 70% of power demand throughout the year, a degree of excess capacity (or overbuild) is required to ensure that sufficient wind and solar power is generated even on days with poor weather conditions.
- **Flexibility:** Power systems need the flexibility to respond to fluctuations in wind and solar power generation by modifying other forms of generation or demand. This can include the use of batteries, hydro pumped storage, interconnectors, and various mechanisms to incentivize demand to respond.
- Battery storage capacity increases to around 2,200 GW by 2050 in *Current Trajectory* and to 4,200 GW in *Net Zero*, which is two orders of magnitude greater than current levels. As more and more renewables are added, batteries that can store and generate energy for longer periods are increasingly deployed. Overall, a majority (70-80%) of the increase in battery storage capacity is concentrated in emerging economies. These markets have the greatest concentration of solar generation, and battery storage is particularly suited to responding to the typical daily variation in solar power.
- **Dispatchable capacity:** This refers to generation capacity that is contractually guaranteed to be available to produce power when it is required. Dispatchable power can include assets and technologies that also provide flexibility, such as battery storage and interconnectors.
- It also includes gas- and coal-fired power stations. As the role of wind and solar increases over the outlook, the value associated with gas- and coal-fired power stations changes from providing power for a considerable amount of the time to providing capacity backup. In *Net Zero*, coal and natural gas account for only 1% and 5% of power generation by 2050, with 75-80% of this generation produced with CCUS.
- **Long duration energy storage (LDES):** this is to mitigate variations in wind and sunshine for infrequent but pronounced episodes of renewables scarcity within a year, and also natural variations in wind and solar resources over longer periods. This is particularly important for wind-dominated energy systems, such as parts of Northern Europe and the US, that can experience relatively infrequent but significant episodes of energy scarcity. Although this need can be met by various forms of dispatchable capacity such as natural gas with CCS, it becomes increasingly expensive if these assets are utilized only infrequently.
- Low carbon hydrogen (together with hydrogen storage) can provide an alternative source of LDES. As with dispatchable thermal power, low carbon hydrogen accounts for only a small share of power generation in *Net Zero* – less than 2% in 2050 – but its value comes from the additional resilience it provides.

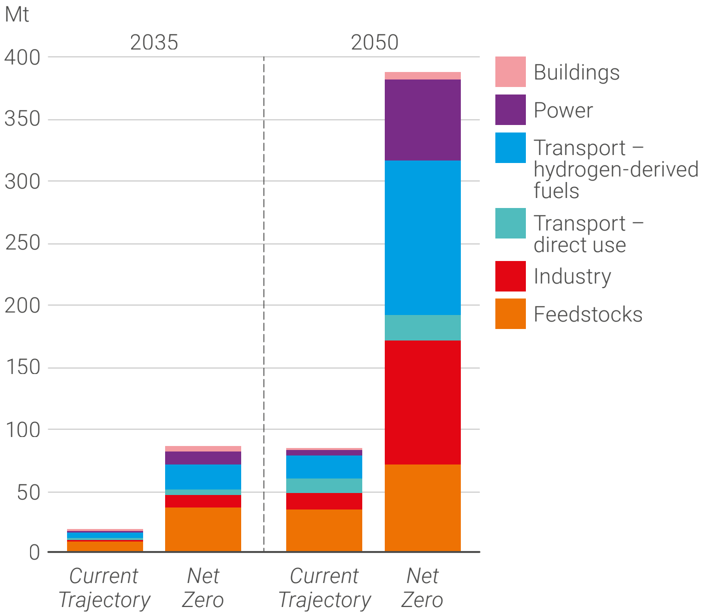
Low carbon hydrogen

The role of low carbon hydrogen depends on the speed of the energy transition

Growth of low carbon hydrogen is largely concentrated in regional markets, but with some global seaborne trade

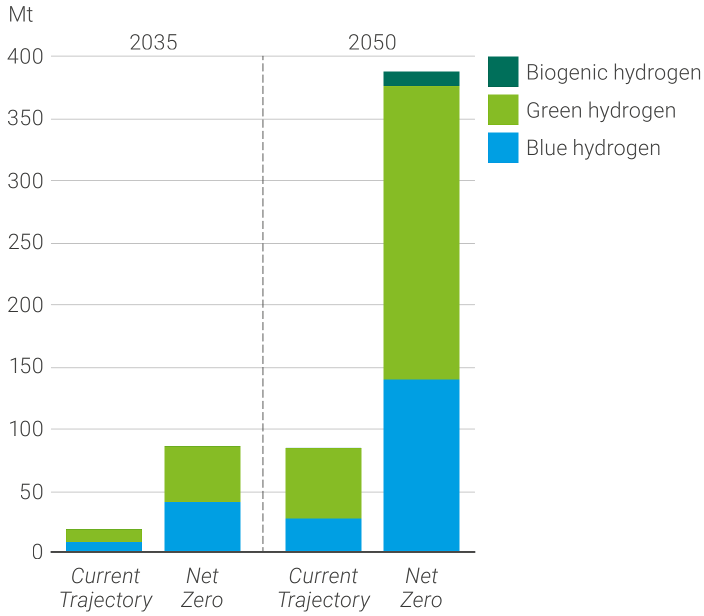
The role of low carbon hydrogen depends on the speed of the energy transition

Low carbon hydrogen demand by sector



Transport – hydrogen-derived fuels include hydrogen used to produce methanol and ammonia in marine and synthetic jet and diesel fuel.

Low carbon hydrogen supply



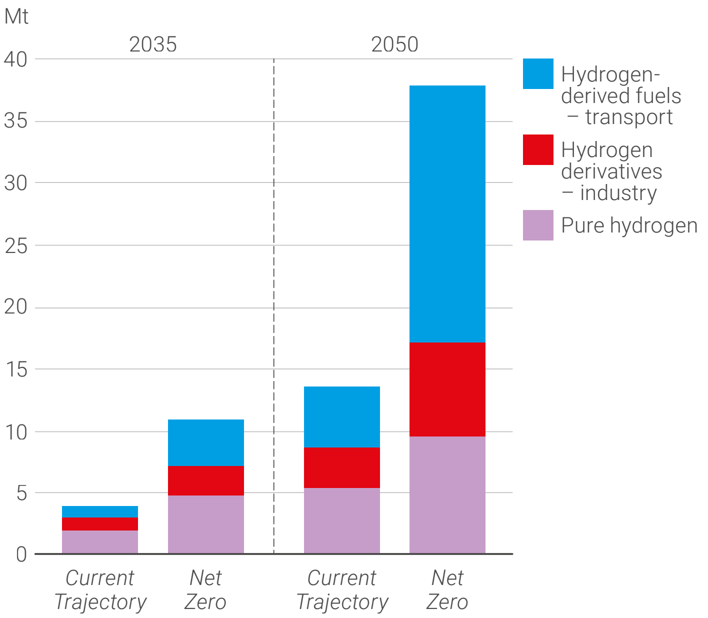
Key points

Low carbon hydrogen complements the growing electrification of the energy system through its use in processes and activities in industry and transport that are hard to electrify and as a source of long-duration energy storage in power markets. The higher cost of low carbon hydrogen relative to fossil fuel alternatives means its significance in the global energy system depends on the pace of the energy transition.

- The role of low carbon hydrogen is most pronounced in *Net Zero*, where it is supported by policies spurring a faster decarbonization pathway. Even then, much of the growth occurs in the second half of the outlook after easier-to-abate processes have been decarbonized and the cost of producing low carbon hydrogen has declined sufficiently from scaling up processes and manufacturing. The use of low carbon hydrogen grows to around 90 Mtpa by 2035 in *Net Zero* before accelerating to reach around 390 Mtpa by 2050.
- The role of low carbon hydrogen in *Current Trajectory* is more limited, increasing to a little less than 20 Mtpa by 2035 and to around 85 Mtpa by 2050.
- The initial growth of low carbon hydrogen is concentrated in its use as a feedstock in refining and in the production of ammonia and methanol for fertiliser and petrochemicals, displacing the current hydrogen feedstock produced from unabated natural gas (grey hydrogen) and coal (black or brown hydrogen). Use also grows in transport, especially in the form of hydrogen-derived fuels (ammonia and methanol) for long-distance marine transportation.
- Demand accelerates in the second half of the outlook, especially in *Net Zero*, as the importance of low carbon hydrogen as an energy source in industry and transport increases and overtakes its role as an industrial feedstock.
- In industry, hydrogen is used in iron and steelmaking as both a reducing agent and an energy source, as well as to fuel high-temperature processes in other parts of heavy industry.
- In transport, low carbon hydrogen plays an important role, alongside bioenergy feedstocks, in producing synthetic jet fuel to help decarbonize aviation, as well as hydrogen-derived marine fuels (ammonia and methanol). The production of these hydrogen-derived fuels requires carbon neutral CO_2 sources. These can be derived from either biogenic sources or from direct air capture (see pages 68-69).
- Low carbon hydrogen, together with the buildout of hydrogen storage capacity, also plays a small but important role in helping to balance power systems in some regions, accounting for around 15% of low carbon hydrogen use in *Net Zero* by 2050. (see pages 58-59).
- Low carbon hydrogen is produced primarily from a combination of green hydrogen – made via electrolysis using renewable power – and blue hydrogen – made from natural gas (and coal) with the associated carbon emissions captured and stored.
- Blue hydrogen starts with a cost advantage relative to green hydrogen and this persists in many regions over the outlook, although it diminishes over time. But the relative costs of production vary significantly across different regions depending on access to natural gas (and coal) and suitable CO_2 storage sites for blue hydrogen, and to sufficiently advantaged renewable resources for green hydrogen. Because hydrogen is costly to transport (see pages 64-65), particularly over longer distances, these relative cost and resource differences, along with policy variations, result in green hydrogen dominating in some regions while blue dominates in others.
- By 2050 around 60% of low carbon hydrogen in *Net Zero* takes the form of green hydrogen, which dominates production in both China and India. Much of the remainder is provided by blue hydrogen derived largely from natural gas, especially in the Middle East and the US, which has a significant global footprint in the production of both blue and green hydrogen.

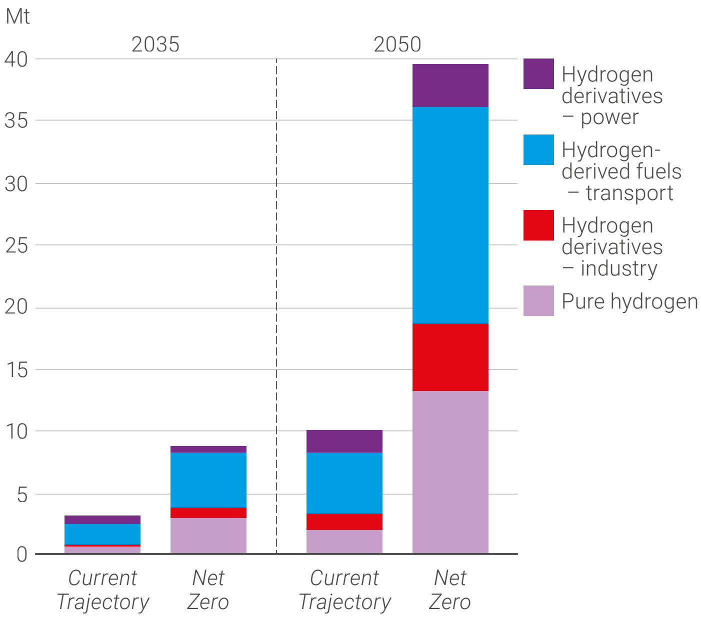
Growth of low carbon hydrogen is largely concentrated in regional markets, but with some global seaborne trade

EU low carbon hydrogen demand



Hydrogen-derived fuels - transport include hydrogen used to produce methanol and ammonia in marine and synthetic jet and diesel fuel. Hydrogen derivatives - industry include hydrogen used to produce methanol and ammonia in chemicals and direct reduced iron. Pure hydrogen includes use in refining, industry, power, buildings, and direct use in transport.

Developed Asia low carbon hydrogen demand



Developed Asia comprises developed economies in Asia and is dominated by Japan, South Korea and Singapore.

Key points

The relatively high cost of transporting hydrogen, especially in its pure form, means that trade in low carbon hydrogen is concentrated in relatively localised, regional markets. But some global trade develops over the outlook, including to the key importing regions of the EU and developed Asian economies, dominated by Japan, South Korea and Singapore, with the major exporting regions including the US, the Middle East, and Australia.

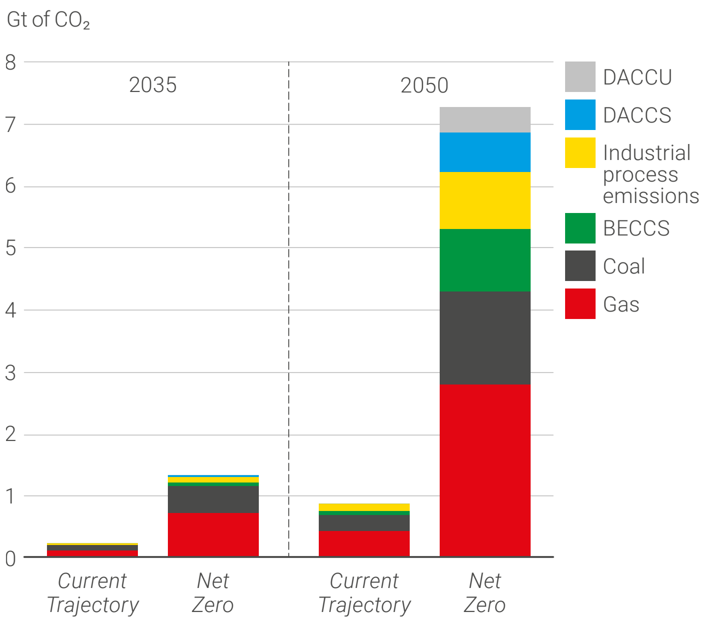
- Hydrogen demand in the EU grows to around 5-10 Mtpa by 2035 in *Current Trajectory* and *Net Zero*, of which around half is used in the form of pure hydrogen. This pure hydrogen is used as a feedstock in refining, to fuel high-temperature heat processes in industry, in buildings, and in transport, in particular for heavy-duty trucking. The cost and difficulty of transporting hydrogen in its pure form, especially over longer distances, means this demand is met by a combination of domestic production and pipeline supplies from North Africa and parts of Northern Europe and the Nordic countries.
- The remaining EU hydrogen demand in 2035 takes the form of hydrogen derivatives, particularly ammonia, and to a lesser extent methanol, for use in chemicals and long-distance marine transportation. Demand for synthetic jet fuel accounts for much of the remaining demand for hydrogen derivatives, especially in *Net Zero*, along with hydrogen-based direct reduced iron (DRI), used in the production of low carbon steel. These derivatives are less costly to transport via seaborne transport than pure hydrogen, so some of this demand is met through imports.
- The EU's use of low carbon hydrogen accelerates to around 15 and 40 Mtpa by 2050 in *Current Trajectory* and *Net Zero* respectively. The growing importance of hydrogen-derived fuels for transport, especially synthetic jet fuel in *Net Zero*, means that the share of EU hydrogen demand that is used in its pure form declines to between 40% and 25% in *Current Trajectory* and *Net Zero* respectively. As a result, by 2050 an increasing share of the EU's hydrogen demand is met via seaborne imports.
- The other key regional centre for hydrogen imports is developed Asian economies, which is dominated by Japan, Korea and Singapore. The increase in hydrogen demand in developed Asian economies in the two scenarios is broadly similar to that in the EU. However, the mix of hydrogen demand, particularly by 2050 in *Net Zero*, is somewhat different from the EU, with a smaller role for synthetic jet fuel and greater demand for pure hydrogen, methanol and ammonia, the latter two driven by greater use in marine. Higher ammonia demand is also driven by use in the power sector.
- In contrast to the EU, Japan and Korea do not have access to pipeline imports of low carbon hydrogen. Some low carbon hydrogen is produced domestically, but most of the demand is met by seaborne imports of hydrogen derivatives, of which some are converted back for use as pure hydrogen.

Carbon mitigation and removals

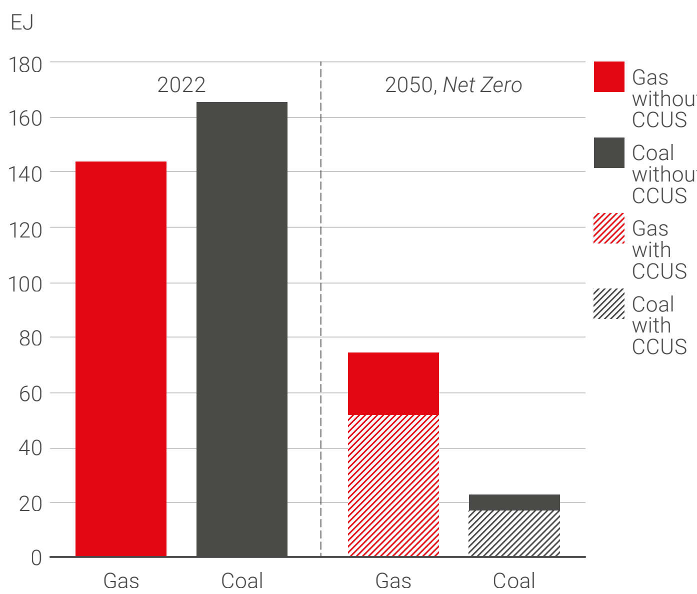
Carbon capture, use and storage plays an important role in supporting deep decarbonization pathways

Carbon capture, use and storage plays an important role in supporting deep decarbonization pathways

Carbon capture, use and storage by emissions source



Gas and coal consumption, abated and unabated



BECCS: Bioenergy with carbon capture and storage.
DACCS: Direct air carbon capture and storage.
DACCU: Direct air carbon capture and use. This includes use as a source of carbon neutral CO_2 for hydrogen-derived fuels such as synthetic jet fuel.

Key points

CCUS plays a central role in enabling the transition to a low carbon energy system: capturing industrial process emissions, enabling energy-based carbon dioxide removal, and abating emissions from the use of natural gas and coal.

- The extra cost associated with adding CCUS to industrial and energy processes means it plays a more substantive role in *Net Zero*, where it is supported by a range of policies incentivising the energy transition. Even for *Net Zero*, long project lead times mean that most of the CCUS capacity is built out in the second half of the outlook. CCUS reaches a little over 1 $GtCO_2$ by 2035 in *Net Zero*, before accelerating to around 7 $GtCO_2$ by 2050. Around 60% of total CCUS deployment in *Net Zero* in 2050 is in China, India, and other developing economies, which require a very rapid scale-up relative to current deployment levels and past experience in oil and natural gas production.
- The importance of CCUS in *Net Zero* stems partly from its ability to capture industrial process emissions and to enable energy-based CDR, neither of which can be replicated or achieved through other methods. These two functions account for around 40% of CCUS capacity by 2050.
- The use of CCUS in industry is particularly important for capturing process emissions from cement manufacturing. These emissions account for around 15% of CCUS capacity by 2050.
- CCUS is used with bioenergy (BECCS) and with direct air capture to provide forms of CDR. BECCS generates useful energy in the form of power and hydrogen generation as well as negative emissions and reaches around 1 $GtCO_2$ by 2050 in *Net Zero*.
- Direct air capture and storage (DACCS) captures CO_2 directly from ambient air and then stores it. DACCS has the potential to be scaled materially but its costs are high relative to other forms of CDR, partly due to its high energy intensity. Direct air capture is used to extract around 1 $GtCO_2$ by 2050 in *Net Zero*, requiring almost 5 EJ of energy or around 1% of total final energy consumption in 2050. Of that 1 $GtCO_2$, around 0.6 $GtCO_2$ is permanently stored, with the remainder used to provide a source of carbon neutral CO_2 for hydrogen-derived fuels such as synthetic jet fuel (see pages 34-35).
- The remaining use of CCUS in *Net Zero* is for the abatement of carbon emissions from the continuing use of natural gas and coal, with around 40% of CCUS used in conjunction with natural gas. CCUS capacity deployed with natural gas is used to produce blue hydrogen (see pages 62-63), to provide a source of dispatchable low carbon power (see pages 58-59), and to abate emissions from the direct combustion of natural gas in industry. Most of the CCUS combined with coal is used in industry and the power sector, with some deployed to produce blue hydrogen, primarily in China.
- Even with the rapid buildout of CCUS in *Net Zero*, the use of natural gas and coal with CCUS in 2050 is equivalent to only around a third and one-tenth of the natural gas and coal consumed respectively in 2022. The use of CCUS in *Net Zero* complements the rapid decline in natural gas and coal consumption: it does not act as an alternative.
- Natural climate solutions (NCS) provide an additional form of CDR, but these are not explicitly modelled in the *Outlook* which focusses on emissions from the production and use of energy and industrial processes. However, this should not detract from the potentially important role NCS can play in reducing carbon emissions, via conservation, restoration and improved land management actions that increase carbon storage and avoid greenhouse gas emissions in landscapes and wetlands across the globe.

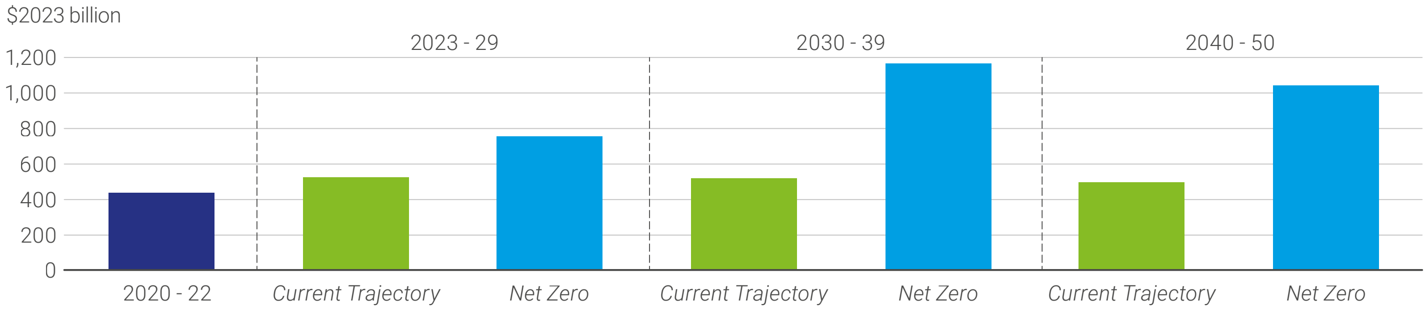
Enablers

Investment in wind and solar capacity increases alongside continued investment in upstream oil and natural gas

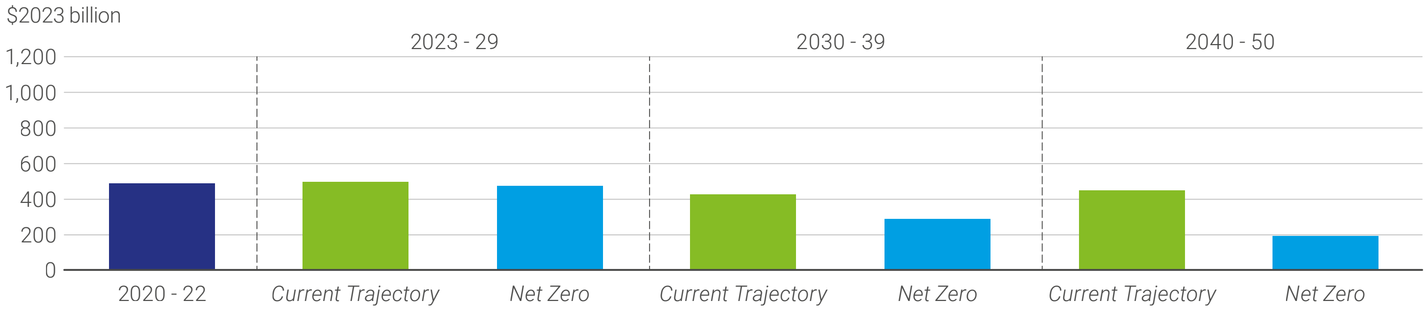
The demand for critical minerals increases substantially as the energy system transitions

Investment in wind and solar capacity increases alongside continued investment in upstream oil and natural gas

Average annual investment in wind and solar



Average annual upstream investment in oil and gas

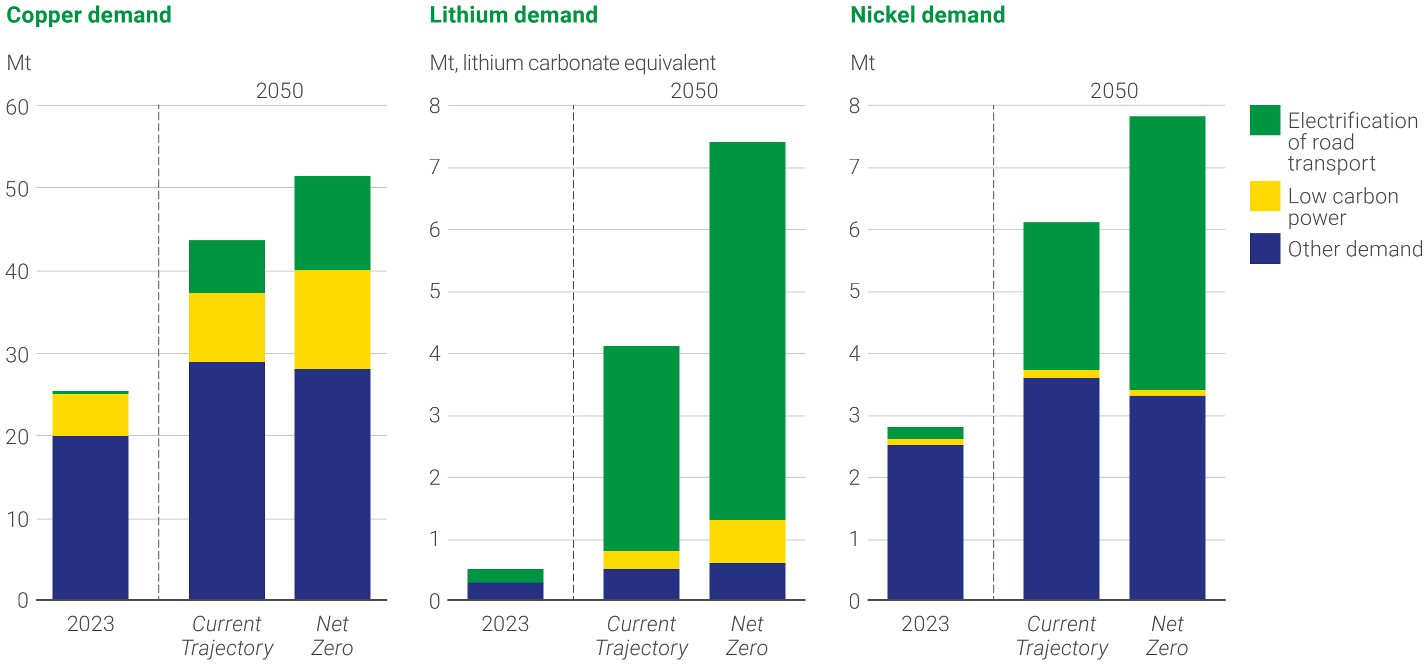


Key points

The transition of the global energy system is supported by substantial investments across a wide range of energy sources and vectors. The rapid growth in wind and solar requires increased investment relative to the recent past. Despite declining demand over the outlook, continuing investment in upstream oil and gas is needed to offset base declines.

- In addition to investment to support the production of different fuels and energy vectors, the energy pathways envisaged in *Current Trajectory* and *Net Zero* require substantial levels of capital expenditure across a wide range of energy infrastructure, such as electricity transmission and distribution, pipelines for low carbon hydrogen and CO_2, and charging networks to support electric vehicles. This investment in energy infrastructure is not modelled explicitly in the *Outlook*.
- The investment estimates considered here refer only to investments in wind and solar capacity and upstream oil and gas production. The assumptions underlying the implied investment requirements, and the associated uncertainties, are described in the Annex (see pages 100-101).
- The scale of investment needed to finance the expansion in wind and solar power is dampened somewhat by the falling cost of wind and solar assets. Even so, the rapid pace of growth in wind and solar capacity still requires a substantial increase in investment flows. This increase is most pronounced in *Net Zero*, in which annual investment averages close to $1 trillion per year over the outlook, more than double recent levels. The increase in investment is less pronounced in *Current Trajectory*, but investment still averages around $500 billion per year.
- Over the outlook as a whole, cumulative investment in wind and solar capacity totals $14 trillion in *Current Trajectory* and $28 trillion in *Net Zero*, roughly equally spread between wind and solar capacity. Around 50% of the total investment in *Current Trajectory* occurs in emerging economies. In *Net Zero* that share is notably higher, with the proportion of wind and solar investments allocated to emerging economies around 70% of the total.
- Although the combined demand for oil and natural gas falls in both scenarios, natural declines in existing production mean that continuing investment in upstream oil and gas is required to meet future demand in both scenarios. Within oil and gas, the share of investment devoted to natural gas increases over time, reflecting the greater resilience of natural gas consumption relative to oil.
- Oil and natural gas investment in *Current Trajectory* remains relatively close to recent levels over the outlook, with gradual declines in upstream oil investment offset by increasing expenditures in natural gas. Upstream oil and gas investment in the final 20 years of the outlook falls more sharply in *Net Zero*, as the energy transition accelerates and an increasing amount of capital is diverted to low carbon energy, including wind and solar power.

The demand for critical minerals increases substantially as the energy system transitions



Key points

Any pathway towards a low carbon energy system requires substantial increases in the use of a range of minerals critical for the infrastructure and assets supporting the transition.

- The re-engineering of the global energy system to produce, distribute and employ growing levels of low carbon energy requires increasing amounts of certain minerals critical for the infrastructure and assets supporting the transition. It is possible to use the scenarios to identify two separate sources of demand associated with the expansion of low carbon energy over the outlook:
  - Growth of low carbon power as the energy system electrifies, driven by an increasing share of low carbon generation. This source of demand includes the extension of transmission and distribution grids, the rapid growth in wind and solar capacity, and the use of batteries to provide a source of flexibility as the share of variable renewable energy sources increases (see pages 58-59).
  - The electrification of road transport and the associated expansion in the use of batteries. The number of electric vehicles grows to between 1.2 and 2.1 billion vehicles by 2050 in *Current Trajectory* and *Net Zero* respectively, implying an increased demand for annual battery capacity within road transport of between 9-16 TWh.
- These growing demands from low carbon energy, together with the broader economic expansion envisaged over the outlook, have significant implications for a range of different minerals, including copper, lithium, and nickel.
- **Copper:** copper demand increases by between 75% and 100% by 2050 in *Current Trajectory* and *Net Zero*. Between a third and a half of this increase in demand in the two scenarios stems from the increasing use of copper outside of the energy system as the size of the world economy doubles.

  Most of the increasing demand for copper inside the energy system stems from its use within electric vehicles, with a 'typical' electric vehicle requiring two times more copper than a corresponding internal combustion engine vehicle in 2022. Most of the increasing use within low carbon power comes from a combination of the extension of electricity networks and the buildout of new wind and solar capacity.
- **Lithium:** the growing importance of batteries over the outlook, especially in electric vehicles and to a lesser extent as a source of flexibility within global power systems, leads to a substantial increase in the global demand for lithium. The use of lithium increases between 8- and 14-fold by 2050 in *Current Trajectory* and *Net Zero* respectively. By 2050, the use of lithium in electric vehicles accounts for around 80% of total lithium demand, compared with around 40% in 2022.
- **Nickel:** nickel demand increases between two- and three-fold by 2050 in *Current Trajectory* and *Net Zero* respectively. Most of this growth (65-80%) is due to the increasing use of lithium-ion batteries in electric vehicles.
- The scenarios assume that the supply of critical minerals scales to meet these growing demands and that the cost and availability of supplies do not act as a significant constraint on the pace or nature of the energy transition. This requires a significant increase in investment and resources within the critical minerals mining sector, as well as an acceleration in planning and permitting.
- The challenge associated with this scaling up is compounded by countries needing to both ensure that sources of supplies and processing are sufficiently geographically distributed to provide security of supply and maintain scrutiny on the sustainability of new and existing mining activity.

What does it take to accelerate the energy transition?

The faster transition in *Net Zero* relative to *Current Trajectory* is driven largely by greater decarbonization in the power and industrial sectors

The faster decarbonization of power markets in *Net Zero* is driven by emerging economies

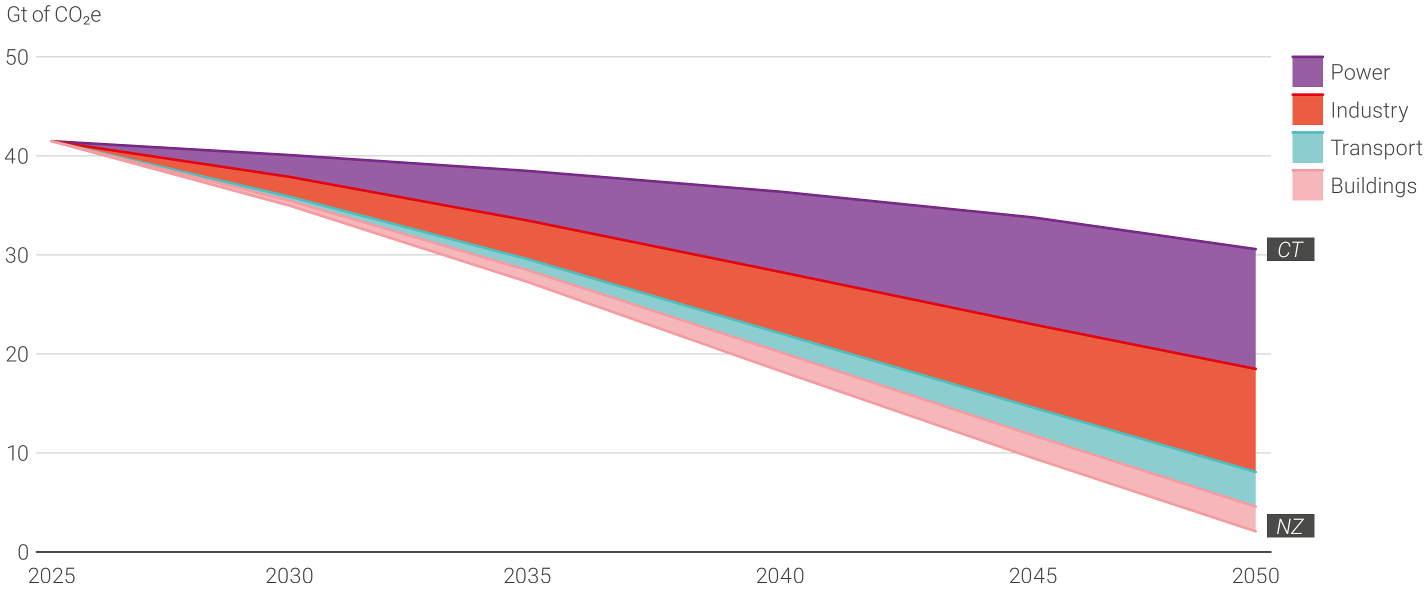
Industry decarbonizes more quickly in *Net Zero* relative to *Current Trajectory*, helped by lower carbon electricity and greater improvements in efficiency

The greater electrification of road transport largely accounts for the faster pace of transport decarbonization in *Net Zero* relative to *Current Trajectory*

Buildings decarbonize more rapidly in *Net Zero* than in *Current Trajectory*, supported by lower carbon electricity and accelerating energy efficiency and conservation

The faster transition in *Net Zero* relative to *Current Trajectory* is driven largely by greater decarbonization in the power and industrial sectors

Decomposition of differences in emissions by use sector (*Net Zero* vs *Current Trajectory*)



Industry includes direct air carbon capture. For more details, see Annex pages 94-95 on decomposition modelling.
CT: *Current Trajectory*. NZ: *Net Zero*.

Key points

The two *Outlook* scenarios can be used to explore some of the key additional changes that might help the world's energy system move from its current course to a faster, deeper decarbonization pathway.

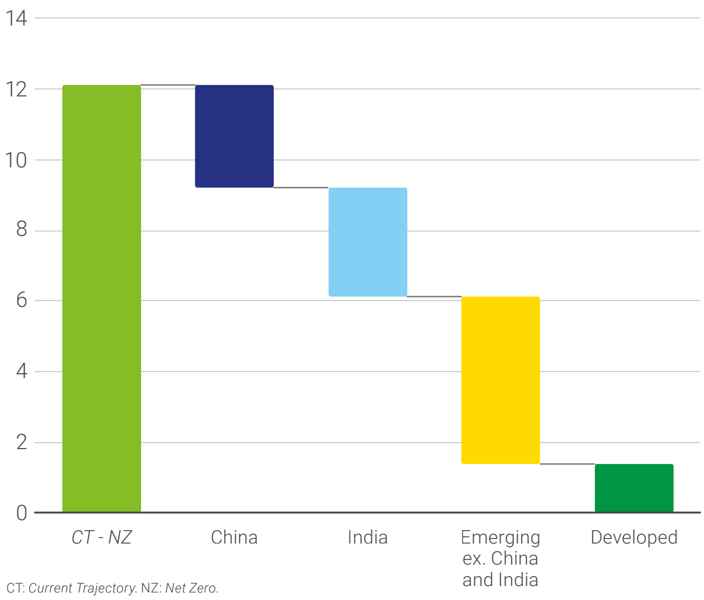
- This year's *Energy Outlook* explores two stylised scenarios:
- *Current Trajectory*, which is designed to capture the broad pathway along which the global energy system is currently travelling. Emissions peak around the middle of this decade but decline by only 25% by 2050.
- *Net Zero* considers a faster and deeper transition in which CO_2e emissions decline by around 95% by 2050 and cumulative emissions remain within the IPCC's estimate of the 2°C carbon budget (see pages 20-21).
- It is possible to compare these two scenarios to identify the key differences in the energy system that distinguish *Current Trajectory* from that in *Net Zero* (or, put differently, that need to change in order to move from the current relatively slow, shallow and geographically uneven decarbonization pathway to a faster global transition that could be considered consistent with the Paris climate goals).
- The single biggest element accounting for the faster transition pathway in *Net Zero* is the quicker and more comprehensive decarbonization of the global power system. The average carbon intensity of global power falls by a little over 60% over the first half of the outlook in *Net Zero* compared with a fall of a little over 35% in *Current Trajectory*. By 2050, the global power sector in aggregate in *Net Zero* is entirely decarbonized, whereas in *Current Trajectory* it reaches only the same reduction in emissions as achieved in *Net Zero* by the mid-2030s. This faster and more complete decarbonization of the power sector accounts for between 40-45% of the difference between *Current Trajectory* and *Net Zero* over the outlook.
- The remaining differences between *Current Trajectory* and *Net Zero* can be accounted for by the different pace the sectors in which energy is ultimately used – industry, transport, and buildings – reduce their carbon emissions, either by improving energy efficiency and conservation, by switching to lower carbon energy, or via the deployment of CCUS.
- The industrial sector accounts for the largest difference across the end-use sectors, accounting for 35-40% of the faster decarbonization pathway in *Net Zero* relative to *Current Trajectory*.
- The remaining difference is due to the faster pace of decarbonization in the transport and buildings sectors.
- The next pages (80-87) consider each of these sectors in turn – power, industry, transport, and buildings – to highlight the key sectoral changes accounting for the differences between *Current Trajectory* and *Net Zero*.

The faster decarbonization of power markets in *Net Zero* is driven by emerging economies

Power sector: differences in emissions in 2050 (NZ vs CT)

By region

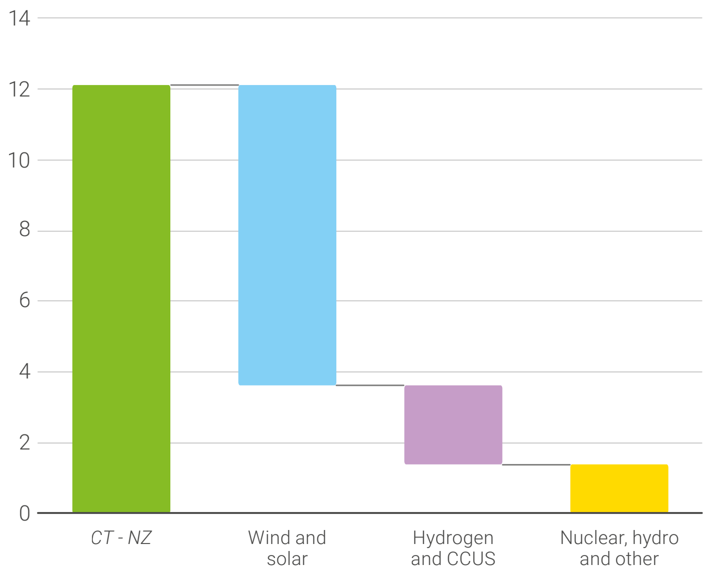
Gt of CO_2



CT: *Current Trajectory*. NZ: *Net Zero*.

By low carbon technology

Gt of CO_2



Key points

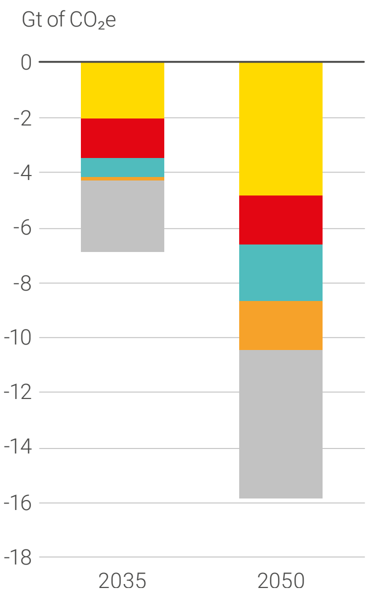
The faster pace of decarbonization of global power markets in *Net Zero* relative to *Current Trajectory* largely stems from faster decarbonization of power generation in emerging economies, as more rapid growth in wind and solar power crowds out coal generation.

- Power generation in developed economies decarbonizes more quickly than in emerging economies in both scenarios. This is helped by slower growth in power demand in developed economies (see pages 58-59), which means a greater proportion of the growth in low carbon power generation there is used to displace fossil fuel generation rather than to meet incremental demand.
- As a result, even in the slower transition path in *Current Trajectory*, the carbon intensity of power generation in developed economies falls by around 85% by 2050.
- This means that much of the faster pace of decarbonization of global power generation in *Net Zero* relative to *Current Trajectory* is accounted for by accelerated decarbonization in emerging economies. This is led by China and India, who each contribute around 25% of the difference in power sector emissions in the two scenarios in 2050, with other emerging economies accounting for much of the remaining difference.
- The faster pace of power decarbonization in emerging economies in *Net Zero* than in *Current Trajectory* is largely due to the acceleration of wind and solar power, which grows at more than twice the pace in *Net Zero*. By 2050, wind and solar accounts for around 70% of power generation in emerging economies in *Net Zero*, compared with around 40% in *Current Trajectory*.
- This much faster growth in wind and solar power in emerging economies in *Net Zero* largely comes at the expense of coal, whose share of power generation falls to less than 1% by 2050 in *Net Zero* compared with 16% in *Current Trajectory*.
- The lower level of carbon emissions across global power systems in *Net Zero* than in *Current Trajectory* is also aided by a greater rollout of CCUS and hydrogen generation, which replaces a significant portion of unabated coal and gas generation while still providing the necessary system flexibility. Greater deployment of nuclear and hydro power is also important in displacing unabated fossil-fuel generation, particularly in emerging economies.
- The greater decarbonization of power markets in both developed and emerging economies in *Net Zero* relative to *Current Trajectory* is also aided by the larger buildout of assets and technologies that aid the flexibility of power systems, such as battery storage, interconnectors, and demand-side response (see pages 58-59).
- To provide a more comprehensive view of the three end-use sectors, in the following pages the carbon savings associated with the faster pace of decarbonization of the power sector in *Net Zero* are allocated to each sector according to their level of electrification.

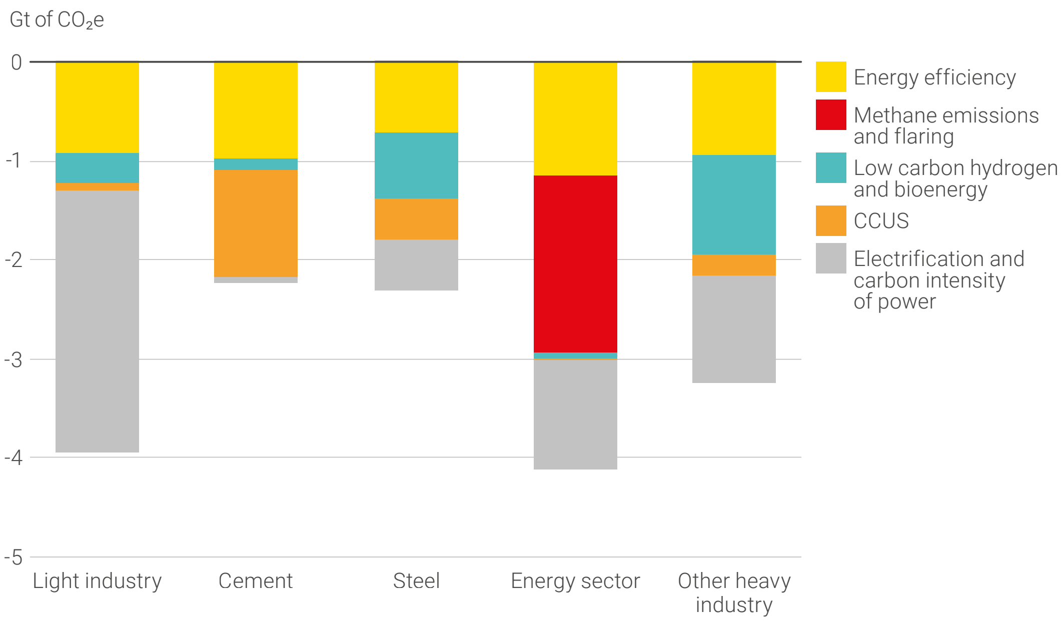
Industry decarbonizes more quickly in *Net Zero* relative to *Current Trajectory*, helped by lower carbon electricity and greater improvements in efficiency

Industrial sector: factors accounting for difference in emissions (NZ vs CT)

By year



By industrial sub-sector in 2050



Electrification and carbon intensity of power includes decarbonization of combined heat & power (CHP) and heat plants. CT: *Current Trajectory.* NZ: *Net Zero.*

Other heavy industry includes the hydrogen sector, petrochemicals, non-ferrous metals, glass, ceramics and brick industry. Light industry includes agriculture, forestry, fishing and all other industry.

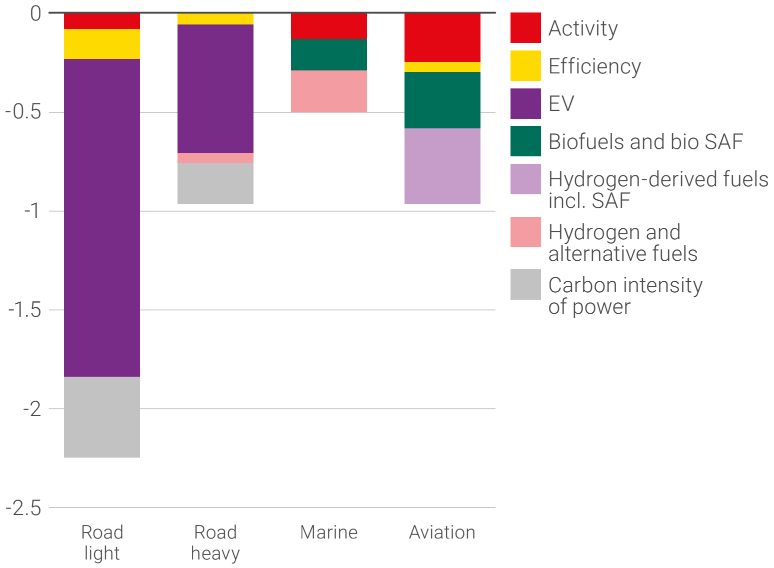
Key points

The faster pace of industrial sector decarbonization in *Net Zero* relative to *Current Trajectory* is supported by several factors, including greater use of lower carbon power, various efficiency measures, and reduced methane emissions.

- The lower levels of industrial emissions in *Net Zero* than in *Current Trajectory* stem in part from the lower carbon intensity of electricity in *Net Zero* (see pages 54-55). This, combined with higher levels of electrification for a range of industrial processes, accounts for around 35% of the difference in overall industrial emissions between the two scenarios in both 2035 and 2050.
- Much of the remaining difference between the two scenarios in 2035 is accounted for by greater levels of efficiency, both in terms of the efficiency of industrial processes themselves and also wider-economy energy conservation measures that reduce the demand for manufactured goods and materials. Methane emissions from the energy sector are also lower, reflecting both more measures to reduce the methane intensity of fossil fuel production, and the lower absolute level of fossil fuel production in *Net Zero* relative to *Current Trajectory*, with the latter impact building over the outlook.
- By 2050, the impact of heightened conservation measures to reduce the demand for materials and goods, such as fewer single-use plastics, greater recycling and reuse of products, and more efficient design and construction methods reducing the use of steel and cement, account for an increased share of the difference in industrial emissions between the two scenarios.
- In the second half of the outlook, the greater use of other low carbon energy sources and technologies also plays a more important role in explaining the difference in industrial emissions in the two scenarios by 2050, with greater use of low carbon hydrogen and bioenergy as an alternative to fossil fuels in heavy industry and the use of CCUS to abate industrial process and energy emissions.
- The factors accounting for the difference in industrial emissions in the two scenarios vary across different sub-sectors.
- For light industry, whose manufacturing processes generally require only low-temperature heat and so are amenable to relatively high levels of electrification, the dominant factor explaining the difference between the two scenarios is the lower carbon intensity of electricity in *Net Zero*, together with some improvements in process efficiency.
- In contrast, in the cement subsector, the most important factor accounting for the difference in emissions is the greater deployment of CCUS, which is used predominantly to capture emissions generated from the process used to produce cement, rather than from the combustion of fossil fuels. Unless captured, these process emissions account for the majority of carbon emissions from the cement sector. In *Net Zero*, CCUS employed in the cement sector reaches 1.4 $GtCO_2$ by 2050, 10 times the level in *Current Trajectory.*
- The steel sector is different again: here low carbon hydrogen plays a significant role in explaining the lower emissions in *Net Zero*, by replacing coal and natural gas as both a reducing agent and as a source of high-temperature heat.
- By 2050, the lower level of emissions in the energy subsector in *Net Zero* relative to *Current Trajectory* largely stems from the lower level of fossil fuels output which, together with improvements in process efficiency and methane intensity, lowers both the fossil fuels used to produce fossil energy and the associated methane emissions.

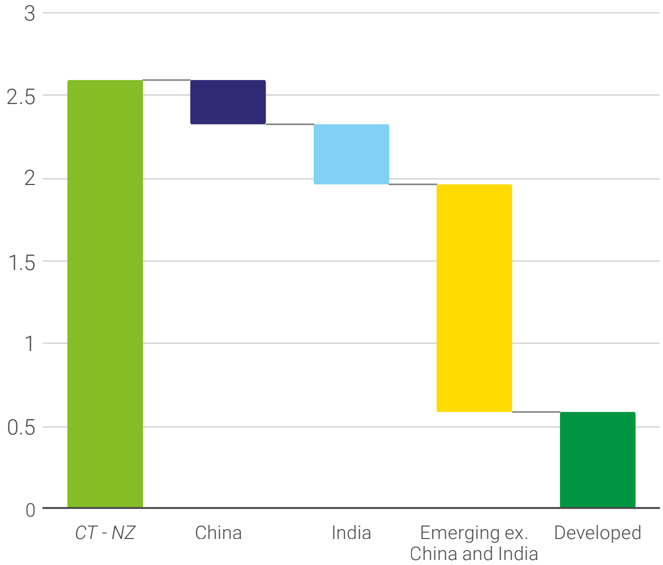
The greater electrification of road transport largely accounts for the faster pace of transport decarbonization in *Net Zero* relative to *Current Trajectory*

Transport subsectors: factors accounting for differences in emissions in 2050 (NZ vs CT)



Carbon intensity of power is the reduction in emissions in the power sector due to decarbonization of the generation mix.
CT: *Current Trajectory*. NZ: *Net Zero*.

Road transport: differences in emissions in 2050 by region (NZ vs CT)



Road transport decomposition does not include the reduction in emissions in the power sector due to decarbonization of the generation mix.

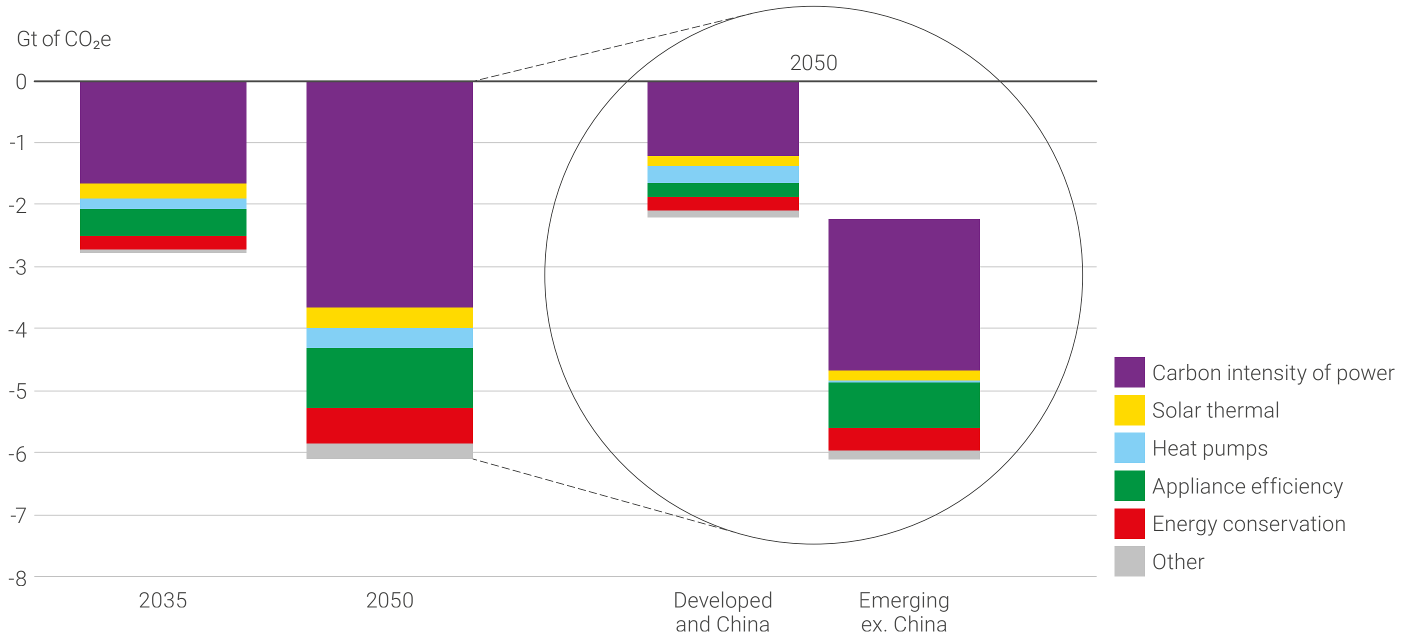
Key points

The faster transition in the transport sector in *Net Zero* than in *Current Trajectory* is driven by the greater switch away from oil into lower carbon fuels, especially electricity in road transport.

- The faster decarbonization of road transport in *Net Zero* accounts for almost two-thirds of the difference in transport sector emissions in the two scenarios in 2050. This difference is driven primarily by the greater electrification of road vehicles in *Net Zero*.
- In light road transport, there are around 2.1 billion electric cars and vans by 2050 in *Net Zero*, making up over 80% of the global car parc. That compares with around 1.2 billion such vehicles, comprising 50% of total light vehicles, in *Current Trajectory*. This faster electrification of light vehicles means that the number of conventional ICE cars in *Net Zero* peaks around the end of this decade and by 2050 is around a third of its level in 2022 (see pages 32-33).
- Likewise, in heavy road transport, around 80% of the heavy-duty trucks (85 million) on the road in 2050 in *Net Zero* are electrified, compared with 40% in *Current Trajectory*. The number of ICE heavy-duty trucks in *Net Zero* peaks in the early-2030s, and by 2050 is around a third of its 2022 level. Most of the greater shift away from ICE trucks in *Net Zero* than in *Current Trajectory* is due to electric trucks, but greater take-up of hydrogen-fuelled trucks also has a small incremental impact.
- The emissions savings associated with greater electrification of light- and heavy-duty vehicles in *Net Zero* is compounded by the lower carbon intensity of electricity as the power sector in *Net Zero* decarbonizes more quickly (see pages 54-55).
- The faster decarbonization of road transport in *Net Zero* is also supported by greater improvements in efficiency and conservation. Most of these improvements stem from the efficiency of the vehicles themselves: by 2050, the amount of energy required per kilometre driven is 30% lower than in *Current Trajectory* and three times lower than in 2022. Some of the reduction in emissions also reflects wider conservation and environmental policies in *Net Zero* encouraging the greater use of public transport and car sharing, which dampens the growth in the distances that road vehicles need to travel.
- Much of the faster decarbonization of road transport in *Net Zero* relative to *Current Trajectory* stems from greater electrification of road transport in emerging economies, led by India and China, together with significant contributions from other emerging Asian economies and from the Middle East. The faster decarbonization of road transport in developed economies in *Net Zero* is concentrated particularly in the US, which in *Current Trajectory* is slower to electrify its road transport than the other main centres of transport demand in the developed economies.
- Outside of road transport, the faster pace of transport decarbonization in *Net Zero* also reflects lower levels of CO_2 emissions in aviation and marine. These lower emissions in 2050 largely stem from a more pronounced switch away from oil-based fuels into lower carbon alternatives. In aviation, this greater switch is mainly into bio- and hydrogen-based SAF. In marine, lower emissions reflect greater use of bio- and hydrogen-based methanol and ammonia.
- The lower carbon emissions in aviation and marine in *Net Zero* also reflect wider efficiency measures, environmental policies and behavioural shifts which dampen growth in air and marine travel.

Buildings decarbonize more rapidly in *Net Zero* than in *Current Trajectory*, supported by lower carbon electricity and accelerating energy efficiency and conservation

Buildings sector: factors accounting for differences in emissions by region (NZ vs CT)



Other refers to electrification measures (excluding heat pumps) and access to clean cooking fuels. Carbon intensity of power is the reduction in emissions in the power sector due to decarbonization of the generation mix.
CT: *Current Trajectory*. NZ: *Net Zero*

Key points

The faster decarbonization of the buildings sector in *Net Zero* than in *Current Trajectory* is driven by several factors including the increasing use of lower carbon electricity, accelerated gains in energy efficiency and energy conservation.

- The greater reduction of buildings emissions in *Net Zero* than in *Current Trajectory* stems in part from the lower carbon intensity of electricity in *Net Zero* (see pages 54-55), which alone accounts for about 60% of the difference in buildings sector carbon emissions between the two scenarios in both 2035 and 2050.
- The impact of lower carbon power is compounded by the greater degree of electrification of buildings in *Net Zero*, which reaches around three-quarters of total energy use by 2050, compared with around a half in *Current Trajectory*. That reflects the faster adoption of electricity in a range of end-uses in buildings, including space and water heating and cooking.
- An important element of the electrification of buildings in both scenarios is the rapidly expanding use of heat pumps, which number around 600 million by 2050 in *Current Trajectory* and over 800 million in *Net Zero*, compared to just 90 million in 2022. The switch from fossil fuels to electricity for space and water heating, combined with the much greater efficiency of heat pumps relative to conventional heating systems, play a significant role in decarbonizing heating in the building sector in both scenarios, with a more pronounced impact in *Net Zero* due to the greater adoption of heat pumps.
- The larger fall in building emissions in *Net Zero* also reflects measures to reduce energy use. Some of those measures are focused on improving energy efficiency within buildings, especially improved efficiency of electrical appliances such as air conditioning, refrigerators and washing machines. Other measures focus on improving the design and construction of buildings to achieve better levels of energy conservation, for example by improving insulation in existing buildings and imposing stricter building standards on new buildings. The more stringent measures in *Net Zero* than in *Current Trajectory* drive an increasing wedge in the speed of decarbonization in the two scenarios over the outlook.
- By 2050, most of the difference in building emissions between the two scenarios stems from lower emissions in emerging economies. In addition to greater electrification, energy efficiency and energy conservation, this difference also reflects the reduction in emissions associated with greater use of solar thermal in emerging economies in *Net Zero*, which provides an alternative, lower carbon source of water heating.

Annex

Data tables

	2022	Level in 2050* Current Trajectory	Level in 2050* Net Zero	Change 2022-2050 (p.a.) Current Trajectory	Change 2022-2050 (p.a.) Net Zero	Share of primary energy in 2050 Current Trajectory	Share of primary energy in 2050 Net Zero
Primary energy by fuel							
Total	**595**	**635**	**437**	**0.2%**	**-1.1%**	**100%**	**100%**
Oil	191	146	52	-0.9%	-4.6%	23%	12%
Natural gas	143	170	65	0.6%	-2.8%	27%	15%
Coal	165	108	23	-1.5%	-6.8%	17%	5%
Nuclear	10	15	21	1.7%	2.8%	2%	5%
Hydro	16	22	28	1.2%	2.0%	3%	6%
Renewables (incl. bioenergy)	70	174	249	3.3%	4.6%	27%	57%
Primary energy by fuel (native units)							
Oil (Mb/d)	97	77	28				
Natural gas (Bcm)	3,985	4,729	1,797				
Primary energy by region							
Developed	**208**	**163**	**125**	**-0.9%**	**-1.8%**	**26%**	**29%**
US	88	73	60	-0.7%	-1.4%	11%	14%
EU	55	40	28	-1.1%	-2.3%	6%	6%
UK	7	5	5	-0.8%	-1.1%	1%	1%
Emerging	**387**	**473**	**312**	**0.7%**	**-0.8%**	**74%**	**71%**
China	146	128	94	-0.5%	-1.6%	20%	21%
India	42	80	51	2.3%	0.7%	13%	12%
Brazil	13	16	13	0.8%	-0.1%	3%	3%

	2022	Level in 2050* Current Trajectory	Level in 2050* Net Zero	Change 2022-2050 (p.a.) Current Trajectory	Change 2022-2050 (p.a.) Net Zero	Share of final consumption in 2050 Current Trajectory	Share of final consumption in 2050 Net Zero
Total final consumption by sector							
Total	**488**	**551**	**383**	**0.4%**	**-0.9%**	**100%**	**100%**
Transport	117	115	85	-0.1%	-1.1%	21%	22%
Industry	210	237	176	0.4%	-0.6%	43%	46%
Feedstocks	41	54	38	1.1%	-0.2%	10%	10%
Buildings	122	144	84	0.6%	-1.3%	26%	22%
Energy carriers (generation)							
Electricity ('000 TWh)	29	54	69	2.2%	3.1%		
Hydrogen (Mt)	75	143	389	2.3%	6.1%		
Production							
Oil (Mb/d)	94	75	29	-0.8%	-4.1%		
Natural gas (Bcm)	4,044	4,730	1,796	0.6%	-2.9%		
Coal (EJ)	175	109	23	-1.7%	-7.0%		
Emissions							
Carbon emissions (Gt of CO_2e)	41	31	2	-1.0%	-10.2%		
Carbon capture use & storage (Gt)	0	0.9	6.8				
Macro							
GDP (trillion US$ PPP)	137	268	268	2.4%	2.4%		
Energy intensity (MJ of PE per US$ of GDP)	4.3	2.4	1.6	-2.1%	-3.4%		

*Exajoules (EJ) unless otherwise stated

Comparing scenario emissions with IPCC carbon budgets

To calculate and compare cumulative emissions 2015-50 between IPCC and bp scenarios we use the following approach:

IPCC scenarios are collected from the IPCC Sixth Assessment Report (AR6) Scenario Database, maintained by the International Institute for Applied Systems Analysis (IIASA) in collaboration with the IPCC Working Group III. Four relevant categories of scenarios were chosen:

C1: limit global warming below 1.5°C in 2100 with a greater than 50% probability and a peak warming higher than 1.5°C with less than or equal to 67%.

C2: limit global warming below 1.5°C in 2100 with a greater than 50% probability but peak warming higher than 1.5°C with a probability of greater than 67%.

C3: limit global warming below 2°C throughout the century with a probability of greater than 67%.

C5: limit global warming below 2.5°C throughout the century, with greater than 50% probability.

Descriptions of the characteristics of these types of scenarios can be found in Table 3.1 in the IPCC Sixth Assessment Report (Climate Change 2022: Mitigation of Climate Change) cited below.

For each scenario, the database provides CO_2 emissions from energy and industry, and methane emissions from the energy sector. This information allows us to calculate CO_2-equivalent (CO_2e) emissions directly comparable to those reported in bp *Current Trajectory* and bp *Net Zero* scenarios.

Since the IPCC database offers data at five-year intervals, we employ linear interpolation to estimate emissions for intermediate years.

To mitigate potential distortions, we eliminate outliers by only including scenarios between the 10th and 90th percentiles for each emission variable within each scenario.

Finally, we calculate the resulting figures for cumulative CO_2e emissions from 2015 to 2050. This timeframe was chosen because recent emission data may deviate significantly from some scenario projections.

Sources

Edward Byers, Volker Krey, Elmar Kriegler, Keywan Riahi, Roberto Schaeffer, Jarmo Kikstra, Robin Lamboll, Zebedee Nicholls, Marit Sanstad, Chris Smith, Kaj-Ivar van der Wijst, Alaa Al Khourdajie, Franck Lecocq, Joana Portugal-Pereira, Yamina Saheb, Anders Strømann, Harald Winkler, Cornelia Auer, Elina Brutschin, Matthew Gidden, Philip Hackstock, Mathijs Harmsen, Daniel Huppmann, Peter Kolp, Claire Lepault, Jared Lewis, Giacomo Marangoni, Eduardo Müller-Casseres, Ragnhild Skeie, Michaela Werning, Katherine Calvin, Piers Forster, Celine Guivarch, Tomoko Hasegawa, Malte Meinshausen, Glen Peters, Joeri Rogelj, Bjorn Samset, Julia Steinberger, Massimo Tavoni, Detlef van Vuuren. AR6 Scenarios Database hosted by IIASA International Institute for Applied Systems Analysis, 2022.

Riahi, K., R. Schaeffer, J. Arango, K. Calvin, C. Guivarch, T. Hasegawa, K. Jiang, E. Kriegler, R. Matthews, G.P. Peters, A. Rao, S. Robertson, A.M. Sebbit, J. Steinberger, M. Tavoni, D.P. van Vuuren, 2022: Mitigation pathways compatible with long-term goals. In IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926.00

From *Current Trajectory* to *Net Zero*

The analysis of the difference in carbon emissions between *Current Trajectory* (CT) and *Net Zero* (NZ) scenarios focuses on both direct and indirect emissions from the power sector and each end-use sector (industry, transport, buildings).

Power sector

To separate the impact of the decarbonisation of the power sector from changes in electricity use in the end-use sectors, the following approach is taken:

The difference in direct emissions in the power sector between CT and NZ can be decomposed into two contributions: the change in total electricity demand, and the change in power emissions intensity. Electricity demand is higher in NZ than in CT as the world electrifies more in NZ. The carbon intensity of power is lower in NZ than in CT as more low carbon power sources contribute a greater share of generation. When accounting for the difference in emissions between CT and NZ in the power sector, we only consider the contribution due to lower carbon intensity. The contribution due to increased electricity demand is instead allocated to the end use sector as a function of the change in electricity demand in each sector.

Emissions from the production of traded heat (via combined heat and power (CHP) or heat plants) are included within the power sector.

End-use sectors

Turning to end-use sectors, the impact of decarbonizing the power sector is again separated from the impact of increasing electricity demand. This is done by initially calculating the changes in carbon emissions associated with drivers such as energy efficiency improvements and electrification while holding the carbon intensity of power at the CT level. At the end of the analysis, the final step is to calculate the reduction in emissions from moving the carbon intensity of power to the NZ level. In the below, we elaborate on our end-use sector methodology by sector.

i) Industrial sector

The industrial sector decomposition includes the contributions from methane emissions from fossil fuel production and from the hydrogen sector. CCUS includes the capture of process emissions from cement production. The contributions from energy efficiency gains include the effects of process efficiency improvements, increased recycling of industrial products and materials, and measures to reduce the demand for industrial products and materials.

ii) Transport sector

The decomposition for the transport sector includes contributions from transport activity and energy efficiency. These reflect changes in how each transport mode is used, such as the average distance travelled by light-duty vehicles and improvements in overall energy efficiency. The remaining contributions directly reflect the impact of the shift away from fossil fuels towards low carbon alternatives.

iii) Buildings sector

The contribution of energy conservation includes the effects of improvements in building fabric through retrofitting, the increase in the number of zero-carbon buildings, and energy demand reductions due to behavioural changes. The contribution from 'Other' refers to all other decarbonization measures that involve the switch to electricity, as well as access to fuels that reduce the use of traditional biomass and its associated methane emissions.

Modelling approach for the *Delayed Net Zero* and fastest IPCC decarbonization pathways

The *Delayed Net Zero* scenario combines elements of both *Current Trajectory* and *Net Zero* scenarios.

In a first step we calculate adjusted emissions pathways for the *Current Trajectory* and *Net Zero* scenarios. This step involves removing methane emissions from energy sources and traditional biomass and adding CO_2 emissions from Agriculture, Forestry and Other Land Use (AFOLU) from the IPCC C3 (for *Net Zero*) and C5 (for *Current Trajectory*) scenarios.

In the *Delayed Net Zero* scenario, emissions accrue as in *Current Trajectory* until 2030. After 2030, the energy system transitions as in the *Net Zero* pathway and CO_2 emissions are calculated based on primary consumption levels for different fuels. The level of cumulative emissions of this scenario is around 900 $GtCO_2$.

This is close to the carbon budget taken from the IPCC Summary for Policymakers report (IPCC, 2021), which estimates that cumulative emissions of 900 $GtCO_2$ are consistent with limiting global temperature increase below 2°C with a likelihood of 83%.

The Fastest IPCC decarbonization scenario discussed in the Energy *Outlook* is a combination of *Current Trajectory* and a selection of IPCC scenarios that it considers consistent with a global warming of 1.5°C degrees subject to a binding constraint for CO_2 emissions.

For our analysis, we begin by selecting all the scenarios from the C1 category in the IPCC Sixth Assessment Report (AR6) Scenario Database that provide data on CO_2 emissions from both CO_2 emissions from energy and industrial processes and from AFOLU. C1 scenarios represent pathways where global warming is limited to below 1.5°C by 2100 with a greater than 50% chance. Finally, we choose the four scenarios with the most rapid decline in emissions following their peak.

The modelling strategy to define the Fastest IPCC decarbonization scenario is as follows: the energy system evolves as per *Current Trajectory* until a specific year, and then starts decarbonizing in an accelerated way, mirroring the average rate of decline in emissions of the four IPCC scenarios selected. Using this clearly highly schematic methodology, 2035 is calculated to be the latest year that the system can move from *Current*

Trajectory to the more rapid pace of decarbonization in the fastest IPCC scenarios, while still limiting cumulative emissions to approximately 900 $GtCO_2$.

Emissions after 2050 are calculated on the assumption that the energy system evolves in a similar path as in 2045-50 in each scenario.

Sources

Edward Byers, Volker Krey, Elmar Kriegler, Keywan Riahi, Roberto Schaeffer, Jarmo Kikstra, Robin Lamboll, Zebedee Nicholls, Marit Sanstad, Chris Smith, Kaj-Ivar van der Wijst, Alaa Al Khourdajie, Franck Lecocq, Joana Portugal-Pereira, Yamina Saheb, Anders Strømann, Harald Winkler, Cornelia Auer, Elina Brutschin, Matthew Gidden, Philip Hackstock, Mathijs Harmsen, Daniel Huppmann, Peter Kolp, Claire Lepault, Jared Lewis, Giacomo Marangoni, Eduardo Müller-Casseres, Ragnhild Skeie, Michaela Werning, Katherine Calvin, Piers Forster, Celine Guivarch, Tomoko Hasegawa, Malte Meinshausen, Glen Peters, Joeri Rogelj, Bjorn Samset, Julia Steinberger, Massimo Tavoni, Detlef van Vuuren. AR6 Scenarios Database hosted by IIASA. International Institute for Applied Systems Analysis, 2022. doi: 10.5281/zenodo.5886911 | url: data.ece.iiasa.ac.at/ar6/

IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 3–32, doi:10.1017/9781009157896.001

Economic impact of climate change

The GDP profiles used in the *Energy Outlook* come from Oxford Economics (OE). These long-term forecasts incorporate estimates of the economic impact of climate change. These estimates follow a similar methodology to that used in *Energy Outlook 2020*, *Energy Outlook 2022* and *Energy Outlook 2023*.

The future effects of climate change on global economic activity are highly uncertain, given the unprecedented nature of the phenomenon and its interaction with a modern economic system, and the many uncertainties around the mitigation and adaptation actions that may be taken in response and the technologies that will be available for those in future. However there have been attempts to model its possible effects. In particular, OE updated and extended the estimation approach developed by Burke, Hsiang and Miguel (2015), which suggests a non-linear relationship between productivity and temperature, in which per capita income growth rises until an average (population weighted) temperature of just under 15°C is reached (Burke et al's initial assessment was 13°C). While, given the uncertainties, any such conclusions need to be treated with caution, this temperature curve suggests that 'cold country' income growth increases with annual temperatures. However, at annual temperatures above 15°C, per capita income growth is increasingly adversely affected by higher temperatures.

The OE baseline emissions forecasts assume average global temperatures reach 1.9°C above pre-industrial levels by 2050. The results suggest that in 2050 global GDP is around 2% lower than in a counterfactual scenario where temperatures remained at their current level. The regional economic impacts are distributed according to the evolution of regional temperatures relative to the concave function estimated by OE. While OE's approach captures channels associated with average temperatures, these estimates remain uncertain and incomplete; they do not, for example, explicitly include impact from migration or extensive coastal flooding.

The mitigation costs of actions to decarbonize the energy system are also uncertain, with significant variations across different external estimates. Most estimates, however, suggest that the upfront costs increase with the stringency

of the mitigation effort, suggesting that they are likely to be bigger in *Net Zero* than in *Current Trajectory*. The IPCC estimates (AR6 – Working Group 3) that mitigation costs to limit global warming to 2°C (with probability >67%) entail losses in global GDP with respect to reference scenarios of between 1.3% and 2.7% in 2050. In pathways limiting warming to 1.5°C (with probability >50%) with no or limited overshoot, costs are between 2.6% and 4.2% of global GDP. These estimates do not account for the economic benefits of avoided climate change impacts.

Given the huge range of uncertainty surrounding estimates of the economic impact of both climate change and mitigation, and the fact that our scenarios include both types of costs to a greater or lesser extent, the GDP profiles used in the *Outlook* are based on the illustrative assumption that these effects reduce GDP in 2050 by around 2% in both of our scenarios, relative to the counterfactual in which temperatures are held constant at recent average levels.

Sources:

Burke, M., Hsiang, S. & Miguel, E. Global non-linear effect of temperature on economic production. Nature 527, 235–239 (2015) https://www.nature.com/articles/nature15725

The global aggregate mitigation cost estimates in terms of GDP losses are taken from IPCC AR6 – Working Group 3: https://www.ipcc.ch/report/sixth-assessment-report-working-group-3/

Investment methodology

Oil and gas upstream

Implied levels of oil and gas investment are derived from the production levels in each scenario. Upstream oil and natural gas capital expenditure includes well capex (costs related to well construction, well completion, well simulation, steel costs and materials), facility capex (costs to develop, install, maintain, and modify surface installations and infrastructure) and exploration capex (costs incurred to find and prove hydrocarbons). It excludes operating costs and midstream capex such as capex associated with developing LNG liquefaction capacity.

Asset level production profiles are aggregated by geography, supply segment (onshore, offshore, shale and oil sands), supply type (crude, condensates, NGLs, natural gas) and developmental stage, i.e., classified by whether the asset is currently producing, under development, or non-producing and unsanctioned. As output from producing and sanctioned assets declines, incremental production from infill drilling and new, unsanctioned assets are called on to meet the oil and gas demand shortfalls. The investment required to bring this volume online is then added to any capital costs associated with maintaining these existing and already approved projects. The average 2023-50 decline rate for assets currently producing and under development, including any infill drilling and wells drilled but not yet producing, is around 3% per year for oil and 2% per year for gas, but varies widely by segment and hydrocarbon type. All estimates are derived using asset-level assessments from Rystad Energy.

Wind and solar

This analysis focuses solely on the capital expenditure associated with deploying wind and solar electricity generation technologies, considering region-specific cost dynamics and deployment profiles. Additional costs related to integrating renewables into the power system including end-use assets, grid enhancements, and flexibility requirements, are not included in this assessment.

Carbon emissions definitions and sources

Unless otherwise stated, carbon emissions refer to:

- CO_2 emissions from energy use (i.e. the production and use of energy in the three final end-use sectors: industry, transport and buildings).
- CO_2 emissions from most non-energy related industrial processes.
- CO_2 emissions from natural gas flaring.
- Methane emissions associated with the production, transmission and distribution of fossil fuels and incomplete combustion of traditional bioenergy, expressed in CO_2 equivalent terms.

CO_2 emissions from industrial processes refer only to non-energy emissions from cement production. CO_2 emissions associated with the production of hydrogen feedstock for ammonia and methanol are included under hydrogen sector emissions.

Historical data for natural gas flaring data is taken from VIIRS Nightfire (VNF) data and produced by the Earth Observation Group (EOG), Payne Institute for Public Policy, Colorado School of Mines. The profiles for natural gas flaring in the scenarios assume that flaring moves in line with wellhead upstream output.

Historical data on methane emissions associated with the production, transportation and distribution of fossil fuels and incomplete combustion of traditional bioenergy are sourced from IEA estimates of greenhouse gas emissions. The profiles for future methane emissions assumed in the scenarios are based on fossil fuel production and take account of policy initiatives such as the Global Methane Pledge. The net change in methane emissions is the aggregation of future changes to fossil fuel production, traditional biomass consumption, and methane intensity.

There is a wide range of uncertainty with respect to both current estimates of methane emissions and the global warming potential of methane emissions. The methane to CO_2e factor used in the scenarios is a 100-year Global Warming Potential (GWP) of 28, recommended by the IPCC Fifth Assessment's GWP values.

Sources

Andrew, R.M., 2019. Global CO_2 emissions from cement production, 1928–2018. Earth System Science Data 11, 1675–1710, (updated dataset July 2021).

IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds).

VIIRS Nightfire (VNF) produced by the Earth Observation Group (EOG), Payne Institute for Public Policy, Colorado School of Mines.

IEA (2024), Global Methane Tracker, IEA, Paris.

Myhre, G., D. Shindell, F.-M. Bréon, W. Collins, J. Fuglestvedt, J. Huang, D. Koch, J.-F. Lamarque, D. Lee, B. Mendoza, T. Nakajima, A. Robock, G. Stephens, T. Takemura and H. Zhang, 2013: Anthropogenic and Natural Radiative Forcing. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Other data definitions and sources

Data

Data definitions are based on the Energy Institute Statistical Review of World Energy, unless otherwise noted. Data used for comparisons, unless otherwise noted, are rebased to be consistent with the Statistical Review.

Primary energy, unless otherwise noted, comprises commercially traded fuels and traditional biomass. In this *Outlook*, primary energy is derived using:

- The direct equivalent method: The direct equivalent method simplifies primary energy accounting by directly equating secondary energy from non-combustible sources (e.g., electricity and heat) to the primary energy used to produce it.

In previous editions of the *Energy Outlook*, the primary energy accounting method used was the so-called substitution method. The substitution method reports primary energy from non-fossil fuel as if they had been substituted by fossil fuels. However, as the energy system decarbonizes, potential insights from this methodology are less informative.

For those interested in shifting to use the substitution method for primary energy, the table below shows the calorific efficiency assumed for fossil fuels in previous editions of the *Energy Outlook*:

Assumed calorific efficiencies of fossil fuels

Year	Factor	Year	Factor	Year	Factor	Year	Factor
1965	36%	1990	36%	2015	40%	2040	44%
1970	36%	1995	36%	2020	41%	2045	44%
1975	36%	2000	36%	2025	41%	2050	45%
1980	36%	2005	37%	2030	42%		
1985	36%	2010	38%	2035	43%		

GDP is expressed in terms of real Purchasing Power Parity (PPP) at 2015 prices.

Sectors

Transport includes energy used in heavy road, light road, marine, rail and aviation. Light duty vehicles include 4-wheel vehicles under 3.5 tonnes gross vehicle weight. Electric vehicles (EVs) include all four wheeled vehicles capable of plug-in electric charging.
Industry includes energy used in commodity and goods manufacturing, construction, mining, the energy industry including pipeline transport, agriculture, forestry, fishing, and for transformation processes outside of power, heat and hydrogen generation.
Feedstocks include non-combusted fuel that is used as a feedstock to create materials such as petrochemicals, lubricant and bitumen.
Buildings include energy used in residential and commercial buildings.

Regions

'Developed economies' is approximated as United States, Canada, Europe and Developed Asia. 'Emerging economies' refers to all other countries and regions not in 'Developed economies'. China refers to the Chinese Mainland. Developed Asia includes OECD Asia plus other high income Asian countries and regions. Emerging Asia includes all countries and regions in Asia excluding mainland China, India and Developed Asia.

Fuels, energy carriers, carbon and materials

Oil, unless otherwise noted, includes crude (including shale oil and oil sands), natural gas liquids (NGLs), gas-to-liquids (GTLs), coal-to-liquids (CTLs), condensates, and refinery gains. Hydrogen-derived fuels are all fuels derived from low carbon hydrogen, including ammonia, methanol, and other synthetic hydrocarbons.

Renewables, unless otherwise noted, includes wind, solar, geothermal, biomass, biomethane, and biofuels and excludes large-scale hydro.
Non-fossils include renewables, nuclear and hydro. Traditional biomass refers to solid biomass (typically not traded) used with basic technologies e.g. for cooking.
Biofuels are liquid fuels made from bio-based solid or gaseous feedstocks. They include i) biogasoline (ethanol), ii) biodiesel, and iii) biojet (ASTM certified jet fuel). Mostly they come to market through blending with the relevant refined oil equivalent products, but the category can include directly usable bio-based liquid drop-in fuels such as renewable diesel (HVO) and bio-methanol.

Biogas is produced via a mature technology (anaerobic digestion) and is used directly for heat and power generation, or upgraded into biomethane for use in transport, utilities & other applications. Biogas which is not upgraded into biomethane is accounted for under modern solid biomass.

Hydrogen demand includes its direct consumption in transport, industry, buildings, power and heat, as well as feedstock demand for the production of hydrogen-dervied fuels and for conventional refining and petrochemical feedstock demand. Low carbon hydrogen includes green hydrogen, biomass, gas with CCUS, and coal with CCUS. CCUS options include CO_2 capture rates of 90-98% over the *Outlook*.

Key data sources

Energy Institute, Statistical Review of World Energy 2023, London, United Kingdom, June 2023.

International Energy Agency, World Energy Balances, July 2023.

Oxford Economics, Global Economics Databank, January 2024.

United Nations, Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022, Online Edition.

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