McKinsey & Company

Global Energy Perspective 2023

Executive Summary

November 2023

About this report

The Global Energy Perspective is produced by Energy Solutions, part McKinsey's Global Energy & Materials practice, in close collaboration with McKinsey Sustainability and the Advanced Industries practice. The Global Energy Perspective 2023 offers a detailed demand outlook for 68 sectors, 78 fuels, and 146 geographies across a 1.5° pathway , as well as four bottom-up energy transition scenarios with outcomes ranging in a warming of 1.6°C to 2.9°C by 2100. The bottom-up scenarios explore potential outcomes ranging from: the current trajectory, the existing climate commitments, and the consequences of "fading momentum" resulting in a delayed transition. Data to fuel these scenarios come from a variety of sources, including the IEA, IPCC, UN, Oxford Economics, USDA, Eurostat, EI Statistical Review of Energy, and EIA, among others.

The purpose of developing such a broad range of scenarios is to show the implications of different pathways as a fact base to inform decision makers. However, these scenarios are not exhaustive in the realm of all possible outcomes.

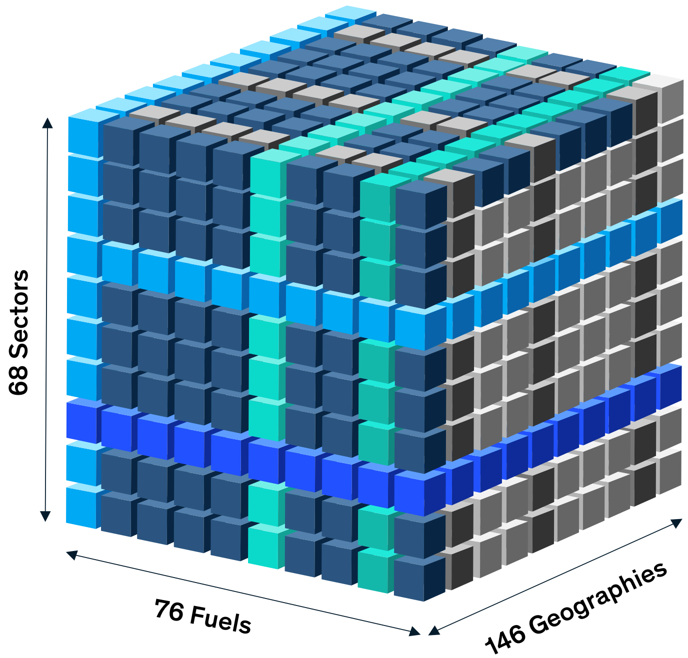
McKinsey is committed to our position that the world requires a major course correction to reach the goals aligned with the Paris Agreement, and our research is focused on helping meet those targets.

About Energy Solutions: Energy Solutions is McKinsey's global market intelligence and analytics group, focused on the energy sector. The group enables organizations to make well-informed strategic, tactical, and operational decisions by using an integrated suite of market models, proprietary industry data, and a global network of industry experts. It works with leading companies across the entire energy value chain to help them manage risk, optimize their organizations, and improve performance.

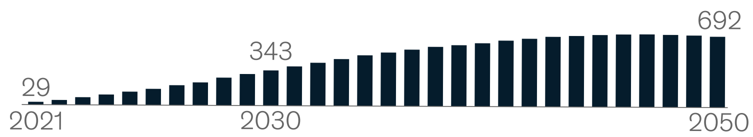
About McKinsey & Company: McKinsey is a global management consulting firm committed to helping organizations accelerate sustainable and inclusive growth. We work with clients across the private, public, and social sectors to solve complex problems and create positive change for all their stakeholders. We combine bold strategies and transformative technologies to help organizations innovate more sustainably, achieve lasting gains in performance, and build workforces that will thrive for this generation and the next.

McKinsey's Global Energy Perspective report is based on a suite of granular, fully integrated models that span the global energy landscape

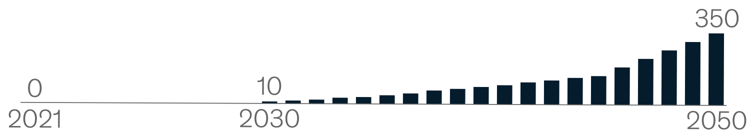
Our suite of models captures supply and demand dynamics across regions, sectors and energy products



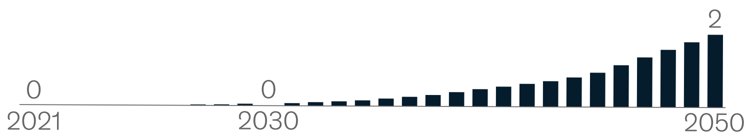
China electricity demand in passenger electric vehicles, TWh



US sustainable fuels demand in aviation, kbd



Brazil hydrogen demand in industry, Mtpa



Builds on 20+ proprietary McKinsey assets, including:

Input
- MCFM electric vehicle adoption model
- Sustainable fuels model
- Fleet decarbonization optimizer
- e-Trucks TCO model

Demand
- Industry demand model
- Chemicals model
- Hydrogen model
- Hydrogen trade flow model

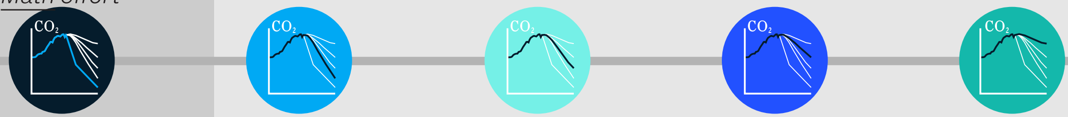
Supply
- McKinsey power model
- Power flexibility model
- Gas intelligence model
- Oil upstream model

Source: McKinsey Energy Solutions' Global Energy Perspective 2023

McKinsey's Global Energy Perspective 2023 explores a 1.5° pathway and four bottom-up energy transition scenarios

Scenarios center around pace of technological progress and level of policy enforcement

Speed of energy transition	*Modeled as part of McKinsey's Climate Math effort*	*Bottom-up energy transition scenarios modeled as part of Global Energy Perspective 2023*			
Slower					*Faster*
Description	**1.5° Trajectory**	**Achieved Commitments (AC)**	**Further Acceleration (FA)**	**Current Trajectory (CT)**	**Fading Momentum (FM)**
	A 1.5° pathway is adopted globally, driving rapid decarbonization investment and behavioral shifts	Net-zero commitments[1] achieved by leading countries through purposeful policies; followers transition at slower pace	Further acceleration of transition driven by country-specific commitments, though financial and technological restraints remain	Current trajectory of renewables cost decline continues; however, currently active policies remain insufficient to close gap to ambition	Fading momentum in cost reductions, climate policies, and public sentiment will lead to prolonged dominance of fossil fuels
Implied CO_2 price,[2] $/t$CO_2$, 2030—50	***$180+***	***$130–180***	***$70–140***	***$60–90***	***<$60***
Global temperature increase linked to emission levels[3]	***<1.5°C*** *(1.1–1.7)*	***1.6°C*** *(1.3–2.0)*	***1.9°C*** *(1.5–2.3)*	***2.3°C*** *(1.9–2.8)*	***2.9°C*** *(2.4–3.5)*



[1]Excluding international bunkers.
[2]Implied CO_2 prices that would trigger investments that enable the marginal abatement associated with each scenario, averaged over the different regions and countries in the world.
[3]Warming estimate is an indication of global rise in temperature by 2100 versus pre-industrial levels (range 17–83rd percentile), based on MAGICCv7.5.3 as used in IPCC AR6 given the respective energy and non-energy (eg, agriculture, deforestation) emission levels and assuming continuation of trends after 2050 but no net-negative emissions.
Source: McKinsey Energy Solutions' Global Energy Perspective 2023

The Global Energy Perspective 2023 explores the outlook for demand and supply of energy commodities across a 1.5° pathway (modelled as part of McKinsey's Climate Math efforts) , as well as four bottom-up energy transition scenarios with outcomes ranging in a warming of 1.6°C to 2.9°C by 2100. The rationale for the modeling is as follows:

1.5°C pathway: to assess what would be required to achieve the world's objective of limiting global warming below 1.5°C, McKinsey has developed a back casting model starting from the global carbon budget that identifies the most economic and feasible path to transition the current energy system across countries.

Bottom-up energy transition scenarios: to assess the different paths forward, McKinsey has established sector-based adoption models, in which it analyses model sector- and country-based adoption speeds of new technologies given a range of underlying insights and assumptions. These include existing and expected regulation, costs, asset lifetimes, supply chains, technological learning curves and economic optimization as a system.

Key insights from McKinsey's Global Energy Perspective 2023

1

Wide-ranging scenarios point to an unclear path ahead

The energy transition has gathered pace, but the path ahead is full of uncertainty in everything from technology trends to geopolitical risk and consumer behavior—making it difficult to shape resilient investment strategies that work in multiple scenarios. It is therefore increasingly challenging for decision makers to address multiple objectives at once, such as meeting long-term goals for decarbonization as well as short-term expectations for economic returns.

The Global Energy Perspective 2023 explores the outlook for demand and supply of energy commodities across a 1.5° pathway (modelled as part of McKinsey's Climate Math effort) , as well as four bottom-up energy transition scenarios. These scenarios sketch a range of outcomes based on varying underlying assumptions—for example, about the pace of technological process and the level of policy enforcement. Despite significant reductions in carbon emissions, all energy transition scenarios remain above the 1.5^{0} pathway and result in warming of between 1.6^{0} and 2.9^{0}C.

These estimates include non-CO_2 emissions, building in assumptions on non-energy emissions from sectors like agriculture, forestry, and waste.

To stay within the carbon budget necessary for the 1.5° pathway, a much steeper reduction in emissions would be required, particularly in the next ten years.

Source: McKinsey Energy Solutions' Global Energy Perspective 2023

2

Fossil fuel demand is projected to peak soon, but the outlook remains uncertain

Total demand for fossil fuels is projected to peak by 2030 in all scenarios. Although a sharp decline in coal demand is expected under all scenarios, natural gas and oil are expected to grow further in the next few years and then remain a core part of the world's energy mix for decades to come.

Total natural gas demand to 2040 is projected to increase under most scenarios, driven in large part by the balancing role that gas is expected to play for renewables-based power generation until batteries are deployed at scale. In the decade to 2050, the outlook for gas demand differs widely by scenario, from a steady increase under slower transition scenarios to a steep decline under scenarios in which renewables and electrification advance faster.

For oil, total demand is projected to continue growing for much of this decade and then to fall after 2030—but the extent of the decline differs significantly across scenarios. In the Achieved Commitments scenario, oil demand almost halves by 2050, mainly driven by the slowdown in car-parc growth, enhanced engine efficiency in road transport, and the continued electrification of transport. In the Fading Momentum scenario, oil demand would decline by just 3 percent over the same period; this reflects much slower electrification of the global car parc and lower penetration of alternative fuels in the aviation, maritime, and chemicals sectors as bottlenecks on materials and infrastructure limit their growth.

3

Renewables will make up the bulk of the power mix by 2050

Renewables are expected to continue their rapid growth, driven in part by their cost competitiveness—in many regions they are already the lowest-cost option for incremental new-build power generation. Renewable energy sources are expected to provide between 45 and 50 percent of global generation by 2030, and between 65 and 85 percent by 2050. In all scenarios, solar is the biggest contributor of renewable energy, followed by wind.

The ramp-up of renewables could see emissions from power generation reduced by between 17 and 71 percent by 2050 compared to present levels, despite a doubling or even tripling of demand. However, the renewables build-out faces challenges, from supply-chain issues to slow permitting and grid build-out implications.

The uptake of nuclear and carbon capture, utilization, and storage (CCUS) technologies could lower the burden on the renewables build-out, but depends on the political landscape and future cost development.

Coal (without CCUS) is expected to be phased out gradually. Power generation from hydrogen-ready gas plants—which support grid stability—is likely to increase.

4

Major investments in the energy sector will be needed, but remain stable as a share of GDP

Despite the increasing regulatory push for decarbonization and a declining demand for fossil fuels, between 25 and 40 percent of energy investments in 2040 will still be deployed in fossil fuels and conventional power generation to meet demand, offset declines in existing production fields, and balance the energy system. There will be a gradual but continued shift of investment focus from fossil fuels to green technologies and electric transmission and distribution. While accounting for only 20 percent of total investments in 2015, power renewables and decarbonization technologies are projected to make up between 40 and 50 percent of total investments by 2040.

Decarbonization technologies show the highest growth at between 6 and 11 percent per annum, mainly driven by the strong uptake of EV charging infrastructure and CCUS, which together are projected to account for the bulk of decarbonization investments by 2040.

In the more progressive scenarios, higher energy investments are mostly offset by lower total operating expenditure for fuels like coal and gas due to the shift towards more capital expenditure-intensive technologies l ike renewables.

Despite the absolute increase, energy investments as a share of GDP remain stable at between 1.2 and 2.2 percent across all years and scenarios.

5

Achieving a successful energy transition would require a major course correction to overcome bottlenecks and reach the goals aligned with the Paris Agreement

To deliver on the steep climate commitments made globally, substantial pivots are needed across industries and geographies. Even the more modest transition scenarios require that multiple bottlenecks are overcome.

Potential bottlenecks include land availability, energy infrastructure, manufacturing capacity, consumer affordability, investment willingness, and material availability.

The adoption of green hydrogen faces steep challenges mainly due to infrastructure needs and the high investments required to achieve large-scale deployment.

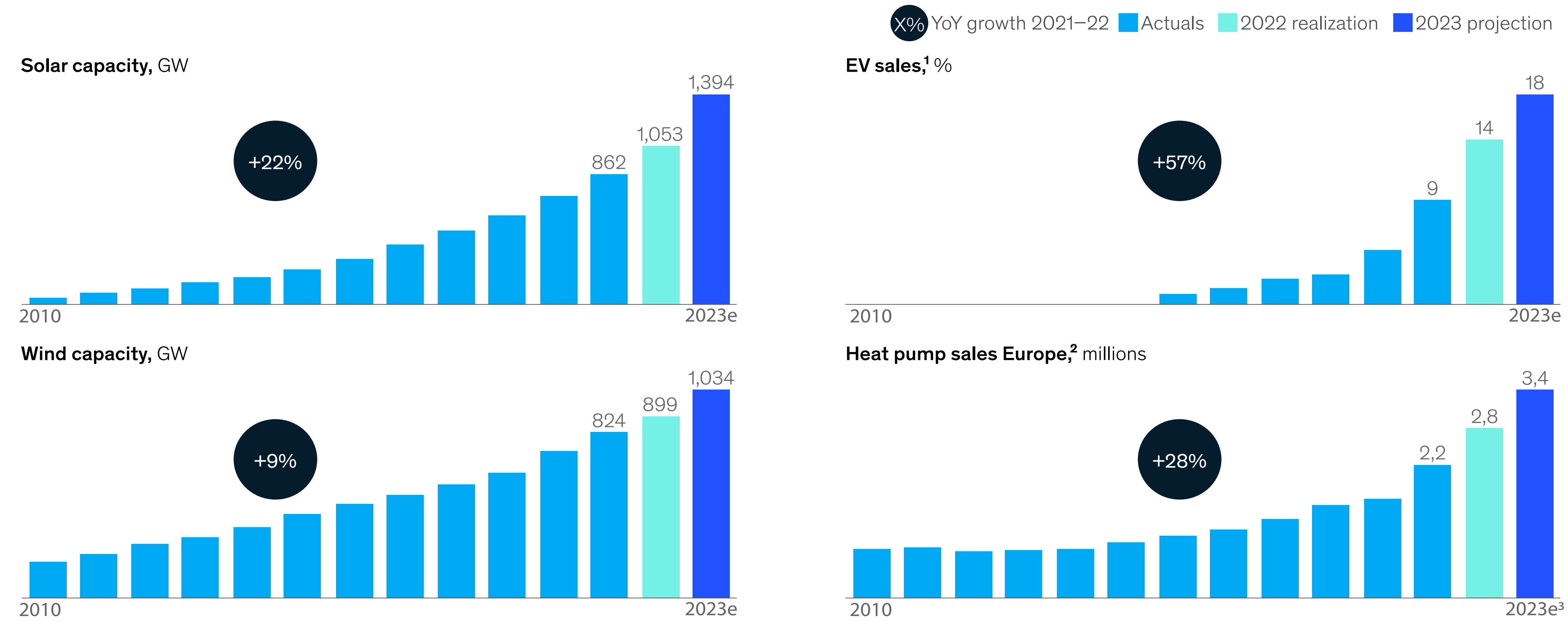
Rare materials are required for most energy transition technologies, with EVs and wind generation both highly impacted by materials bottlenecks.

Costs continue to be a barrier, but EVs and heat pumps are expected to become economically viable. Despite the big upfront investments needed, renewables become cost competitive in the Further Acceleration and Achieved Commitments scenarios.

While these bottlenecks could limit growth of some of the technologies known today, shortages are also likely to lead to price spikes that create additional investment opportunities and innovation.

Uptake of low-carbon technologies continued to grow in 2022 ...

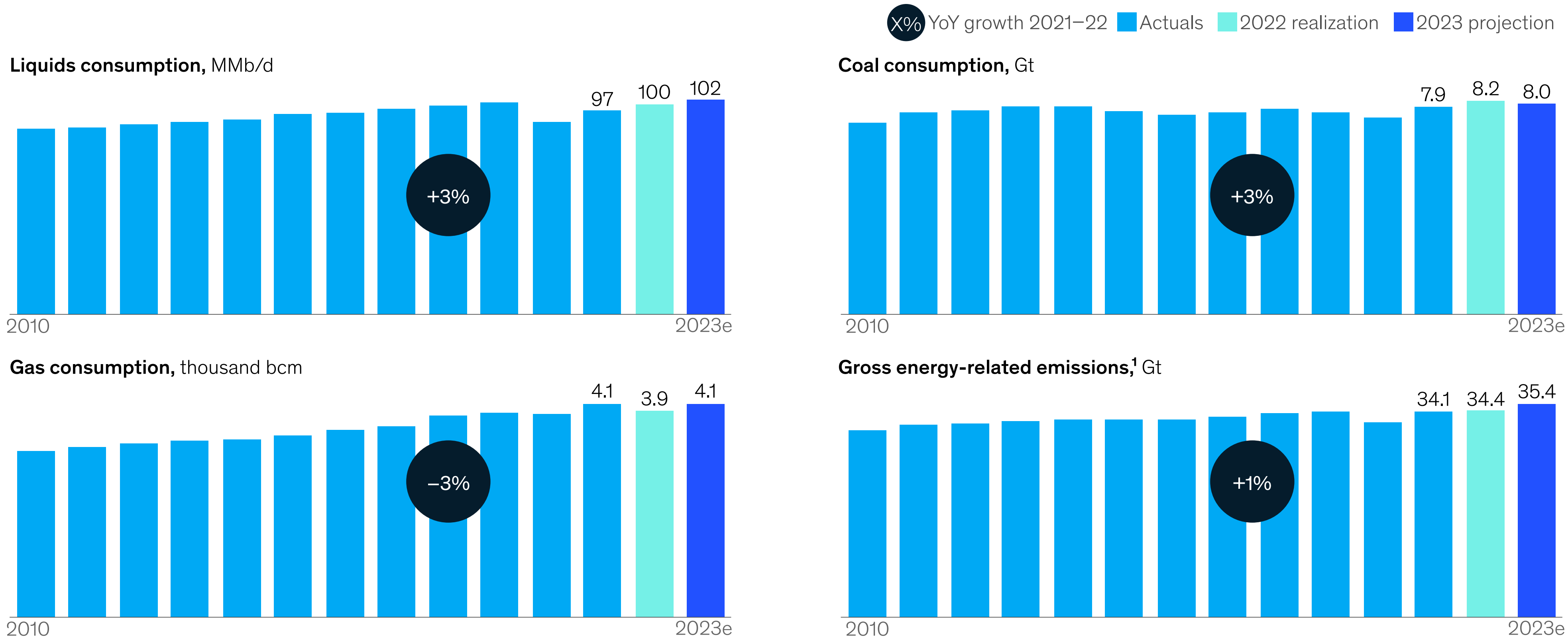
Investment into low-carbon technologies was $1,620 billion in 2022



[1]In 2022, the split in EV sales was ~70% fully electric and ~30 PHEV, excluding HEV.
[2]EU 21.
[3]2023 expected values are based on the expectations found in external sources, which are based on at least mid-year results. These depict a global average and may deviate by region.
Source: HP Europe; IEA; McKinsey Energy Solutions' Global Energy Perspective 2023

… alongside a persistent demand in fossils fuels and increase in emissions

Fossil-fuel investment was $1,000 billion in 2022

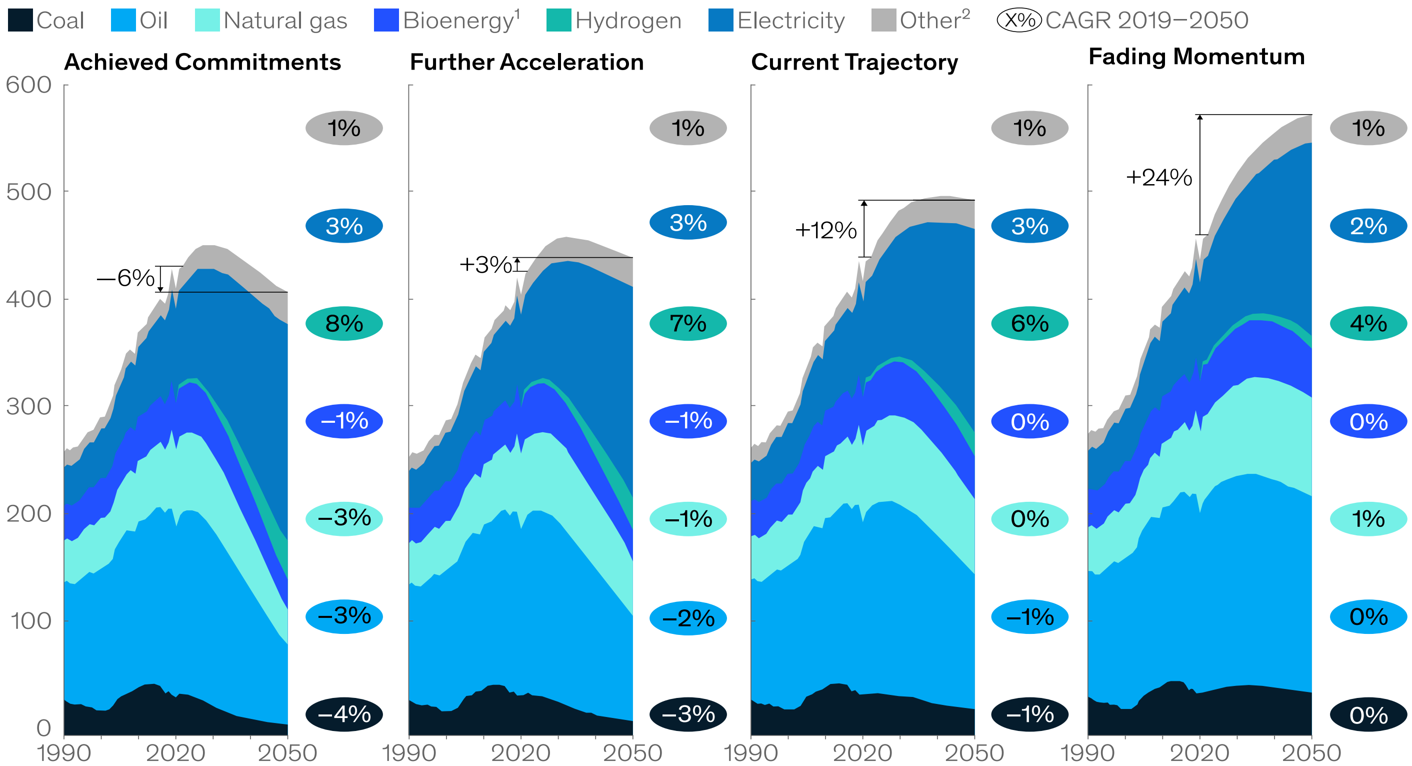


[1]Gross energy related CO2 emissions, excluding process emissions.
Source: HP Europe; IEA; McKinsey Energy Solutions' Global Energy Perspective 2023

Faster transition scenarios show stronger energy-efficiency gains and a faster uptake of electrification and low-carbon fuels

Share of electricity and hydrogen in final consumption is projected to be 27–37% by 2035 and 35–60% by 2050 across energy transition scenarios

Final energy consumption by fuel, million TJ



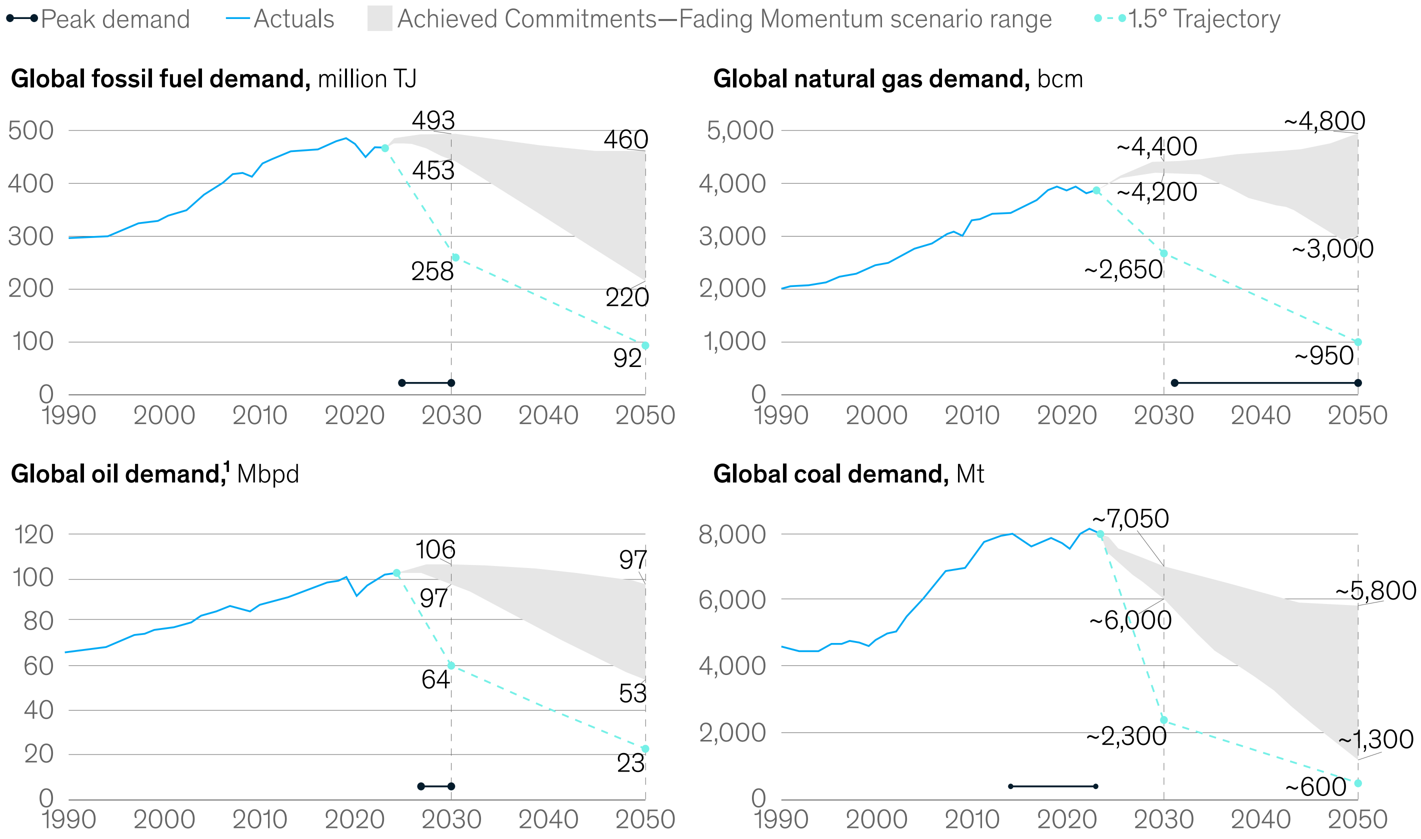
[1] Includes synthetic fuels, biofuels, and other biomass.
[2] Includes heat, geothermal, and solar thermal.
Source: McKinsey Energy Solutions' Global Energy Perspective 2023

Overall energy consumption is flattening or even declining in more progressive scenarios as the share of electrification increases (to 31–49% of the total energy mix). Electrification includes more efficient technologies:

- An **electric vehicle** is ~3–4x more efficient than an internal combustion engine vehicle.
- A **residential heat-pump** is ~2–4x more efficient than a natural gas boiler.
- An **industrial heat-pump** is ~3–5x more efficient than a coal or gas furnace for low to medium temperature heat.

Fossil fuel demand is projected to peak soon, but the outlook remains uncertain

Oil demand is projected to peak between 2025 and 2028, while coal is projected to continue its downward trend



[1]Includes biofuels, synfuels. Remaining oil in 1.5C by 2050 mainly in Aviation/Maritime and Chemicals.
Source: IEA World Energy Balances; McKinsey Energy Solutions' Global Energy Perspective 2023

Total **fossil fuel demand** is projected to peak before 2030 depending on the scenario, and is expected to make up 36% to 66% of global energy demand by 2050.

Total **natural gas** demand to 2040 is projected to increase under most scenarios, driven in large part by increasing electrification and the balancing role that gas is expected to play for high renewables-based power generation until batteries and alternative long duration energy storage become economically feasible and deployed at scale. In the decade to 2050, the outlook widens between scenarios as higher decarbonization ambitions limit the role of gas to pure balancing.

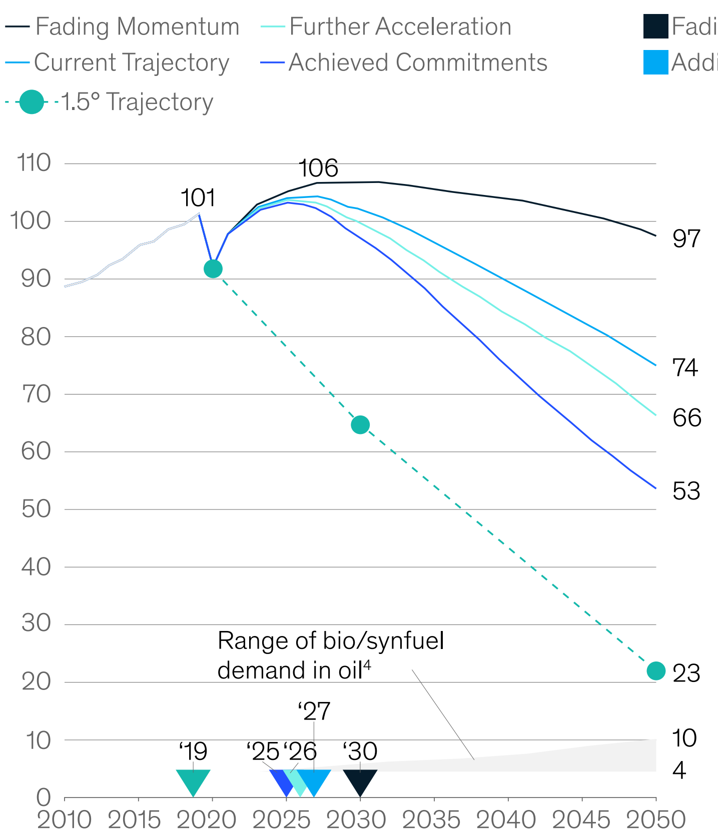
Oil demand growth is expected to slow substantially, with a projected peak in the mid 2020s, followed by a 48% decline in demand by 2050, mainly driven by car-parc growth slowdown, enhanced engine efficiency in road transport, and electrification.

Coal demand is projected to decrease by almost 25% to 85% between 2019 and 2050 depending on scenario, driven mainly by the phaseout of coal plants in the power sector across regions.

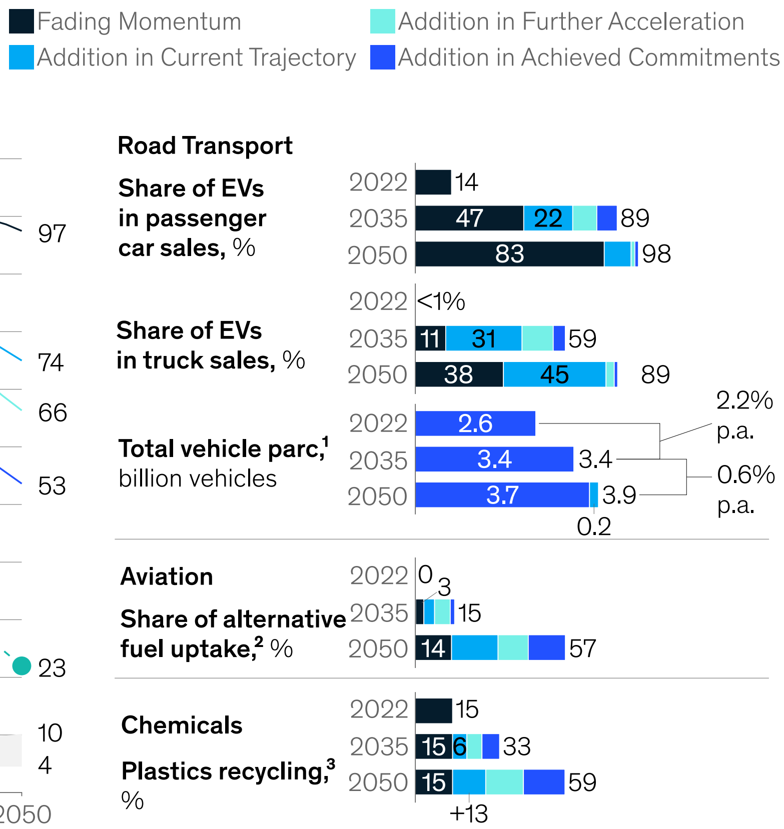
Trends in road transport, aviation, and chemicals are projected to drive oil demand decline across scenarios

These sectors account for >60% of the difference in the range of liquids demand in 2050

Oil demand (including bio- and synfuel), MMb/d



Key oil demand drivers



After a steep decline due to COVID-19, oil demand has started to increase and is expected to reach pre-pandemic levels by 2023. However, peak demand is expected by 2030 in all scenarios.

The speed of EV uptake is expected to be the biggest factor that will determine the timing of peak oil demand, even though total vehicle parc is still projected to grow.

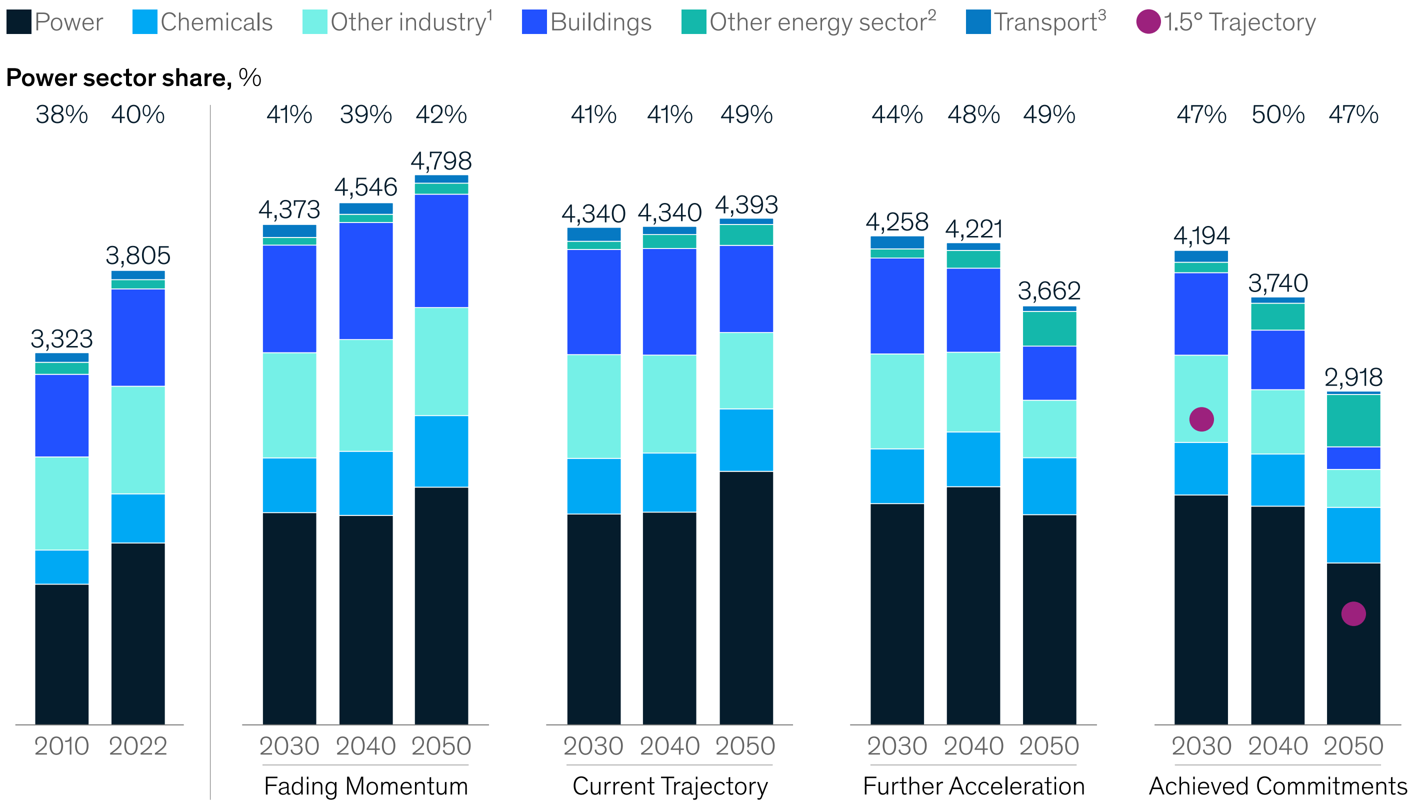
The extent to which growth in demand for chemicals and aviation will slow down will likely also play a decisive role. In chemicals, high oil prices and circularity ambitions may increase plastic recycling rates. In aviation, growth of both bio- and synfuels might further reduce the need for crude oil.

[1]Scenarios shown in order of smallest to largest car parc.
[2]Includes biofuels, synfuels, hydrogen, natural gas, and electricity.
[3]% of global plastic waste to recycling, incl. pyrolysis.
[4]Range between Achieved Commitments and Fading Momentum scenarios, excluding 1.5° Trajectory.
Source: McKinsey Energy Solutions' Global Energy Perspective 2023

Gas demand is expected to increase to 2040 across scenarios but varies by around 2,000 bcm by 2050

Growth in power offsets decline in industry and buildings—until power also starts to decline

Natural gas demand by sector, bcm



[1]Iron and steel, heat generation, and primary industries.
[2]Refining, hydrogen, and other sustainable fuel production.
[3]Aviation, maritime, rail, road transport.
Source: McKinsey Energy Solutions' Global Energy Perspective 2023

Power, industry, and buildings remain core sectors driving gas demand to 2050. In the longer term, the growing importance of gas used for blue hydrogen production is also likely to drive demand.

Chemicals and **blue hydrogen production** are the only sectors expected to show continuous growth in gas demand until 2050.

In the **power sector,** gas is projected to increasingly assume a balancing role for renewables generation until batteries are deployed at scale. Thus, demand is expected to grow aggressively in the AC and FA scenarios before declining after 2035. In contrast, the more conservative FM and CT scenarios will see more moderate growth to 2050.

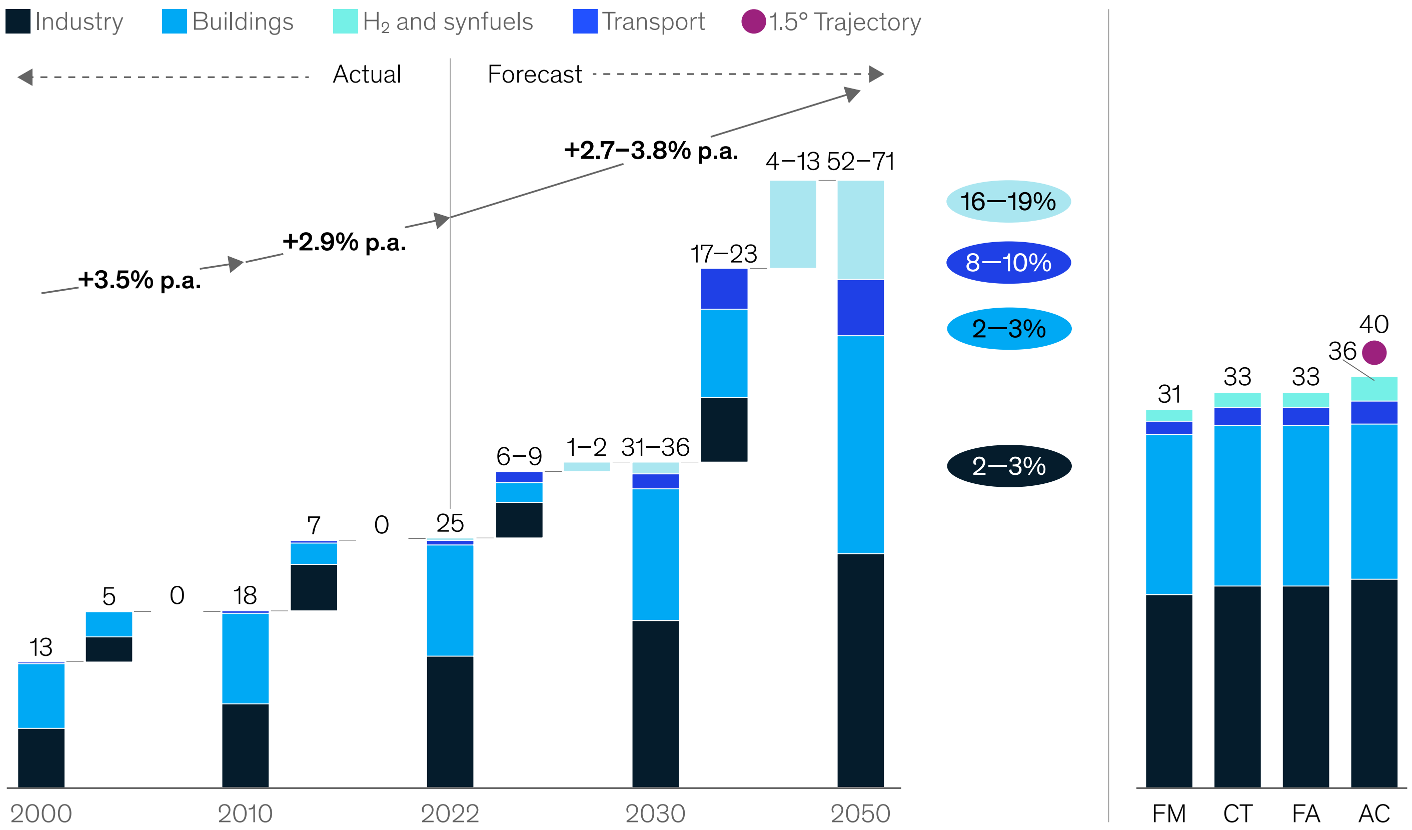
In the **buildings sector,** electrification and biogas are likely to displace gas as more energy efficient designs are applied. While demand in the FM and CT scenarios grows until the late 2030s, demand already declines by the 2020s in the FA and AC scenarios.

In **industry** (excluding chemicals), the electrification of heat and machine drive is projected to ultimately result in a gradual decline in gas demand, mirroring the buildings sector.

Power demand is projected to keep increasing by 3–4% p.a. across scenarios due to electrification and a rising green H_2 demand

Relative growth is projected to be largest in the transport and green hydrogen sector

Global power consumption by sector across scenarios (Fading Momentum to Achieved Commitments), thousand TWh



Source: IEA; IRENA; McKinsey Energy Solutions' Global Energy Perspective 2023

Electricity demand is projected to more than double from ~52,000–71,000 TWh by 2050, driven by:

Transport: The relative growth of power demand is steep in the transport sector, driven by passenger EVs, which are projected to reach subsidy-free cost parity with ICE vehicles by ~2025 in Europe, China, and the US, resulting in a 1.3 billion passenger BEV car parc by 2050 (almost the same number as total cars today).

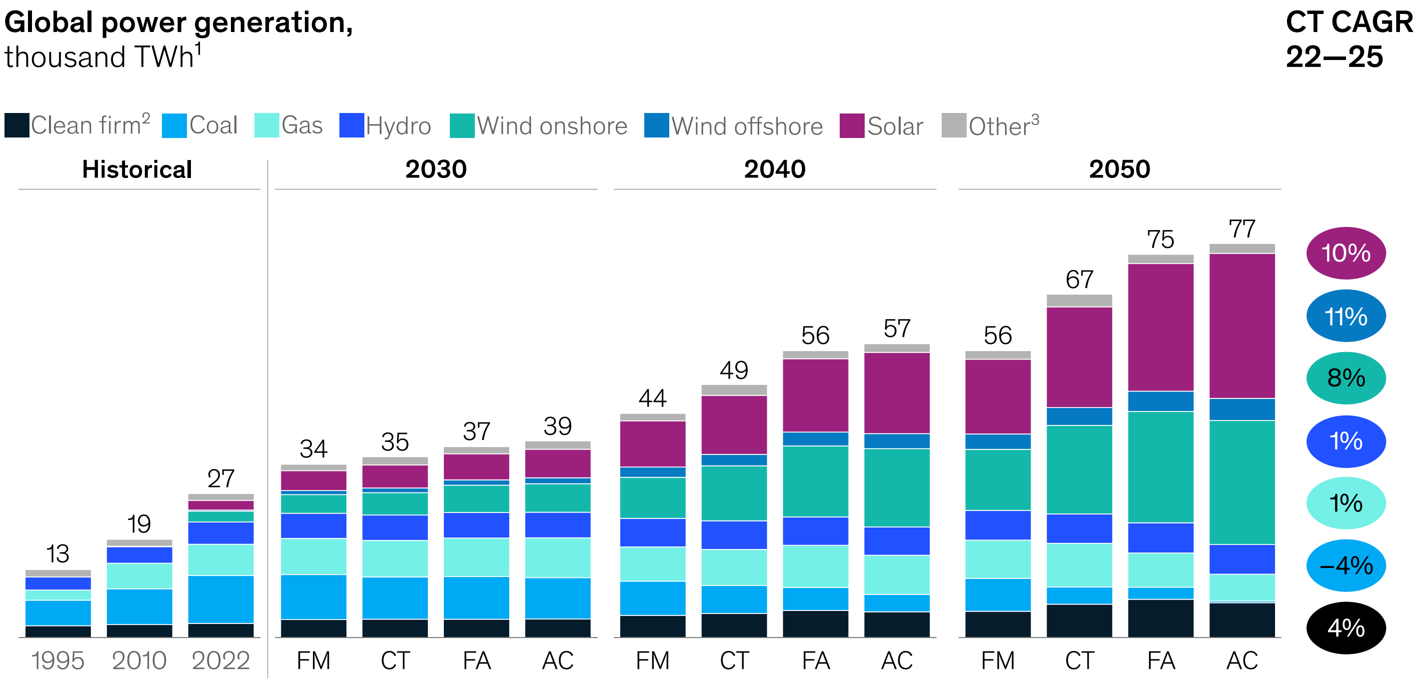
H_2 and synfuels: While demand today is still negligible, power demand for green H_2 is projected to scale rapidly, especially after 2030, driven by road transport and chemicals.

Industry: Power demand for industry is projected to double from 2019 to 2050, driven mainly by electrification of low- to medium-heat processes.

Buildings: Electrification is projected to double power demand, with high adoption of heat pumps and increased cooling demand in OECD countries pushing rapid growth before 2035.

Renewables are projected to make up the bulk of the power mix into the future, while clean firm and gas power generation increase across most scenarios

The share of renewables in the power mix could more than double in the next 20 years



	1995	2010	2022	2030 FM	2030 CT	2030 FA	2030 AC	2040 FM	2040 CT	2040 FA	2040 AC	2050 FM	2050 CT	2050 FA	2050 AC
Share of renewables,[4] %			32%	~45%	~50%	~50%	~50%	~60%	~65%	~70%	~70%	~65%	~75%	~80%	~85%
CO_2 emissions, Gt			13	~13	~12	~12	~11	~11	~9	~8	~7	~11	~8	~6	~4

[1] Excludes generation from storage (pumped hydro, batteries, LDES).
[2] Includes gas and coal plants with CCUS, nuclear, and hydrogen.
[3] Other includes bioenergy (with and without CCUS), geothermal, hydrogen-fired gas turbines, and oil.
[4] Includes solar, wind, hydro, biomass, BECCS, geothermal, and marine and hydrogen-fired gas turbines.
Source: McKinsey Energy Solutions' Global Energy Perspective 2023; McKinsey Power Model

Renewables are expected to continue to grow rapidly, and are projected to provide ~45–50% of generation by 2030 and ~65–85% by 2050. By 2050, emissions could be reduced by 18–72% compared to present levels. However, renewables build-out poses several challenges, from supply chain issues to slow permitting and local resistance.

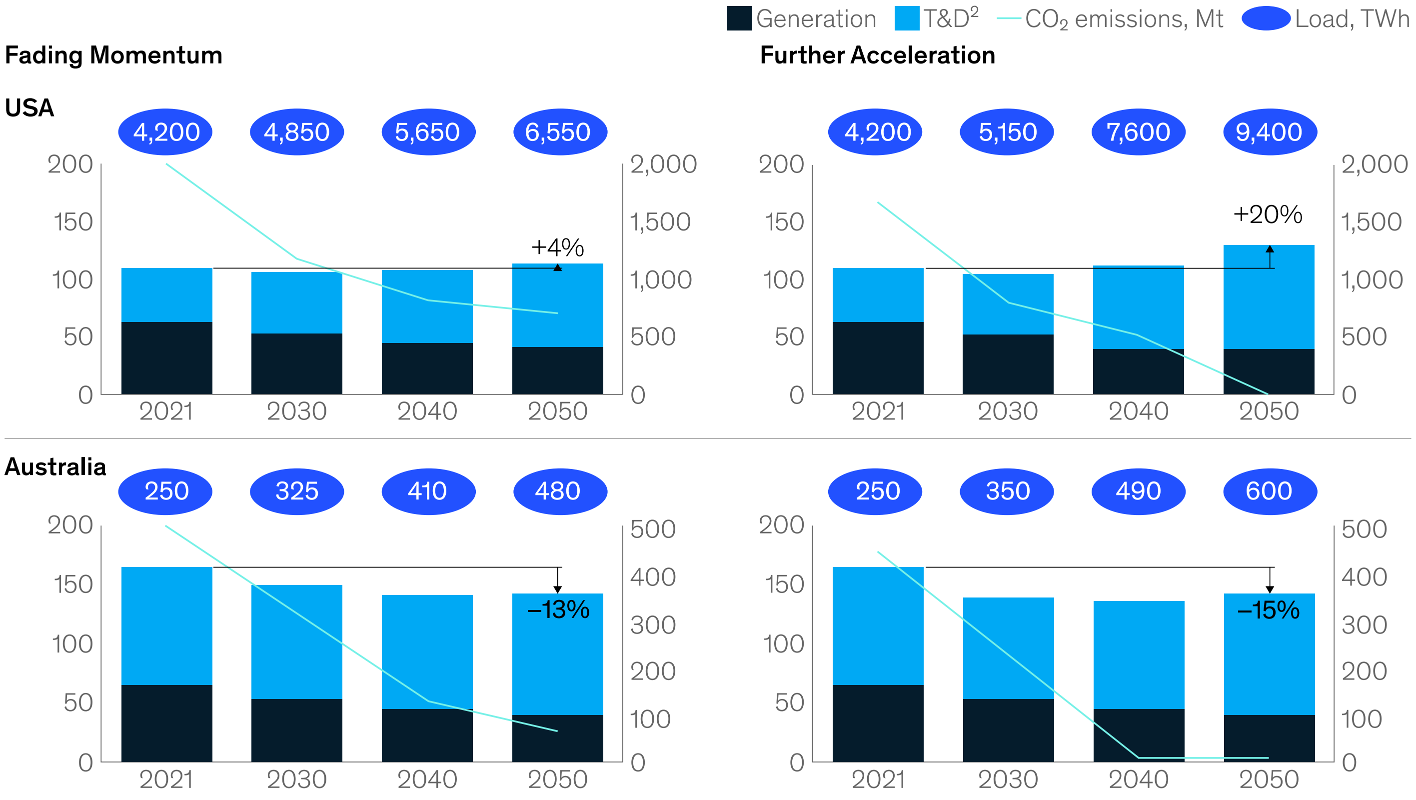
The uptake of nuclear and CCUS technologies could lower the burden on renewables build-out, but depends on the political landscape and future cost development.

Amongst the thermal technologies, **coal (without CCS)** is expected to be phased out gradually. Power generation from **H_2-ready gas plants** is likely to rise due to their importance for grid stability.

The share of grid cost in total average delivered power costs to customers is expected to increase across scenarios and regions

Delivery costs per MWh are projected to increase to 60–70% of costs by 2050 in the US and Australia

Average system cost of electricity,[1] 2021 $/MWh



[1]Excludes retail margin, VAT, carbon taxes, subsidy recovery, etc. Assumes electrolyzers are co-located with renewables. 2. Transmission and distribution; distribution costs are preliminary and most depend upon system planner preference.
Source: McKinsey Energy Solutions' Global Energy Perspective 2023

The cost of power generation over time tends to decline in future power systems; however, delivery costs (T&D) per MWh is projected to grow from ~40% in the US to 60–70% of costs by 2050, with a similar outlook in Australia.

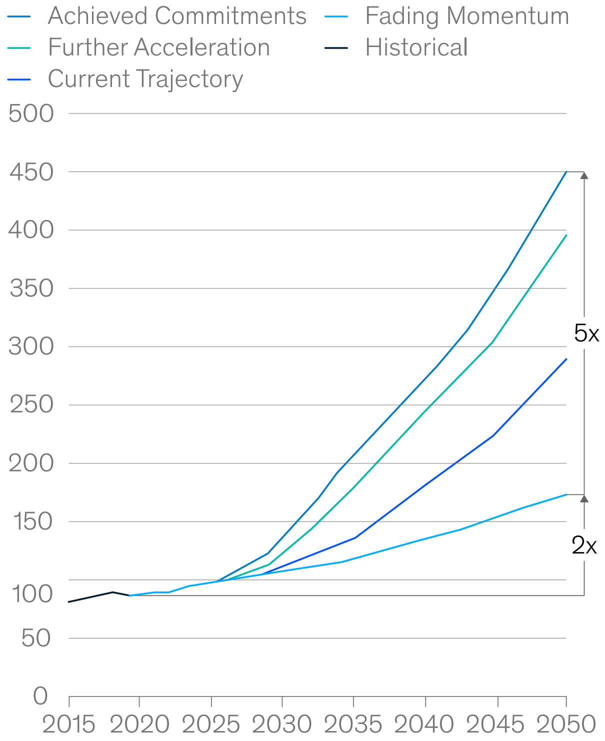
Larger T&D investments in faster transition scenarios are partially offset by a higher load in a more electrified economy, but not entirely. Faster transition scenarios' advantage in generation cost reflects the more rapid cost declines for renewables (eg, $15–20/MWh for solar by 2050). Whereas generation costs decline as the share of low-cost renewables increases (depending on the country), a rise in T&D costs offsets this trend. As a result, aggregate power costs are projected to remain flat in most countries and can potentially rise once power systems approach full decarbonization.

System design choices have a large impact on total costs, including factors such as undergrounding for resiliency, grid modernization to support DERs, and siting of heavy industrial loads (eg, hydrogen or datacenter clusters).

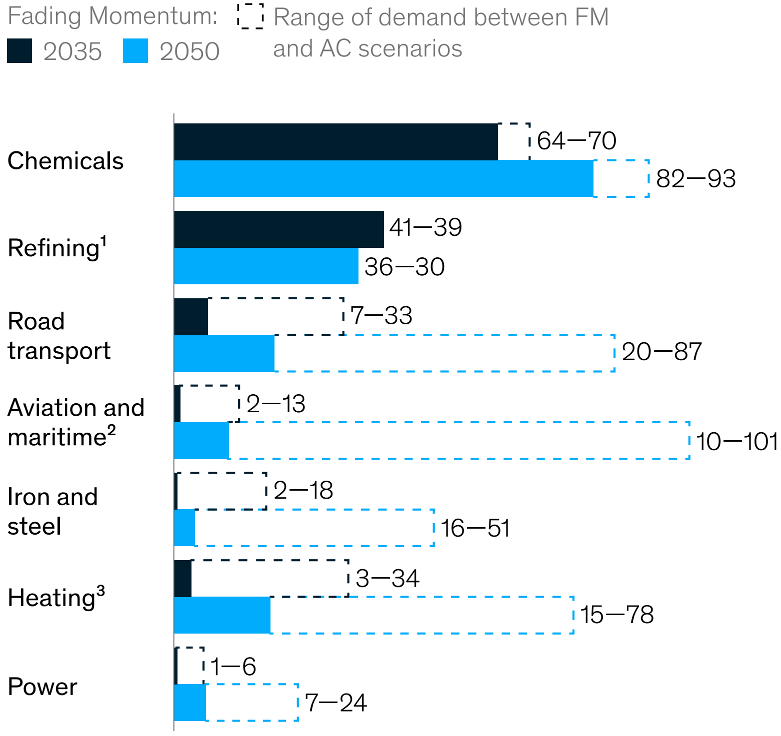
Across scenarios, hydrogen demand is projected to grow two to five times by 2050

Scenarios show strong differentiation post 2030, as growth trajectory for hydrogen remains uncertain

Global hydrogen demand outlook by scenario, Mtpa



Global hydrogen demand by sector, Fading Momentum to Achieved Commitments scenarios, Mtpa



Hydrogen demand today is mostly driven by **chemicals and refining,** accounting for a total of ~90 Mtpa, which is almost entirely supplied by fossil fuel-based production.

Going forward, the decarbonization agendas of governments and companies are expected to drive hydrogen uptake in new sectors which will demand clean hydrogen.

The level of decarbonization achieved will likely drive significant uncertainty in hydrogen uptake in these new applications across scenarios.

Refining is the only sector in which demand is expected to decline compared to today as a result of the shift from oil to electrification of transport.

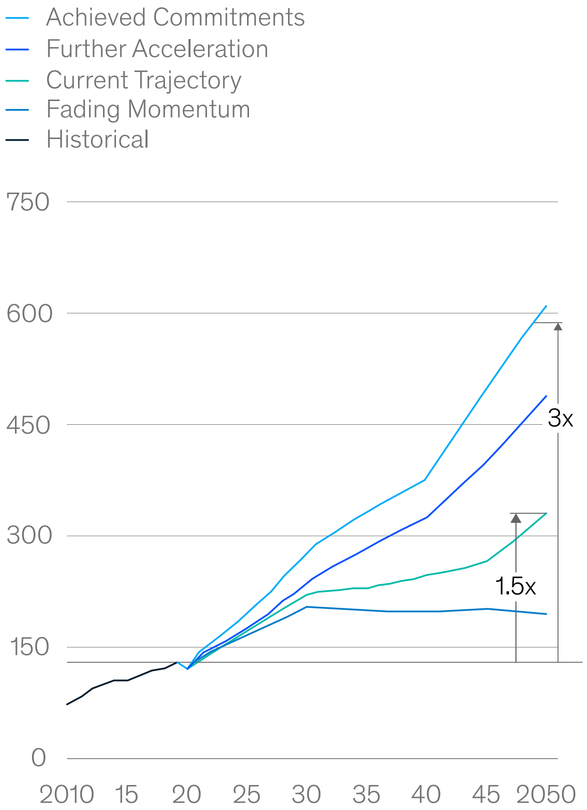
Post-2030, in the Achieved Commitments scenario, more ambitious legislation and faster technological developments will drive higher penetration of low-carbon hydrogen technologies, especially in hard-to-abate sectors.

[1] Includes conventional fuels refining and biofuels hydrogenation and refining.
[2] Aviation and maritime include direct use of hydrogen and hydrogen-derived synfuels including kerosene, diesel, methanol, gasoline, and ammonia. The category also includes some hydrogen-derived synfuels in road transport.
[3] Includes hydrogen demand for heating in other industry and buildings.
Source: McKinsey Energy Solutions' Global Energy Perspective 2023

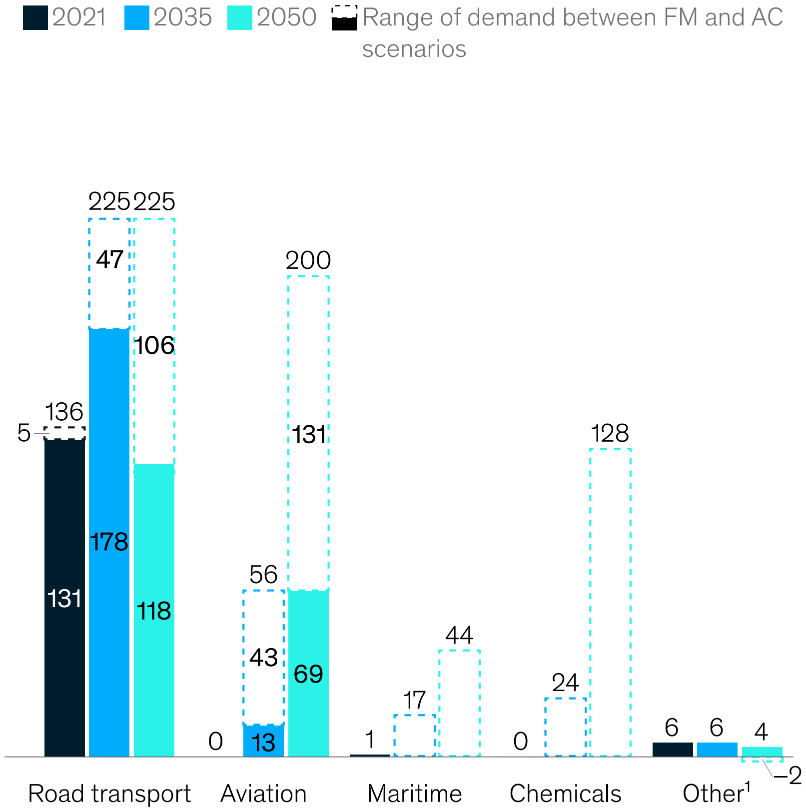
Sustainable fuels demand is expected to grow significantly, tripling by 2050 in some scenarios

Main differentiation in growth rates between scenarios occurs in 2030–2050

Global sustainable fuels demand outlook by scenario, Mta



Global sustainable fuels demand by sector, Fading Momentum to Achieved Commitments scenarios, Mta



Across scenarios, sustainable fuels are expected to play an increasingly important role in the transportation sectors, including hard-to-abate sectors such as aviation, maritime, and heavy-duty road transport.

The demand for sustainable fuels is projected to be consistently high for road transport given its strong starting point and existing momentum for decarbonization, the variability between scenarios is largely driven by the less mature markets like aviation, maritime, and chemicals.

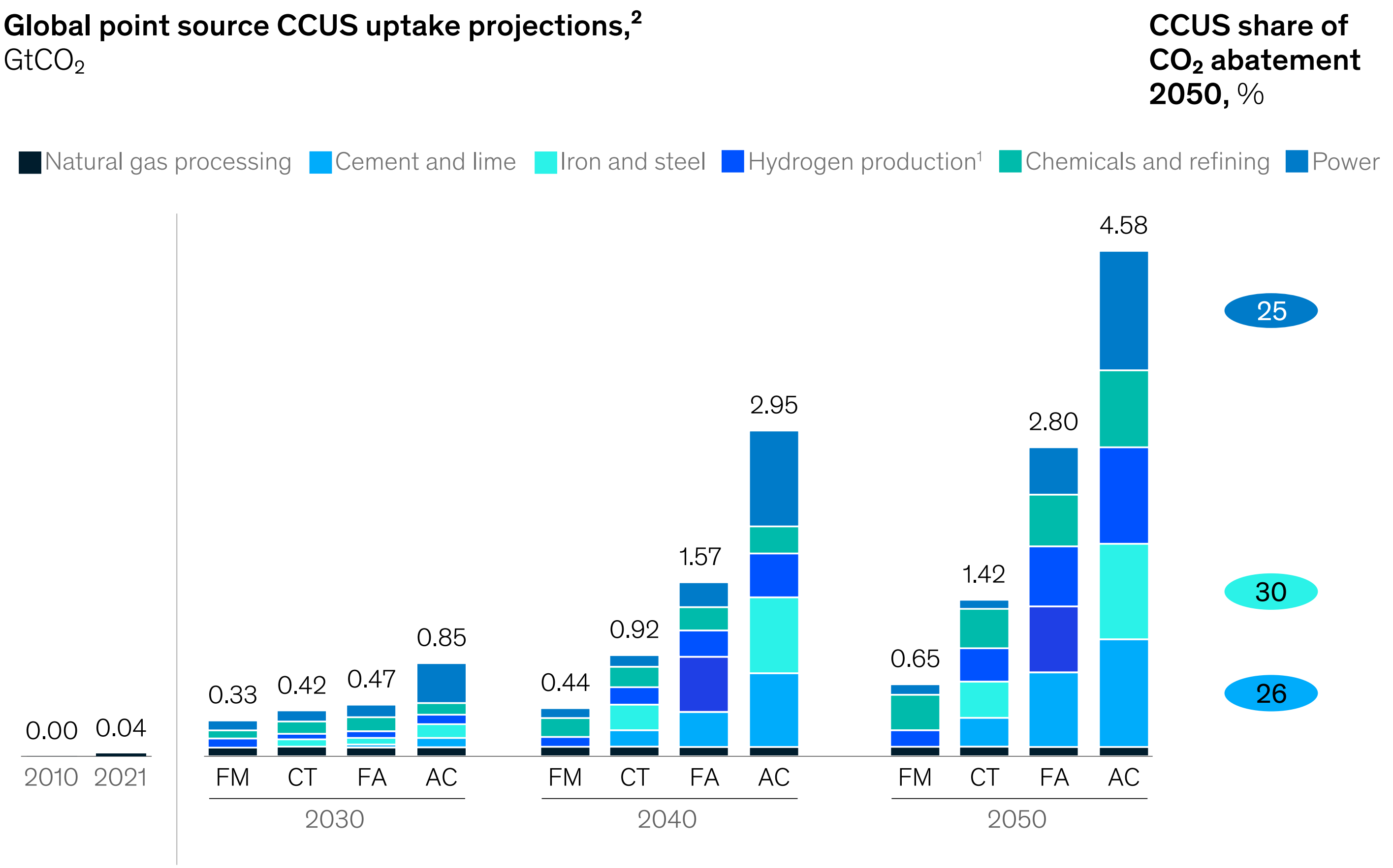
The long-term contribution of sustainable fuels to decarbonization will likely be driven by the level of regulatory ambition (including subsidies, mandates, and tax credits) and technological advancement. Uptake of sustainable fuels by 2030 will mainly be driven by regulation which has already been proposed. By 2050, the demand for sustainable fuels could be between ~190 Mta (in the Fading Momentum scenario) and ~600 Mta (in Achieved Commitments) depending on the level of net-zero ambition across countries.

[1]Other includes iron and steel, other industry, buildings, and electricity generation.
Source: McKinsey Energy Solutions' Global Energy Perspective 2023; McKinsey Sustainable Fuels Model

Global CCUS landscape is diversifying with carbon emissions being captured from a wider array of sources

Cement, blue hydrogen, iron and steel, and power are projected to account for over 80% of total CCUS uptake by 2050

Global point source CCUS uptake projections,[2]
$GtCO_2$



[1]Hydrogen production excluding H_2 for ammonia, methanol, and refineries.
[2]Emerging negative emission technologies (eg, BECCS and DACCS) can add uncertainties to CCUS demand outlooks, but these technologies are currently at a very early stage.
Source: McKinsey Energy Solutions' Global Energy Perspective 2023

Globally, cement, blue H_2, iron and steel, and power collectively represent over 80% of the total uptake of CCUS by 2050, although industry composition varies significantly by region.

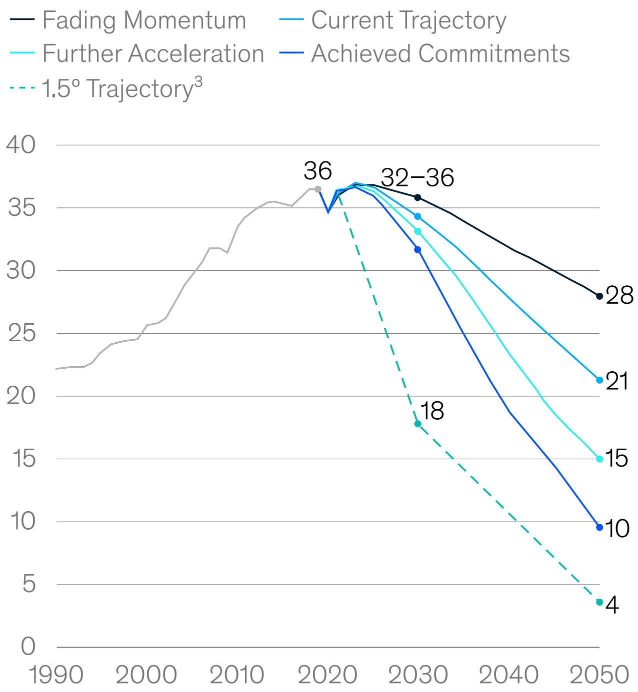
While physical storage space to reach these levels of sequestration is available, CCUS adoption includes high uncertainties, influenced by factors such as regulatory incentives, technological advancements, economic feasibility, and how it interacts with alternative decarbonization technologies, as addressing emissions in hard-to-abate sectors requires a holistic approach that considers multiple technologies (eg, BF-BOF and CCUS, EAF, DRI-H_2-EAF in iron and steel).

CCUS can potentially play a significant role in the decarbonization of power (reaching about 1–2 Gtpa in 2050), particularly in regions where renewable energy faces limitations due to grid constraints or the scarcity of optimal sites. CCUS also offers a solution to prevent stranded assets for regions with young coal and gas power plants.

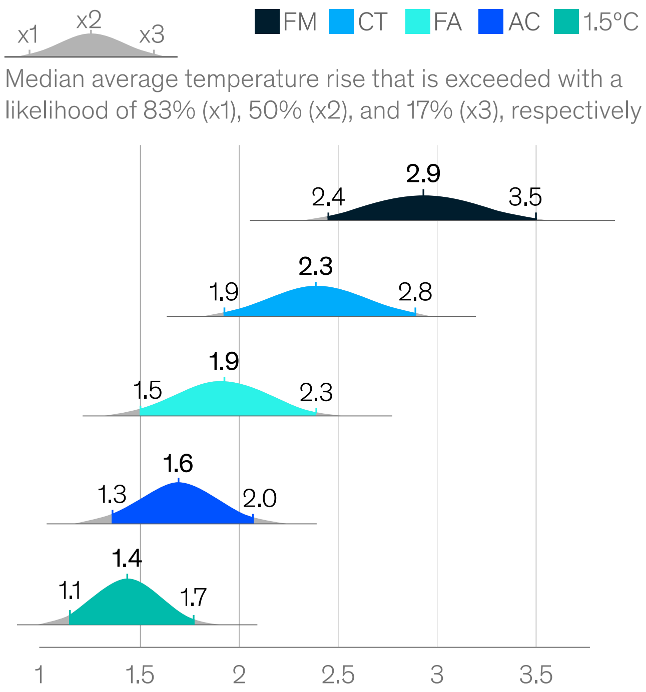
Global emissions remain above a 1.5° pathway even if all countries deliver on their current commitments

Knock-on effects and regional differences could drive significantly higher temperature increases locally

Global CO_2 emissions from combustion and industrial processes,[1]
GtCO₂ p.a.



Average global warming estimate,[2]
°C increase compared to 1850



Emissions are expected to peak in the mid-2020s across energy transition scenarios. The global warming estimates include non-CO_2 emissions, and include assumptions on emission pathway developments of non-energy emissions in sectors like agriculture, forestry, and waste.

Despite these significant reductions in emissions, all our four bottom-up scenarios (AC, FA, CT, and FM) remain above the net-zero target required to achieve a 1.5°C pathway, and result in average projected warming of 1.6°C to 2.9°C.[2]

To stay within the carbon budget necessary to keep warming within 1.5°C, a much steeper reduction in emissions is required, particularly in the next decade. After 2030, the 1.5° pathway sees a more gradual decline in emissions toward net zero by 2050.

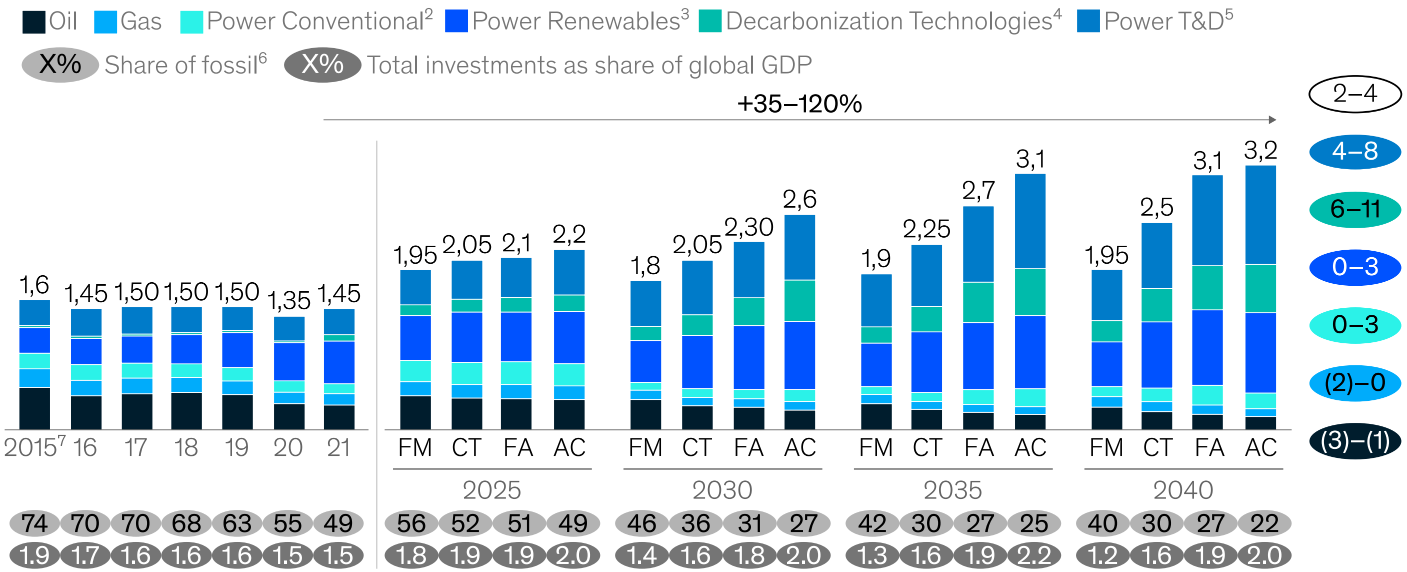
[1] Includes process emissions from cement production, chemical production and refining, and negative emissions from applying CCUS.
[2] Warming estimate is an indication of global rise in temperature by 2100 versus pre-industrial levels, based on MAGICCv7.5.3 as used in IPCC AR6 given the respective energy and non-energy (eg, agriculture, deforestation) emission levels and assuming continuation of trends after 2050 but no net-negative emissions.
[3] The remaining emissions in 2050 (~4Gt) are compensated by negative emissions from DACCS, BECCS, and reforestation.
Source: IEA World Energy Balances; IEA Global Energy Review 2022; McKinsey Energy Solutions' Global Energy Perspective 2023

Investments in the energy sector grow by 35–120% until 2040 but stay in line with historical shares of GDP

Decarbonization technologies are projected to outgrow total investments significantly, at 6–11% p.a.

Global investments in the energy sector[1]
annual, $ trillion (2021)

CAGR 2021–40, %



[1]Includes upstream and selected parts of midstream and downstream (ie, power T&D, EVCI, CCS capture, compression, transport, and storage); total values rounded.
[2]Power conventional includes power generation from coal, gas, nuclear, and oil (including plants with CCS technologies).
[3]Power renewables includes power generation from solar PV, onshore wind, offshore wind, hydro, storage (incl. batteries), and other.
[4]Decarbonization technologies include sustainable fuels production, hydrogen production, CCS, EVCI, and district heating.
[5]T&D includes hardware and labor (ie, T-circuit, D-circuit and T&D transformers new build-out, excluding upgrades of existing stock).
[6]Includes oil, gas, and power conventional (compared to total investment, excluding power T&D).
[7]Historical values are based on IEA data, with the exception of decarbonization technologies values which are based on IRENA data until 2020. 2021 is the first year modeled by McKinsey Energy Solutions' Energy & Pricing Value Pools model.
Source: IEA World Energy Investments 2023; IRENA World Energy Transition Outlook 2023; McKinsey Energy Solutions' Global Energy Perspective 2023; McKinsey Energy Solutions' Energy & Pricing Value Pools 2023; McKinsey Global Institute

Total annual investments in the energy sector[3] are projected to grow by up to 4% p.a. until 2040, reaching ~$2.0 trillion to $3.2 trillion.

Despite the increasing regulatory push for decarbonization and a declining demand for fossil fuels in the mid term, ~20–40% of investments[2] in 2040 will still be deployed in fossil fuels. This is partially driven by increasing unitary capex for fossil fuels from higher development cost, whereas unitary capex for green technologies is projected to decrease.

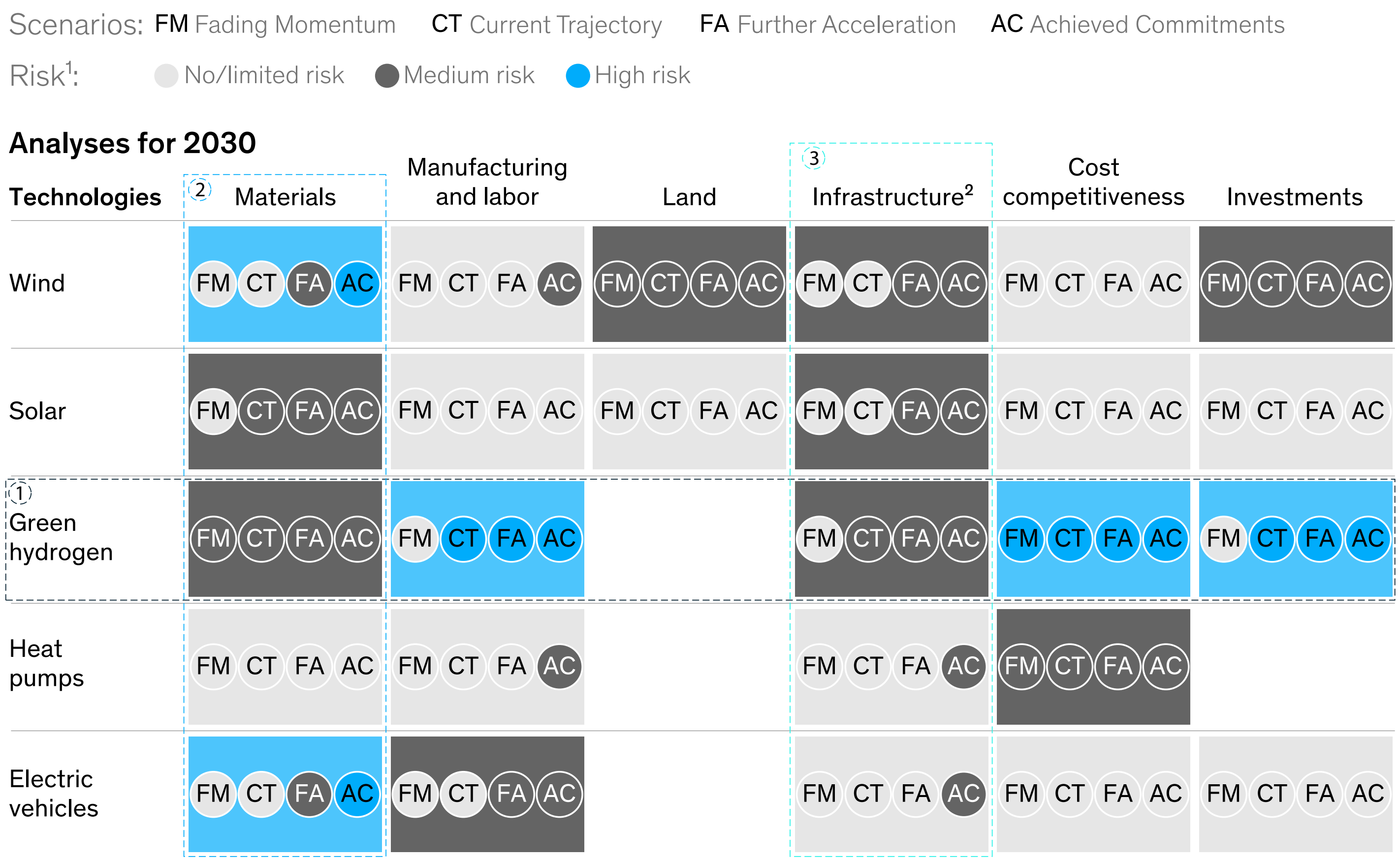
A gradual but continuous shift of investment focus from fossil fuels to green technologies is expected. While accounting for only ~25% of total investments (excluding T&D) in 2015, power renewables and decarbonization technologies are projected to make up ~60–80% of total investments (excluding T&D) by 2040.

Decarbonization technologies show the highest growth (6–11% p.a.), mainly driven by the strong uptake of EVCI and CCS (together accounting for 50–60% of decarbonization investments by 2040).

Higher investments in progressive scenarios are mostly offset by lower total opex (eg, fuel cost), due to the shift toward more capex-intensive technologies (such as renewables). Nonetheless, investments as a share of GDP remain at ~1.2–2.0% by 2040.

Achieving a successful energy transition would require a major course correction to overcome bottlenecks and reach the goals aligned with the Paris Agreement

To unlock critical energy transition technologies, key bottlenecks need to be overcome



[1]Medium risk represents where bottlenecks have been identified as well as potential unlocks of historic examples that demonstrate ramp-up is realistic. High risk represents where bottlenecks have been identified and no unlocks to address issue are available yet.
[2]T&D for wind and solar, transport and fueling infrastructure for (green) H_2, EVCI for electric vehicles.
Source: McKinsey Energy Solutions' Global Energy Perspective 2023

The rapid growth of some of the most critical energy transition technologies requires the expansion and partial creation of markets and supply chains. Meeting this growth will require innovation, entrepreneurship, and regulation to overcome bottlenecks. Potential bottlenecks include land availability, energy infrastructure, manufacturing capacity, consumer affordability, investment willingness, and material availability. Some example areas that require particular focus are:

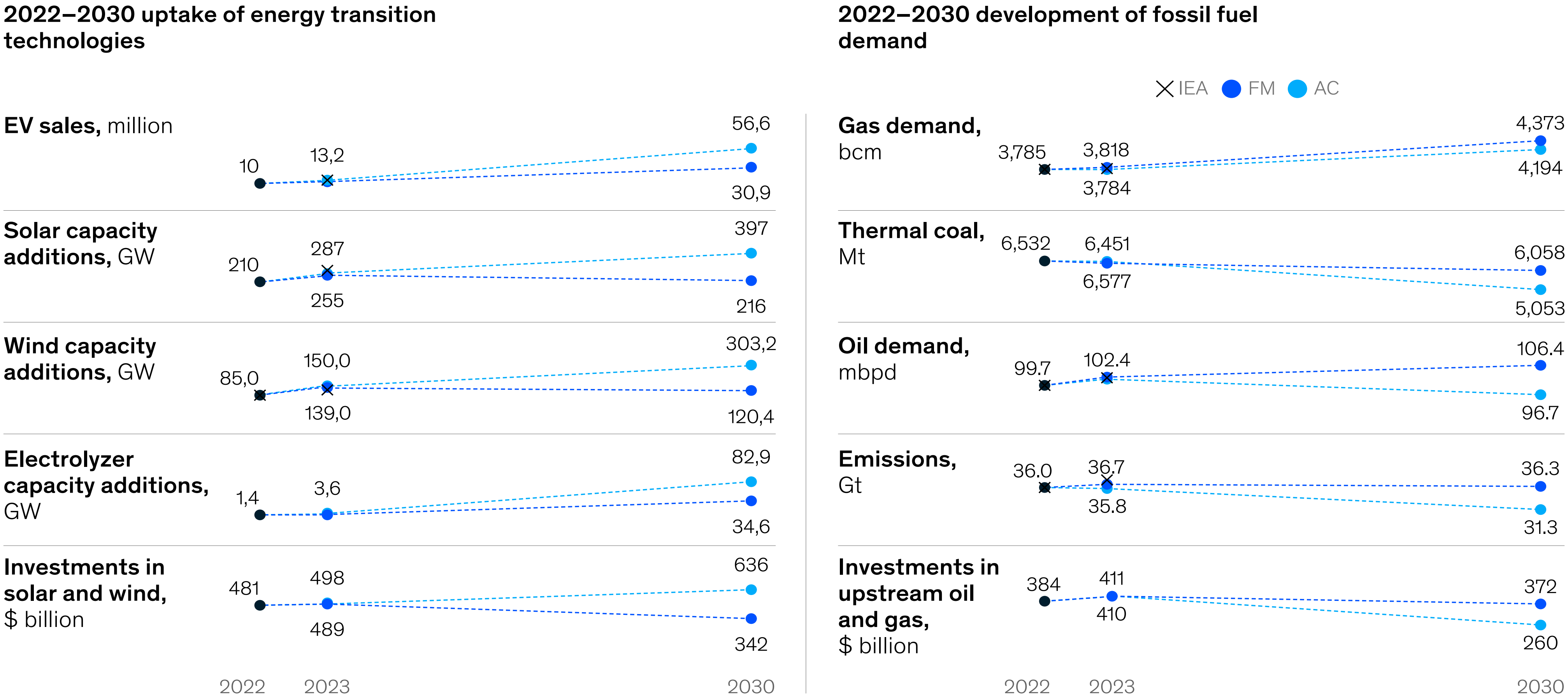
1. **Green hydrogen**
High risk of becoming bottlenecked is mainly due to infrastructure needs and high investments required to achieve large-scale deployment.

2. **Materials**
Rare materials are required for most of the energy transition technologies, with EVs and wind generation being highly impacted.

3. **Infrastructure**
While RES, EVs, and heat pumps are or are becoming cost-competitive despite the high upfront investment, execution of the required grid build-out could be a risk due to slow investment and suboptimal scale (eg, regional DSOs).

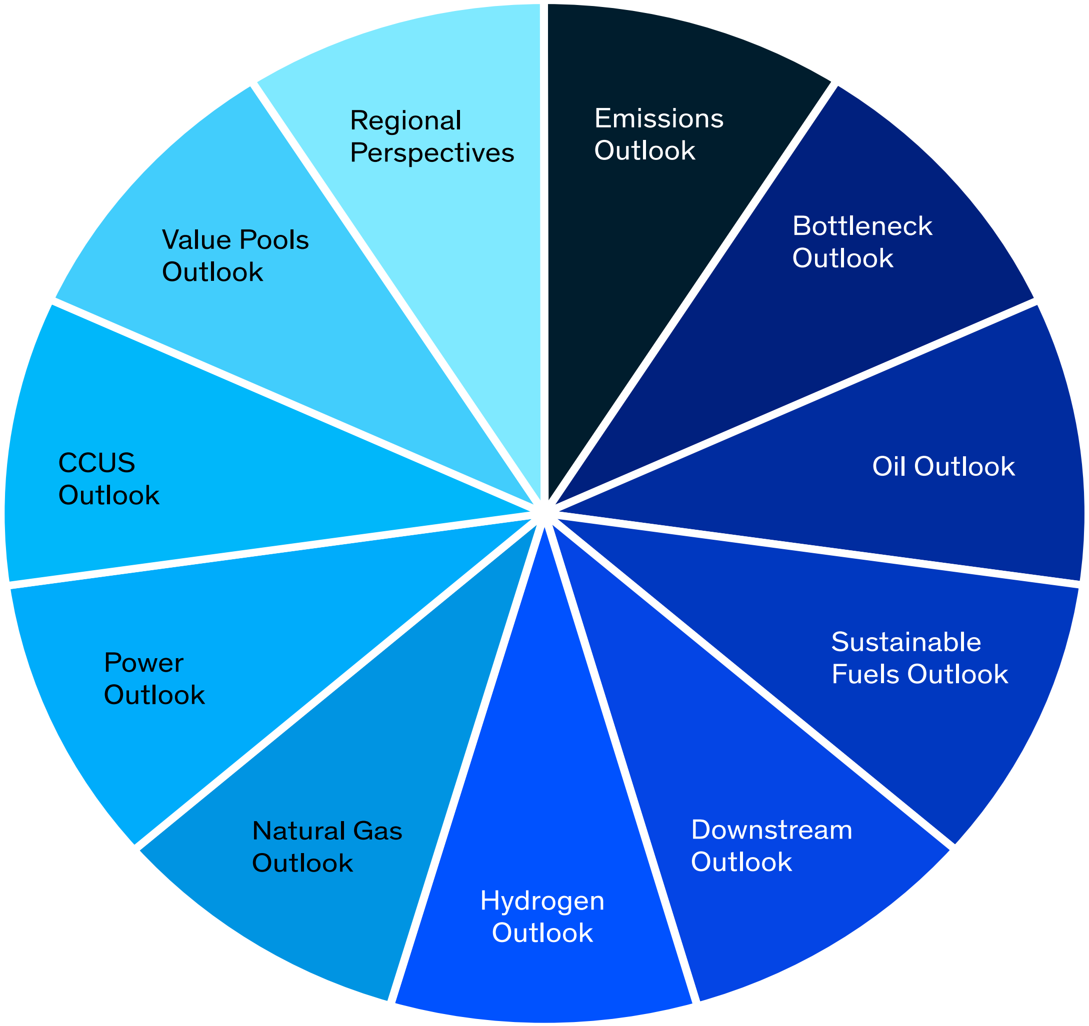
Key signposts that could shape the energy transition

Several key signposts could be important to watch in order to assess how the global energy landscape evolves, and calibrate energy transition strategies accordingly



Note: Best estimate based on data available by mid-Jan. McKinsey Global Energy Perspective 2022 Current Trajectory projection of deployment in 2022.
Source: IEA; McKinsey Energy Solutions' Global Energy Perspective 2023

Global Energy Perspective 2023: We will publish a series of follow-up articles in the coming months



Get in touch

For more information about our Global Energy Perspective please contact us: GEP_Info@mckinsey.com

Ole Rolser
Partner

Bram Smeets
Partner

Namit Sharma
Senior Partner

Christer Tryggestad
Senior Partner

Michiel Nivard
Solution Manager

Humayun Tai
Senior Partner

Micah Smith
Senior Partner

Alexander Weiss
Senior Partner

Christian Therkelsen
Partner

Rory Clune
Partner

Luciano Di Fiori
Partner

Jesse Noffsinger
Partner

Jesus Rodriguez Gonzalez
Partner

Tamara Gruenewald
Solution AP

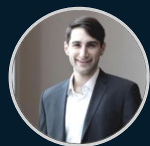
Gillian Boccara
Solution AP

Enrico Furnari
Solution Manager

Jasper van de Staaij
Solution AP

Krysta Biniek
Senior Expert

Cherry Ding
Solution AP



Nathan Lash
Solution AP

Directly access McKinsey's proprietary energy demand scenarios, data, and modelling tools behind this report via our web-based platform:

- Access granular energy demand datasets and assumptions
- Assess key energy transition sensitivities
- Create bespoke scenarios with available bottom-up methodologies and trainings

GEP website

GEP_Info@mckinsey.com

© Copyright 2023 McKinsey & Company
This report contains confidential and proprietary information of McKinsey & Company and is intended solely for your internal use. Do not reproduce, disclose, or distribute the information contained herein without McKinsey & Company's express prior written consent.

Nothing herein is intended to serve as investment advice, or a recommendation of any particular transaction or investment, the merits of purchasing or selling securities, or an invitation or inducement to engage in investment activity.

This material is based on information that we believe to be reliable and adequately comprehensive, but we do not represent that such information is in all respects accurate or complete. McKinsey & Company does not accept any liability for any losses resulting from use of the contents of this report

McKinsey & Company