McKinsey & Company

Global Energy Perspective 2022

Executive Summary

April 2022

McKinsey’s Global Energy Perspective is a collaboration between Energy Insights and adjacent practices

About us

The Global Energy Perspective is developed by Energy Insights in collaboration with McKinsey Sustainability and the Global Energy and Materials and Advanced Industries practices.

Energy Insights 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.

McKinsey Sustainability is the firm’s client-service platform that aims to assist the transformation of all industry sectors and their efforts to cut carbon emissions by half by 2030, and to achieve net zero by 2050. McKinsey Sustainability seeks to be the preeminent impact partner and adviser for our clients—from the board room to the engine room—on sustainability, climate resilience, energy transition, and environmental, social, and governance (ESG) factors. To facilitate a meaningful wave of innovation and economic growth that safeguards the planet and advances sustainability, McKinsey Sustainability leverages thought leadership, innovative tools and solutions, and top experts—and so creates a vibrant ecosystem of industry associations and knowledge partnerships.

McKinsey’s Global Energy and Materials Practice (GEM) serves clients in industries such as oil and gas, mining, steel, pulp and paper, cement, chemicals, agriculture, and power. It assists them to make decisions on the most important issues regarding strategy, operations, marketing and sales, organization, and other functional topics. In addition, MineLens, MineSpans, and Energy Insights—specialist divisions within the practice—offer fundamental insights into commodity-market dynamics. GEM serves many of the top global players, including corporations and state-owned enterprises, and works with more than 80% of the largest mining companies and 90% of the largest oil and gas companies worldwide.

McKinsey’s Advanced Industries Practice brings together three well-established global industry practices with roots in technically complex design and manufacturing: automotive and assembly, aerospace and defense, and advanced electronics and semiconductors. The global network of deeply experienced industrial partners works with industry executives to address issues that include strategy, organization, operations, technology, marketing, sales, and risk. The practice focuses on core operating capabilities and helps clients take a long-term, through-cycle view of the evolving competitive landscape. It works with many high-performing and iconic industrial companies around functional, business unit, and enterprise transformations to accelerate revenue generation, technology integration, operations design, and margin and cash flow improvements.

About this report

The Global Energy Perspective 2022 offers a detailed demand outlook across 55 sectors, 70+ energy products, and 146 countries for five key scenarios.

This Executive Summary is a selection of key charts and analysis from the outlook. To inquire about the complete Global Energy Perspective 2022, please contact us.

The scenarios we explore are not exhaustive in the realm of all possible outcomes, and currently do not reflect the impact of the invasion of Ukraine on energy markets.

Get in touch

Learn more

Editor's note

April 2022

We publish this long-term energy outlook at a time when global energy markets are facing unprecedented uncertainty. The global energy landscape has been impacted by increased market uncertainty due to the conflict in Ukraine. Already before the conflict began, the rebound in energy demand triggered supply constraints and price spikes for multiple commodities. Additionally, the long-term shift to low-carbon energy systems continues to gain momentum and has been accelerating in several respects.

We choose to publish this report now to contribute a set of scenarios that may help calibrate the invasion of Ukraine with the longer-term energy transition momentum. The conflict is having immediate impacts on energy markets around the world. The resulting uncertainty is something that the world has not seen in a long while and, as of today, the potential scenarios that could unfold remain very uncertain. As a firm, we have been exploring overall scenarios on how the situation might evolve and what the implications on the energy markets could be. As we continue to monitor the situation, we will provide regular updates on where the energy market could be headed as stakeholders try to balance affordability, energy security, and long-term decarbonization ambitions. At the same time, most of the developments may be pertinent to the longer-term trends in energy systems that we have observed in the past decade, like increased competitiveness of electrification and renewables. This report specifically focuses on those longer-term trends and is based on the insights and analytics developed by McKinsey's Energy Insights as well as the expertise of our industry and regional practitioners.

Looking back to 2021, the economic recovery from the effects of the COVID-19 pandemic brought a rebound in energy demand around the globe. This, coupled with supply side constraints, caused energy prices to see notable increases, especially for natural gas and electricity. While gas prices hit a 30-year low at the start of the pandemic, they reached a nearly two-decade-high point in 2021. Power prices showed similar volatility, impacting energy costs for many businesses and households.

At the same time, the transition to a low-carbon economy is continuing. In the context of COP26, a large number of countries, as well as many of the world's largest corporations, have committed to achieving net zero emissions within the next few decades. Although most of these pledges have yet to be translated into concrete policies and actions, the continued growth of low-carbon technologies shows that key enablers for the energy transition keep momentum.

These shifts and their interplay raise several key questions about the potential path ahead for the global energy landscape. Will price spikes delay the energy transition, or will high fossil fuel prices accelerate adoption of low-carbon alternatives? Will governments and businesses further increase their efforts to decarbonize, or will challenges in implementation lower ambition levels? How might the invasion of Ukraine influence the direction and speed of the transition? And, will there be an orderly transition to a low-carbon economy, or will rapid shifts come with instability and unrest?

Our 2022 Global Energy Perspective presents a new suite of five energy scenarios. Based on contributions from hundreds of McKinsey expert practitioners from around the world, these scenarios cover a spectrum of possible outcomes, ranging from strong decarbonization in line with many of the recent net-zero pledges to a scenario that sees fading momentum for a transition of the global energy system. We use these scenario outlooks—and the underlying models—to support hundreds of leaders around the world and across a broad range of sectors, helping organizations navigate the transitions in energy systems.

This report is divided into four parts. Part one provides a perspective on the development of fundamental drivers for the global energy system. Part two provides an outlook for power systems, and outlooks for each energy type and carrier, including hydrogen, sustainable fuels, natural gas, oil, and coal, as well as a view on the role of CCUS. Part three discusses carbon emissions, and part four reflects on implications for business leaders and policy makers, including a view on value pools and an outlook for energy investments.

We hope that this report provides valuable insight into the energy transition, and that it helps inform thinking around the low-carbon future.

Key insights from McKinsey's Global Energy Perspective 2022

1

While governments and businesses are increasingly committed to steep decarbonization targets, energy markets face extreme volatility driven by geopolitical tensions and a rebound in energy demand

The conflict in Ukraine, as well as other factors, have triggered significant peaks in energy prices as uncertainties around supply security and affordability are paramount. This comes at a time where markets are already tight following the COVID-19 rebound

Throughout 2021, global energy demand and emissions increased by 5% compared to 2020, almost reaching pre-COVID-19 levels (~33 Gt energy-related CO_2 equivalent)

In the context of COP26, a total of 64 countries (accounting for 89% of global CO_2 emissions) have made net-zero pledges, while financial institutions and private sector enterprises also continue to increase their decarbonization aspirations

2

Going forward, the energy mix is projected to shift toward power. By 2050, electricity and enabling hydrogen and synfuels could account for 50% of the energy mix

Electricity demand is projected to triple by 2050 as sectors electrify and hydrogen and hydrogen-based fuels increase their market share due to decarbonization

Renewable generation is projected to reach 80–90% of the global energy mix by 2050 as the global build-out rates for solar and wind grow by a factor of five and eight respectively

Hydrogen demand in new sectors could reach 350–600 mtpa in 2050 (compared to ~80 mtpa today); global demand for sustainable fuels is expected to mature, reaching 8–22% of all liquid fuels by 2050

3

The projected peak in demand for fossil fuels continues to move forward; demand for oil is projected to peak in the next five years

Peak oil demand is projected to occur between 2024 and 2027[1] driven largely by EV uptake—a development that is already underway. Coal demand peaked in 2013 and, after a temporary rebound in 2021, is projected to continue its downward trajectory

The conflict in Ukraine is leading to price spikes as the market and consumers balance supply security and affordability

Toward 2035, gas demand across all scenarios is projected to grow another 10–20% compared to today[1]; after 2035, gas demand will likely be subject to larger uncertainties, driven especially by the interplay with hydrogen

Two to four[1] Gt of CO_2 will need to be captured by CCUS by 2050 to decarbonize heavy industries where fossil fuels continue to play a significant role

4

Even if all countries with net-zero commitments deliver on their aspirations, global warming is projected to reach 1.7°C by 2100

All scenarios require substantial shifts to occur across the energy landscape. Even in the Current Trajectory scenario, significant investments will likely be required to kickstart new technologies

With current government policies, additional commitments, and projected technology trends, global warming is projected to exceed 1.7°C, making a 1.5° pathway increasingly challenging

To keep the 1.5° Pathway in sight, the global energy system may need to accelerate its transformation significantly, shifting away from fossil fuels toward efficiency, electrification, and new fuels, quicker than even the announced net-zero commitments

5

Total investments across energy sectors are projected to grow by more than 4% per annum and are projected to be increasingly skewed towards non-fossil and decarbonization technologies, while returns remain uncertain

Annual investments in energy supply and production are expected to double by 2035 to reach \$1.5 trillion to \$1.6 trillion[1]; almost all growth is expected to come from decarbonization technologies and power, which will by 2050 exceed today's total energy investments

EBIT in decarbonization technologies and power is expected to grow by 5% per annum, and could outpace the growth in underlying investments

Business models in a highly decarbonized system are expected to remain uncertain across sectors, and will likely rely on adjustments in market design (for example, capacity payments for flexible thermal power generation), subsidies, or other support mechanisms (for example, support for CCUS on top of CO_2 prices)

1. Between Current Trajectory and Achieved Commitments scenarios

Source: McKinsey Energy Insights Global Energy Perspective 2022

While developments of the conflict in Ukraine are highly uncertain, today's decisions could impact the long-term energy transition and path towards decarbonization

There are many questions related to the development of the conflict, as well as the impact on GDP and energy markets

Potential uncertainties related to development of the conflict

Duration and scale of disruption

- What will be the duration of the conflict?
- Does the conflict expand (within and beyond Ukraine)?
- Does the number of refugees further increase?
- Do sanctions escalate?
- To what extent and for how long are energy and commodity markets (severely) disrupted?

Government policy and consumer response

- Will governments accelerate monetary measures to limit inflation?
- Will governments invest in improving long-term growth prospects?
- Will there be a structural shift in consumer behavior in response to the current crisis?
- Will consumers see fiscal support for energy and food cost?
- Will governments see investment in energy infrastructure?

Energy markets are affected by GDP, but are also a driver for GDP

GDP / Energy

- To what extent is GDP disrupted?
- How does inflation develop?
- What will the increased share of wallet on energy mean for growth in other sectors?

Demand

- How will high prices affect energy demand?
- Will policies drive fuel switching?

+

Supply

- What share of natural gas can be substituted by alternatives?
- How can Europe substitute its Russian gas supply with LNG from elsewhere?

+

Infra-structure

- Can Europe scale the grid fast enough to allow for faster renewables build-out?
- What infrastructure and connection bottlenecks exist that need to be addressed for a changed energy mix (LNG, gas, renewables etc.)?

McKinsey's latest perspective on the impact of the conflict in Ukraine on energy markets is regularly updated. Please refer to: War in Ukraine: Lives and livelihoods, lost and disrupted

Source: McKinsey Energy Insights Global Energy Perspective 2022

McKinsey's Global Energy Perspective 2022 offers a detailed demand outlook across key dimensions

Our report assesses energy systems across countries, sectors, and energy products

Non-exhaustive

55 segments

Transport
- Road transport (including buses, trucks, and cars)
- Rail
- Aviation
- Marine
- Other transport

Sustainable Fuels

Buildings
- Residential buildings
- Commercial buildings

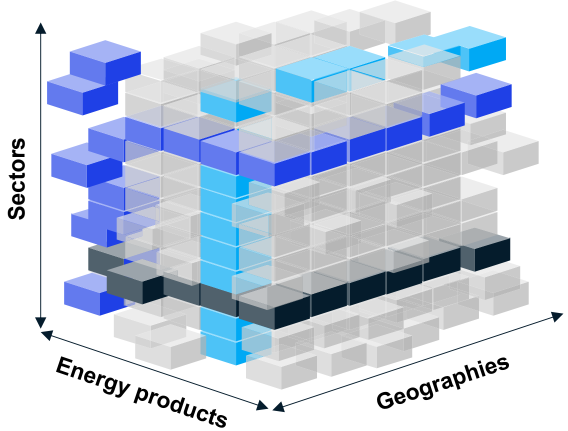
Heat

Industry
- Iron and steel
- Chemicals
- Manufacturing
- Mining
- Refining
- Other industry

CCUS

Power
- Electricity generation
- Hydrogen production

Hydrogen Supply



70+ energy products

- Natural gas
- Coal
- Oil products (eg, gasoline, diesel, and HFO)
- Renewable resources (eg, solar, wind, and hydro)
- Sustainable fuels (eg, HVO, SAF)
- Electricity
- Hydrogen

146 countries

- 45 in Asia
- 43 in Europe
- 31 in Africa
- 27 in the Americas

Builds on 20+ state-of-the-art McKinsey assets, including:

McKinsey Hydrogen Model

Combines energy and hydrogen demand projections with country-specific supply-cost dynamics. Models detailed cost outlooks for underlying technologies such as electrolyzers, SMR, RES cost decline, and CCUS

McKinsey Sustainable Fuels Model

Provides global regulatory tracking and country-level demand outlooks for more than ten bio/synfuel types (eg, advanced HVO, PtL SAF, drop-in bio/synfuel gasoline), along with advanced fuels project database, feedstock availability, and production cost models

McKinsey Power Model

Projects capacity additions in the power sector and simulates dispatching decisions based on system-cost optimization. Captures more than 80% of global power demand at the country and subcountry level and models at an hourly granularity

McKinsey e-Trucks TCO Model

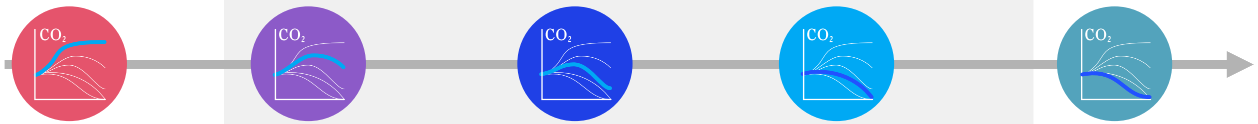
Assesses future evolution of commercial vehicle parc by country and vehicle class and projects powertrain mix development based on total cost of ownership. Incorpo-rates views on the cost decline of of battery- and hydrogen-fueled engines in e-trucks and efficiency improvements of ICE trucks

Source: McKinsey Energy Insights Global Energy Perspective 2022

In our Global Energy Perspective 2022, we explore five scenarios

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

Slower — Modelled bottom - up as part of GEP 2022 — *Faster*



Speed of energy transition					
Scenario description	**Fading Momentum**	**Current Trajectory**	**Further Acceleration**	**Achieved Commitments**	**1.5° Pathway**
	Fading momentum in cost reductions, climate policies, and public sentiment will lead to prolonged dominance of fossil fuels	Current trajectory of renewables cost decline continues, however active policies currently remain insufficient to close gap to ambition	Further acceleration of transition driven by country-specific commitments, though financial and technological restraints remain	Net-zero commitments[3] achieved by leading countries through purposeful policies; followers transition at slower pace	A 1.5° pathway is adopted globally, driving rapid decarbonization investment and behavioral shifts
Required CO_2 price[1] €/tCO_2, 2030-50	*< € 50*	*€ 55 - 130*	*€ 75 - 140*	*€ 100 - 180*	*€ 200+*
Global temp. increase linked to expected emission levels[2]	*> 2.4 °C*	*2.4 °C* (1.9 - 2.9)	*1.9 °C* (1.6 - 2.4)	*1.7 °C* (1.4 - 2.1)	*<1.5 °C*

1. Global average CO_2 prices required in 2030 and 2050 to trigger decarbonization investments sufficient to fulfil the scenario. Prices are weighted by country and sector emissions and are holistic in that they include both explicit costs (eg, carbon tax, emission trading system) and implicit costs (eg, subsidies, feed-in-tariffs) to incentivize abatement
2. Warming estimate is an indication of global rise in temperature by 2100 versus pre-industrial levels (median - 17th/83rd percentile), based on IPCC assessments given the respective emission levels and assuming continuation of trends after 2050 but no net-negative emissions
3. Excluding international bunkers

Source: McKinsey Energy Insights Global Energy Perspective 2022

As the state of energy transition is evolving (eg, national and industry climate commitments, financial sector changes) this report introduces a revised set of scenarios to assess the potential impact on fuels and sectors

The three main scenarios used in this report are:

- Achieved Commitments
- Further Acceleration
- Current Trajectory

Of these, Further Acceleration will be presented as the central scenario throughout this report

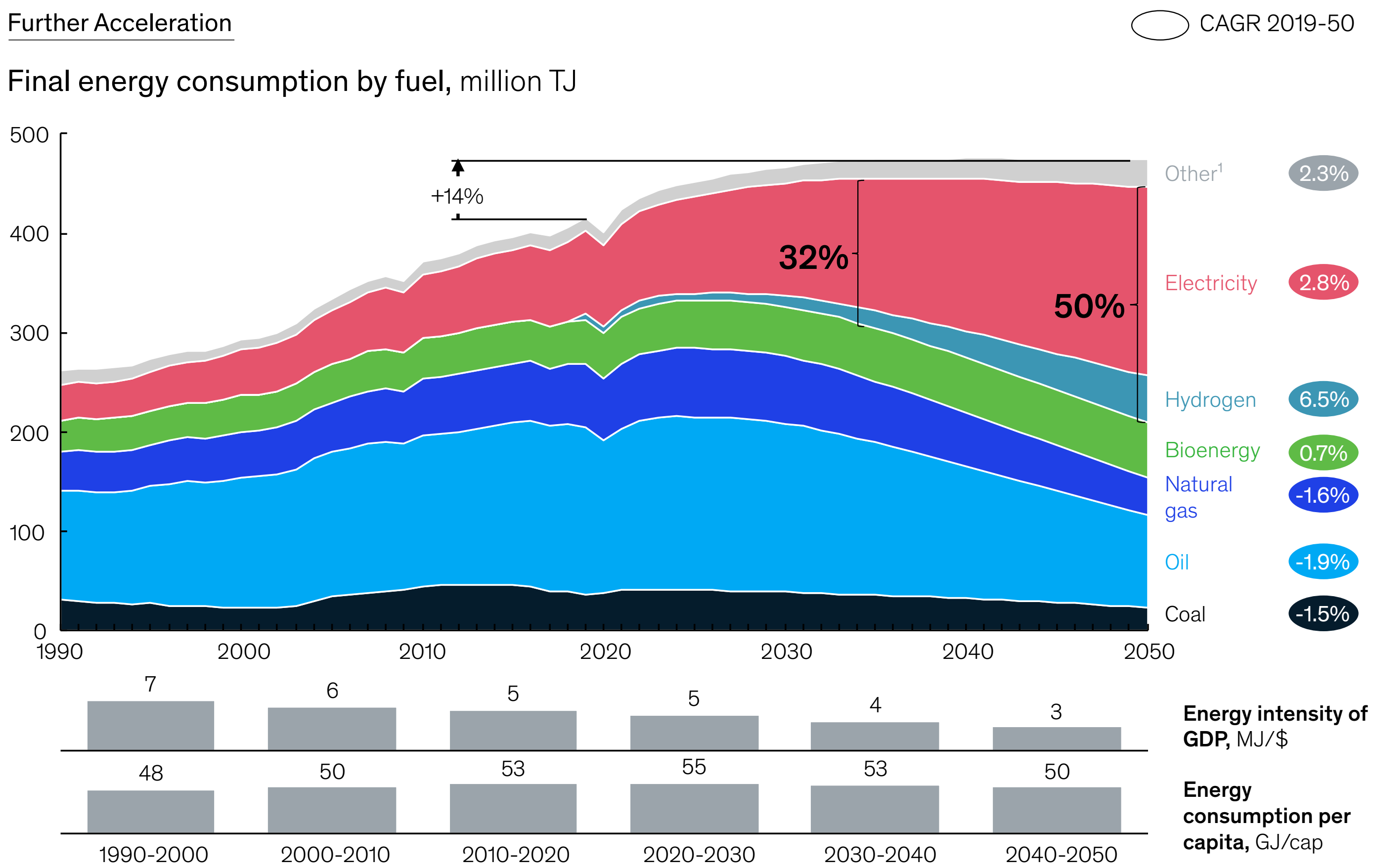
These scenarios are centered around the pace of technological progress and various levels of policy enforcement

This report therefore uses these scenarios to evaluate long-term trends and fundamentals and their impact on the energy transition.
The uncertainties surrounding the conflict in Ukraine are not addressed by these scenarios

Analysis conducted before the invasion of Ukraine in February 2022

The global energy mix is projected to shift rapidly towards power and hydrogen

Share of electricity and hydrogen in final consumption may grow to 32% by 2035, and 50% by 2050



1. Includes heat and synthetic fuels

Source: McKinsey Energy Insights Global Energy Perspective 2022

Global energy consumption is projected to flatten in the coming decades. Despite rapid growth of the global economy and population growth of two billion people, energy consumption is projected to grow by only 14%

Continued reductions in the energy intensity of GDP are a key driver, triggered by greater end-use efficiency in buildings, transport, and industry. Electrification plays an important role in this, as a shift to electrical solutions tends to come with a step-change in efficiency in many segments, such as space heating and passenger cars

The role of electricity in the final consumption mix is projected to grow from ~20% today to 40% by 2050. The corresponding doubling of electricity consumption combined with uptake of hydrogen is projected to offset fossil-fuel consumption (which excludes primary demand of coal and gas for power generation), which could be ~40% lower in 2050 compared to 2020

Power supply and demand

Chapter summary

Power consumption is expected to triple by 2050 as electrification and living standards grow

Electrification is often the first lever projected to achieve the emission-reduction goals, being the cheapest and easiest to implement in most sectors

Transportation is projected to see the fastest transition to electricity due to EVs reaching cost parity with ICE cars already in the mid-2020s

In buildings, increasing living standards are projected to drive the increasing demand for appliances and space cooling, bringing the sector to ~60% electrification in 2050 from ~30% today

Particularly for the long term, green hydrogen production is projected to be the biggest driver of additional power demand (42% of the growth between 2035–2050), with hydrogen playing a key role for hard-to-abate sectors such as iron and steel

Renewables are expected to become the new baseload, accounting for 50% of the power mix by 2030 and 85% by 2050

Solar and wind builds already come at a lower cost than than existing fossil fuels in most countries and are projected to become increasingly cost competitive globally

Thermal generation is projected to shift to a role of back-up flexibility provider to support grid stability, with load factors declining ~30% globally from 2019 to 2050 (from 40% to 28%)

There are expected regional differences in the decarbonization paths for the power mix, driven by active policies, political preferences, economic factors, and the availability of land and resources

Flexible assets like gas plants, batteries, and hydrogen electrolyzers are key for grid stability and decarbonization

Both traditional and new flexible capacity are needed to ensure system security (globally, 24 TW capacity additions by 2050). Flexible capacity additions are estimated to account for ~25% of total additions between 2030 and 2035, with hydrogen, EVs, and batteries making up a large share of this capacity

Green hydrogen is projected to account for 28% of power demand by 2050. Despite creating additional demand, dispatchable electrolyzers allow for the integration of more intermittent renewable energy sources in the system, reducing specific emissions by ~15%

Green hydrogen is projected to contribute as a storage mechanism for power production. Gas turbines converted to hydrogen can provide additional flexibility. New technologies, such as vehicle-to-grid and long-duration energy storage, could play a key role if they reach technological maturity and prove to be cost-effective

Technologies like CCUS[1] and nuclear will likely see additional growth if renewables build-out remains constrained

The large projected build-out of intermittent renewables can pose challenges around land use, transmission capacity, and overall acceptance

Should roadblocks arise that limit the deployment of renewables, low-carbon technologies such as CCUS, nuclear, and long-duration energy storage (LDES) could help meet emission goals

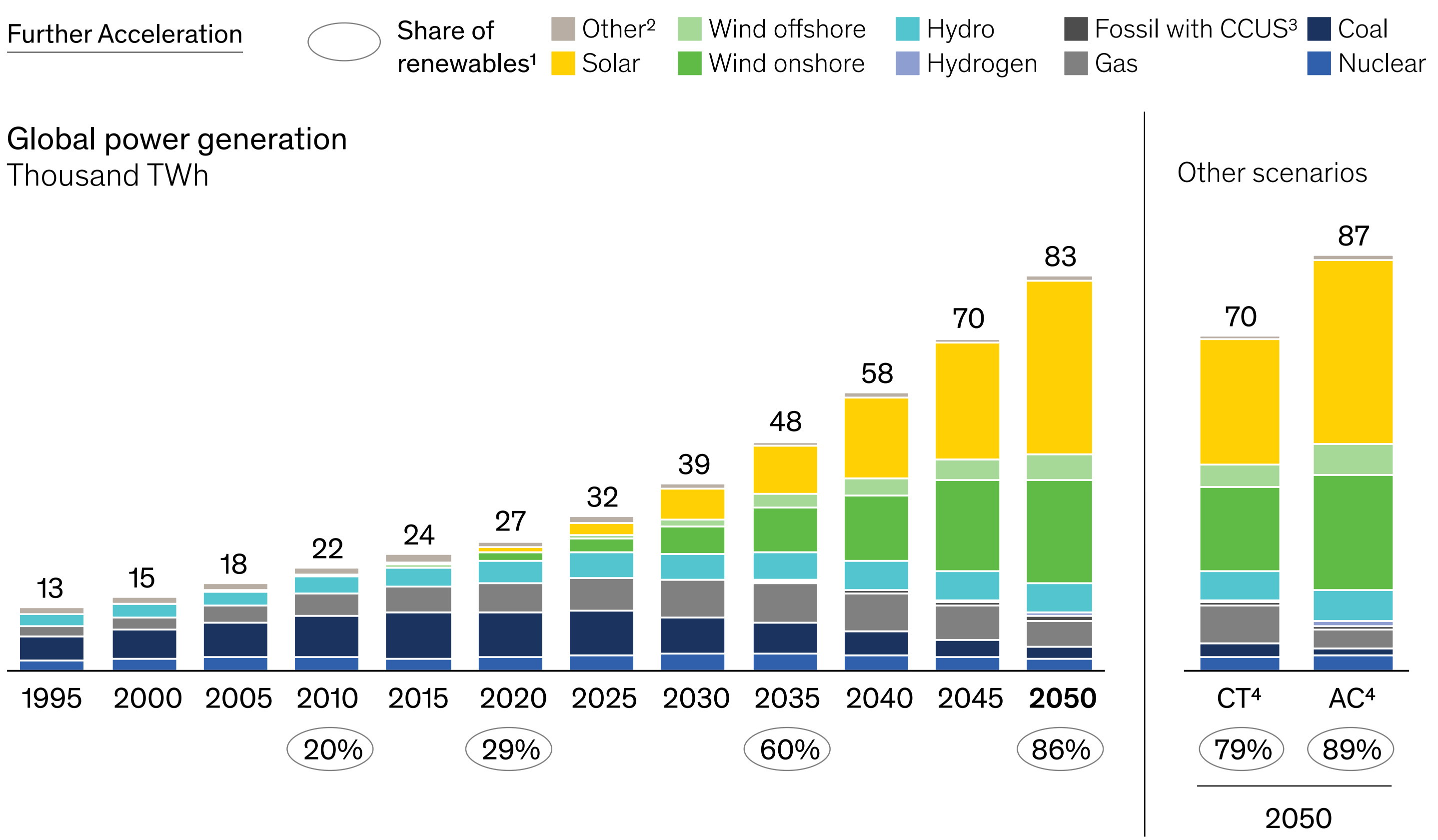
Nuclear uptake could be significant in land-constrained regions, while CCUS could cover 8—17% of the remaining fossil generation by 2050, if growing CO_2 prices make it attractive in regions with low-cost fuels

1. Carbon capture, utilization, and storage

Source: McKinsey Energy Insights Global Energy Perspective 2022

Renewables are projected to account for 80—90% of power generation globally by 2050

Share of renewables in the power mix is projected to double in the next 15 years



1. Includes solar, wind, hydro, biomass, BECCS, geothermal, and marine and hydrogen-fired gas turbines
2. Other includes bioenergy (with and without CCUS), geothermal, marine, and oil
3. Includes gas and coal plants with CCUS
4. CT refers to the Current Trajectory scenario; AC refers to the Achieved Commitments scenario

Source: McKinsey Energy Insights Global Energy Perspective 2022; McKinsey Power Model

In all scenarios, renewables are projected to lead the power generation mix, reaching 80—90% in 2050. In the Further Acceleration scenario, RES share is expected to double in the next 15 years, from 29% to 60%

Most of the growth in RES is expected to come from solar and onshore wind, due to declining costs, and they are projected to make up 43% and 26% of generation respectively in 2050 under the Further Acceleration scenario. Offshore wind is projected to remain limited to less than 7% of global generation due to permitting constraints and policy hurdles, with potential to grow further if constraints on onshore wind such as land use persist

Thermal generation is still expected to play an important role as a flexibility provider, with gas providing substantial shares of base-load generation up to 2040 in regions with favorable fuel costs

Nuclear generation is still expected to require economic support from policies, which is not yet present in many regions as public acceptance continues to prove challenging

Oil demand

Chapter summary

Global liquids demand is expected to peak around 102 MMb/d in the next two to five years, despite a near-term recovery of liquids demand from the impacts of the COVID-19 pandemic

COVID-19 resulted in a significant drop in liquids demand; while regional demand has largely bounced back, pre-pandemic levels are projected to be reached only by 2023, mainly due to low international aviation traffic

Global liquids demand is projected to peak in the next two to five years, driven primarily by electrification and efficiencies across sectors

Liquids demand in 2050 could be 35—50% lower than today's levels; however, reaching the target set by the 1.5° Pathway would require an even steeper decline in liquids demand

On a regional level, liquids demand in major oil markets, such as the US and EU, has already peaked, and all markets, including developing regions such as India and Southeast Asia, are likely to peak before 2040

A decline in liquids demand in road transport will likely drive a peak across markets, while growth in chemicals and aviation may slow down

Liquids demand in road transport is projected to decline 75% by 2050 after peaking in the early 2020s, driven by slowing growth in the number of cars on the road, increased efficiency, and accelerating uptake of electric vehicles (EVs), with bio- and synfuels decreasing demand for crude oil further

Aviation liquids demand is projected to continue growing, but uptake of bio- and synfuels may result in a decrease in the demand for fossil kerosene. Indeed, the demand for fossil kerosene is projected to peak by the mid-2030s, while sustainable aviation fuels may grow to 40% of aviation liquids demand by 2050

Chemicals remain one of the few growth avenues for liquids demand; demand is projected to grow 50% by 2050, despite increasing downward pressure from demand reduction, recycling, and pyrolysis

Crude oil demand is expected to decline rapidly after 2030, while remaining liquids demand growth may mostly be seen in non-energy use of oil and bio- and synfuels

Crude oil used for combustion is expected to decline from 80%-45% of total liquids by 2050, as growth in non-energy use of oil continues and bio- and synfuels increase their share, especially in transport applications

Shifts across sectors—such as faster EV uptake, increased usage of alternative fuels in aviation and maritime, and increased plastic recycling—could accelerate the energy transition further. As a result, crude oil demand could fall to 40 MMb/d by 2050 in the Achieved Commitments scenario, a 25% decrease from the Further Acceleration scenario

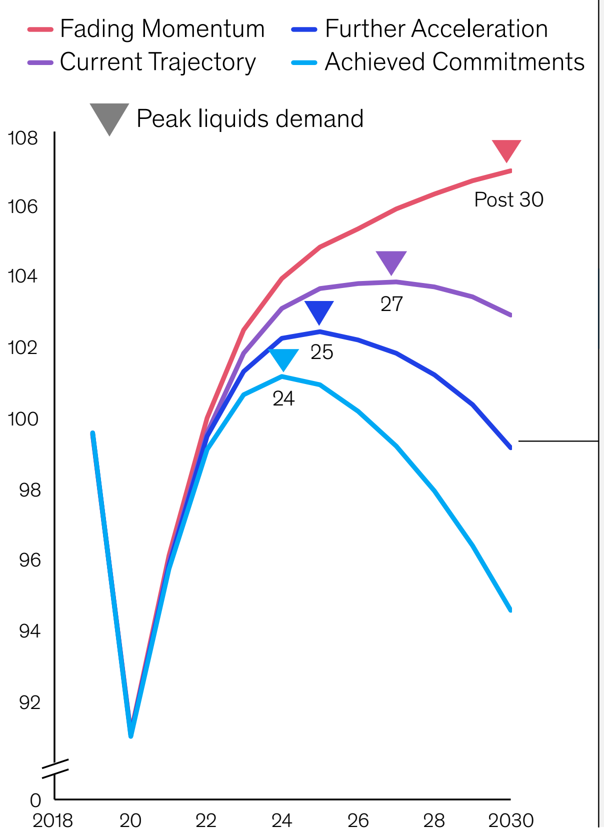
Source: McKinsey Energy Insights Global Energy Perspective 2022

Analysis conducted before the invasion of Ukraine in February 2022

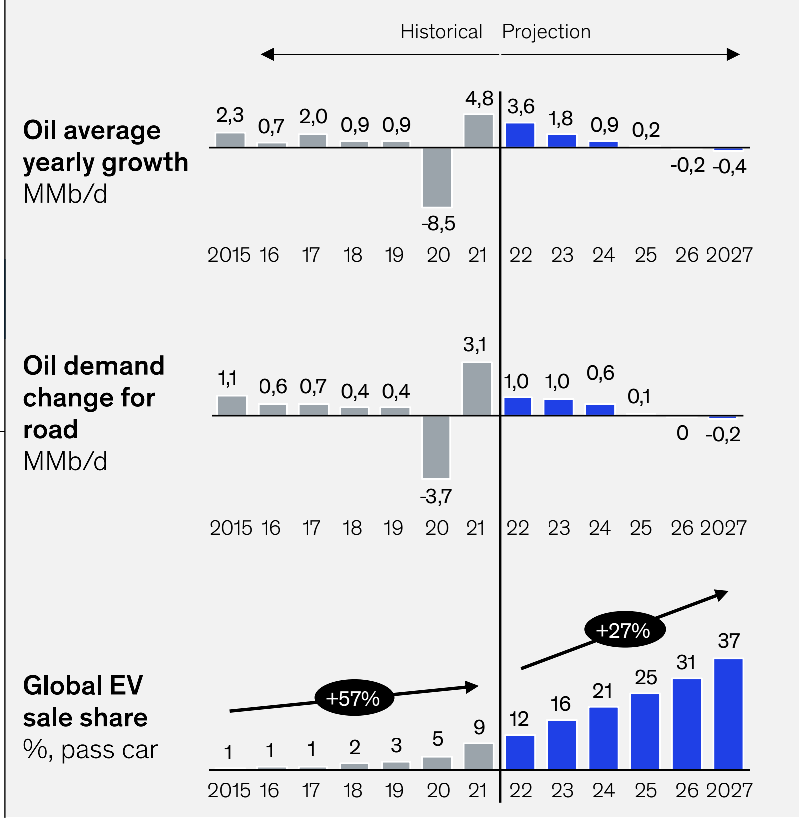
Oil demand could peak in the next two to five years

The uptake of electric vehicles is the main driver for stagnating growth in oil demand

Liquids[1] demand, MMb/d



Key drivers for peak in 2025, Further Acceleration



Liquids demand is projected to peak within this decade. The primary driver for the reduction in growth is a slow-down in demand growth for road transport

Historically, oil demand was growing by 1—2 MMb/d, half of which was through growth in road transport. While oil demand continues to recover post-COVID-19 in 2022 and 2023, the trends are projected to change from 2024 onwards

The primary driver for reduced oil demand for road transport is the continued uptake of EVs:

- Global EV sales grew 62% per annum on average in the last four years and by 96% in 2021 alone. EV sales in absolute terms increased from 2.3 million in 2019 to 6.6 million in 2021
- EV sales in Europe accounted for more than 20% of total car sales in 2021; US EV sales only accounted for 5%, but doubled year on year

Alongside this, the use of oil in power and heat is decreasing. In the buildings sector, a ban on new domestic oil heaters continues the decline in line with historical trends

1. Crude oil products, liquid biofuels, and synthetic fuels

Source: McKinsey Energy Insights Global Energy Perspective 2022; US Energy Information Administration, Short-term Energy Outlook

Analysis conducted before the invasion of Ukraine in February 2022

Natural gas demand

Chapter summary

Gas has gradually increased its share in the energy mix and is expected to play a key role throughout the transition with its wide range of applications

The global gas price rally in 2021 was supported by high gas demand due to rapid economic recovery and unexpected weather conditions, and a lower supply due to unexpected outages and underinvestment

Uncertainty around the pace and shape of the energy transition may impact the volatility in gas prices and lead to even more pronounced investment cycles

Going forward, gas could play a new role in blue hydrogen and ammonia production, and gas infrastructure could be repurposed for low-carbon fuels such as hydrogen and biogas, or CO_2 transportation for CCUS

Gas demand is projected to grow by 10% in the next decade in all scenarios. After 2030, gas projections diverge across scenarios driven by increasing decarbonization pressure in buildings and industry

The demand for gas is projected to be more resilient than for other fossil fuels. Its share in primary energy demand is expected to decline from 23% today to 23—15% by 2050

In the Achieved Commitments scenario, the remaining gas demand in 2050 is due to countries without net-zero commitments, carbon offsets, or the deployment of CCUS, which explains 54%, 15%, and 31% of gas demand respectively

Relatively robust absolute gas demand translates into a reducing role of gas in providing heat and power due to high growth of low-carbon alternatives in these sectors

Gas demand is projected to peak by 2035. Demand growth in power and industry, particularly in Asia, may eventually be offset by decline, especially in buildings

Gas demand in power is set to grow strongly until between 2035 and 2040, after which it is projected increasingly to play the role of back-up to renewables

Long-term gas demand is likely to be supported by industry (for high-temperature heat and chemicals), particularly in Asia

Gas demand in buildings is expected to decline after 2025. The decline will likely be driven by increased insulation, electrification, and usage of green gases such as hydrogen or biomethane

The regional shift of gas demand to Asia is expected to continue, as China's role of demand-growth engine is taken over by Southeast Asia after 2030

China's gas consumption is likely to be supported by coal-to-gas switching and the role of CCUS in power and industry

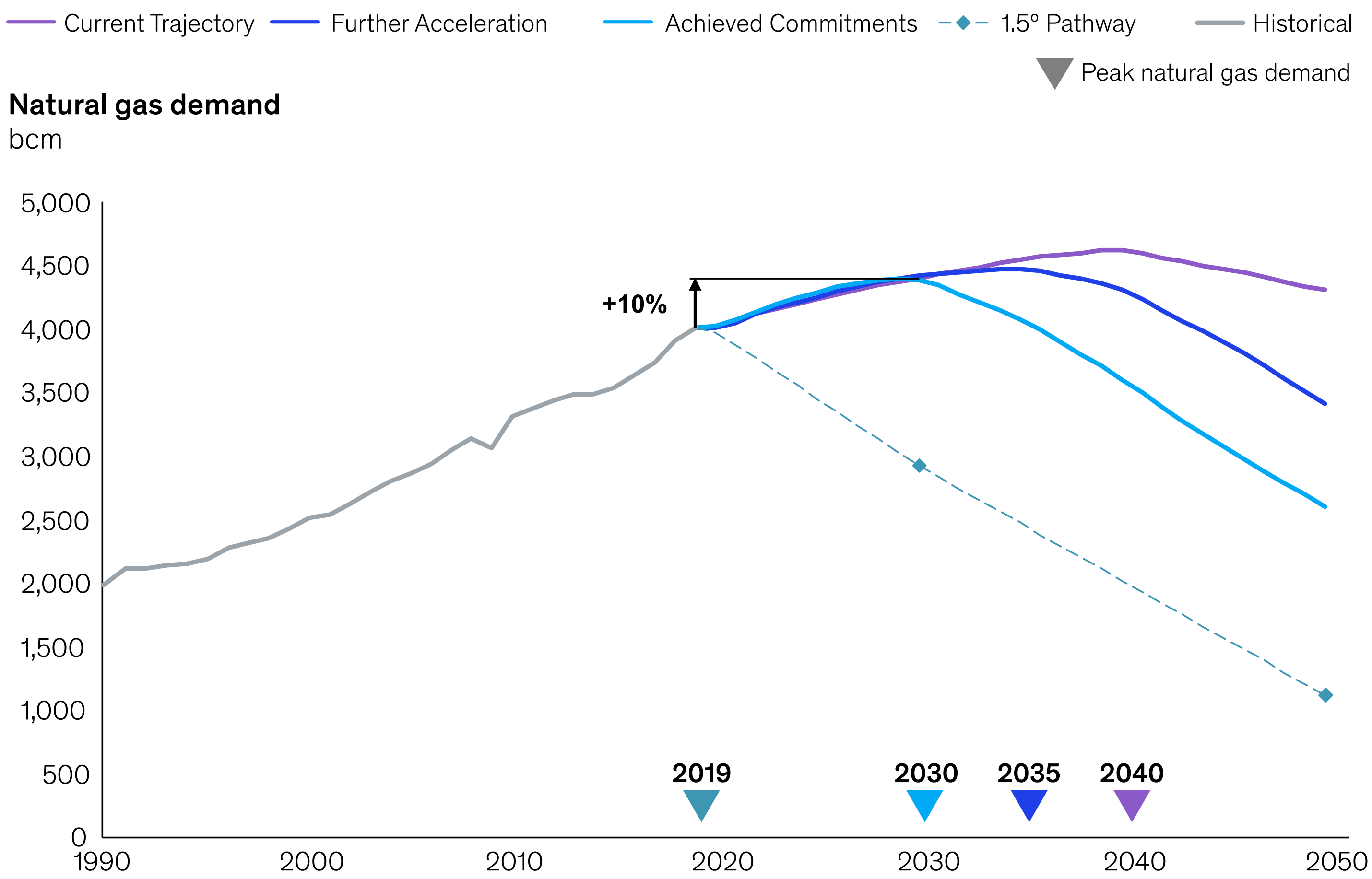
Almost all additional demand for imported gas is supplied by LNG , which is projected to lead to a growth of 20–70% in 2050 compared to 2019, depending on the scenario

Source: McKinsey Energy Insights Global Energy Perspective 2022

Analysis conducted before the invasion of Ukraine in February 2022

Gas demand is projected to grow by 10% in the next decade in all scenarios

Scenarios diverge after 2030, driven by increasing decarbonization pressure in buildings and industry



In the Further Acceleration scenario, gas demand is projected to grow until 2035. The decline thereafter is driven primarily by government policies to decarbonize the industrial and buildings sectors. Alternative fuels in buildings and industry may need strong policy support to become viable

In the Current Trajectory scenario, gas demand is projected to increase by 16% from today before it reaches a peak in 2040

In the Achieved Commitments scenario, the decline is expected to start in 2030, driven by decarbonization targets in buildings and industry

However, even progressive scenarios are far from achieving the 1.5° Pathway, in which gas consumption must decline substantially before 2030

Overall, the decline in gas demand post 2030 is driven by electrification, strong renewables uptake, and green hydrogen adoption in the power, buildings, and industrial sectors

Source: McKinsey Energy Insights Global Energy Perspective 2022

Analysis conducted before the invasion of Ukraine in February 2022

Hydrogen demand

Chapter summary

Hydrogen demand is projected to grow fivefold by 2050, driven primarily by road transport, maritime, and aviation

Growth to 2035 is driven by sectors with favorable economics versus alternatives, such as road transport where fuel cell electric vehicles (FCEVs) will likely displace conventional diesel trucks

Beyond 2035, private and public sector commitments could drive the adoption of hydrogen in sectors with unfavorable economics, such as the aviation and maritime sectors, which are likely to adopt hydrogen-derivative fuels like synthetic kerosene and ammonia

This growth is not without precedent; historical natural gas adoption in the European Union (EU) indicates it is possible to rapidly change the energy system

Hydrogen supply is projected to shift from nearly 100% grey hydrogen to 60% clean production by 2035, as costs decline and policymakers support hydrogen technology adoption

In the Further Acceleration scenario, clean hydrogen supply totals around ~110 Mt (~60% of total supply) by 2035 and ~510 Mt (~95%) by 2050. Some regions are projected to fully phase out grey hydrogen (from fossil fuels) by 2050, such as the EU and the UK

Announcements of new clean hydrogen production projects tripled year on year in 2021. Around 22 Mt of clean hydrogen capacity has been announced to date, approximately 15–20% of what is needed by 2035

Hydrogen production will likely be a major driver of energy demand growth. By 2050, hydrogen is projected to add approximately 18,000 TWh of electricity consumption (~36% of electric demand growth) and around 300 bcm to natural gas demand

Three fundamental enablers may be needed to support the development of the hydrogen economy

Infrastructure and supply chain: Timely deployment of infrastructure across the whole supply chain is likely required to meet hydrogen demand. Transport and storage infrastructure may be key to enabling a global hydrogen value chain

Technology advancement and manufacturing scale-up: Cost reduction and increased scale-up in renewable energy production, electrolyzers, and carbon capture, utilization, and storage will likely be needed to make clean technologies cost competitive against conventional high-carbon production routes

Government support: Government support and targeted actions, such as an increase in CO_2 prices, could be key. Such moves are particularly needed in segments where hydrogen will not be cost competitive compared to the high-carbon alternative, such as the aviation sector. Around 40 countries already have dedicated hydrogen strategies in place

New trade flows could emerge to connect demand centers with resource-rich regions

Regions with cost-optimal production resources, such as natural gas or renewable energy, could become major hydrogen export hubs and be at the forefront of a new global hydrogen trade

Hydrogen imports would enable the uptake of hydrogen in countries that have decarbonization ambitions, but lack resources such as renewable energy, natural gas, and carbon dioxide storage (such as Japan, South Korea, and parts of Europe)

Converting hydrogen to synfuels (a liquid fuel mixture containing hydrogen, such as ammonia or methanol) at the export hub could expedite international hydrogen shipping

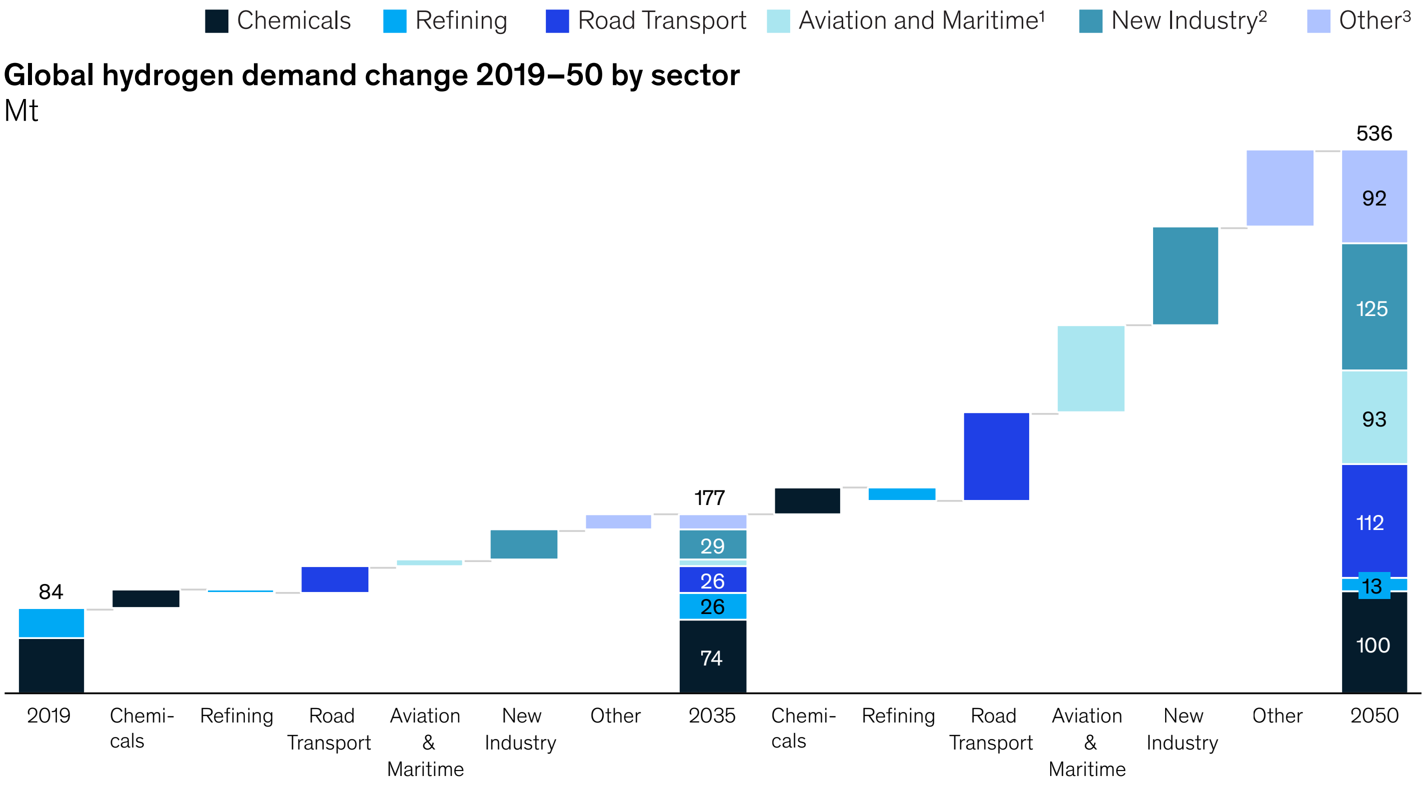
Source: McKinsey Energy Insights Global Energy Perspective 2022

Analysis conducted before the invasion of Ukraine in February 2022

Transport and new industrial uses could drive two-thirds of hydrogen demand growth to 2035

Beyond 2035, hydrogen is projected to scale across all sectors of the energy economy

Further Acceleration



1. 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
2. New industry includes all new uses of hydrogen in Industrial processes, eg, iron and steel production, whereas chemicals and refining are traditional hydrogen uses
3. Other includes buildings and electricity generation

Source: McKinsey Energy Insights Global Energy Perspective 2022

In the Further Acceleration scenario, before 2035, 29 Mt (30%) of hydrogen demand growth is projected to come from new industrial uses such as iron and steel, driven by early decarbonization targets and by new-built plants. Another 26 Mt (30%) comes from road transport, driven by the increasing cost competitiveness of hydrogen vehicles

Hydrogen demand is projected to accelerate after 2035 across all sectors, with road transport and new industrial uses still accounting for more than 50% of demand growth

Demand for synfuels production, mainly kerosene, diesel, and ammonia for aviation and maritime sectors, is also projected to accelerate after 2035, resulting in a total of 93 Mt in 2050, equivalent to ~17% of total H_2 demand

Refining is the only sector where demand is projected to decline post 2030. As hydrogen is involved in the hydrotreating processes of oils in refineries, the shift from oil to cleaner fuels for transport (including direct hydrogen use in aviation and maritime, synfuels, BEV, and FCEV) consequently decreases demand for hydrogen

Sustainable Fuels

Chapter summary

Sustainable fuels can provide GHG reductions comparable to BEVs and are applicable in multiple sectors

Sustainable fuels include biofuels such as hydrotreated vegetable oil (HVO) or bioethanol, and synthetic fuels (synfuels) such as ammonia or methanol. They can be used as drop-in fuels in conventional internal combustion engines (ICE)

Even though the costs of using sustainable fuels are projected to be higher than alternatives in the long term, the use of 100% renewable diesel, such as HVO, can achieve comparable lifecycle greenhouse-gas (GHG) reduction to the use of electric vehicles (EVs), allowing for faster decarbonization of existing fleets in the short term

Sustainable fuels are needed to meet 2030 decarbonization targets

New regulations, such as Fit for 55 in the EU, will likely drive the demand for sustainable fuels

Even in a world with fast EV uptake—where EVs account for ~75% of total vehicle sales by 2030—reaching regulatory GHG reduction targets for transportation could require a significant contribution from sustainable fuels

The demand for sustainable fuels is projected to triple over the next 20 years

Growth in sustainable fuels until 2035 is driven primarily by road transport, reaching 290 Mt in the Further Acceleration scenario, while aviation plays an increasingly important role thereafter

Post 2035, increasing BEV penetration is expected to cause a decline in ICE vehicles and a corresponding decline of sustainable fuels used in road transport. However, increasing sustainable aviation-fuels demand driven by mandates is projected to more than offset the decline, resulting in a net total demand of almost 400 Mt by 2050

Limited availability of certain bio-feedstocks calls for the uptake of other advanced options

In the late 2020s, waste oil feedstock (EU REDII Annex IX Part A and B) is projected to reach global supply caps at ~30 Mt in the Further Acceleration scenario

Meeting the growing demand for sustainable fuels beyond 2030 is expected to require greater use of other types of feedstocks, including RFNBO (CO_2 and H_2)[1] and lignocellulosic materials that require novel production pathways

Investments in sustainable fuels are gaining momentum—$40 billion to $50 billion of investment expected by 2025

With ~70% of investments already after a Financial Investment Decision (FID), 49 Mt of sustainable-fuels capacity is projected by 2025

However, further investments of between $1 trillion and $1.4 trillion are needed by 2040 to meet decarbonization commitments and regulated demand

In the coming decades, business cases may need to consider integrated production logic with volumes shifting from road to aviation, where profitability of production is projected to depend on supply-demand balance, feedstock availability, and consumer attractiveness

1. Renewable fuels of non-biological origin

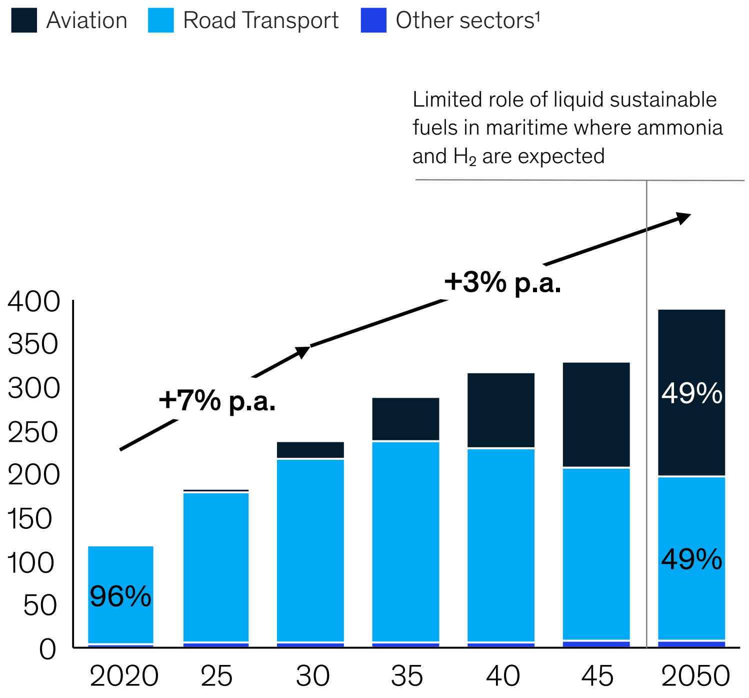
Source: McKinsey Energy Insights Global Energy Perspective 2022

New advanced feedstocks will likely be necessary to meet the growing demand for sustainable fuels

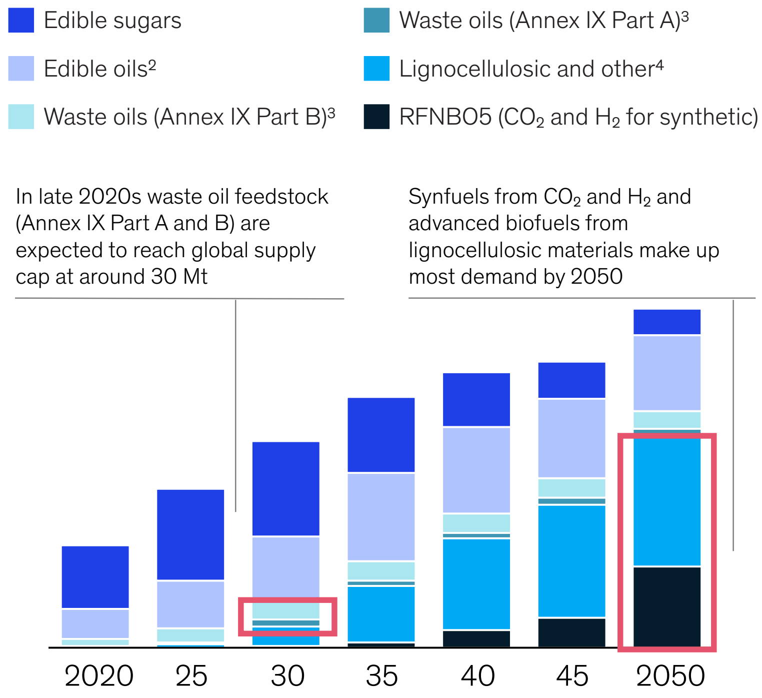
Limited availability of certain bio-feedstocks might call for the uptake of other advanced options

Further Acceleration

Sustainable fuel demand by sector, Mt



Sustainable fuel demand by feedstock type, Mt



1. Maritime, rail, buildings, chemicals, industry, and other
2. Oils from edible crops
3. Feedstocks listed in Annex IX of REDII directive (2018/2001/EU), Annex A (POME, tall oil), and Annex B (UCO, animal fats)
4. Includes all feedstocks for relatively unconstrained technologies, i.e., PtX, gasification, AtJ, bio/syn methane, green H_2 for refinery use, or more HVO if more feedstock is unlocked
5. Renewable fuels from non-biological origin
6. Indirect land use change

Sustainable fuel demand is projected to increase rapidly in the 2020–30s, driven primarily by demand growth in the road transport market

After 2035, however, the projected increase in EV penetration of the transport market may cause a decline in the use of ICE vehicles and a corresponding decline of liquid fuels, and thus sustainable fuels, in road transport. On the other hand, increasing mandates in aviation could outweigh the decline, resulting in further growth of the total demand for sustainable fuels, reaching almost 400 Mt by 2050 in the Further Acceleration scenario

However, since the availability of waste oil feedstocks is highly constrained, the global supply cap (30 Mt) is projected to be reached in the late 2020s, unless purposely-grown volumes of low ILUC[6]/ cover crops are rapidly scaled. Indeed, meeting the growing demand for sustainable fuels will require significant growth in the use of other feedstocks beyond oils and sugars, including RFNBO (CO_2 and H_2 for synthetic fuels) and lignocellulosic

Source: McKinsey Energy Insights Global Energy Perspective 2022; Renewable Energy Directive II (2018/2001/EU)

Analysis conducted before the invasion of Ukraine in February 2022

Carbon capture, utilization, and storage (CCUS)

Chapter summary

CCUS is niche today but is projected to scale notably, reaching ~2—4 Gt by 2050. This will likely require a significant acceleration compared to the current pipeline

To meet announced net-zero commitments in the Achieved Commitments scenario, CCUS uptake will need to grow 120 times by 2050, reaching ~4.2 Gt and decarbonizing 45% of remaining emissions in the industry sector. It could act as an important decarbonization lever for hard-to-abate sectors and as a kick-starter for blue hydrogen

In the Further Acceleration scenario, hard-to-abate sectors in countries without net-zero commitments are projected to decarbonize to a lesser extent, only scaling up when economically viable and reaching ~3.6 Gt by 2050

In the Current Trajectory scenario, CCUS demand would reach ~2.1 Gt by 2050, assuming the scale up is mainly in line with today's pipeline

However, CCUS uptake is subject to uncertainty, mostly driven by a lack of clarity on commercially-viable business models of CCUS relative to alternative decarbonization levers, as well as on the regulatory development

By 2050, ~80% of CCUS uptake is projected to be deployed in cement, iron and steel, and H_2 production, yet is expected to be subject to sector-specific uncertainties and to show regional differentiation

Among the industrial segments, the highest CCUS uptake is projected for the blue hydrogen production, iron and steel, and cement sectors (together accounting for 85% of global total in the Further Acceleration scenario)

CCUS could play a larger role in the decarbonization of the power sector and may reach 1—2 Gt by 2050 if renewable energy sources (RES) build-out is limited by increased land costs in the US, and if India and China choose to avoid stranding young coal and gas plants

The role of CCUS in reducing emissions varies by industry segment. It is the only scalable solution for cement to reduce process emissions, but is facing strong competition from alternatives in other segments

CCUS uptake differs per region, mainly depending on decarbonization ambitions, the economics of blue hydrogen, and the availability of alternative decarbonization levers for hard-to-abate sectors

CO_2 revenue schemes are uncertain, as projected CO_2 prices of up to $150–$205/ton are likely insufficient to accelerate CCUS uptake towards a net-zero trajectory

The costs and economic viability of CCUS applications vary widely depending on segment and geography

There is large uncertainty on the revenue streams for CCUS, given that the projected carbon dioxide prices are insufficient to scale up CCUS on their own, especially for low-purity point sources where additional revenues may be required

Additional revenues are projected to account for ~15% of total revenues required to make business cases toward 2050. These could be from market and regulatory incentives (such as voluntary carbon markets, government subsidies), consumer willingness to pay, and CO_2 end use (such as enhanced oil recovery)

Especially in early years, large additional revenue is required to kick-start CCUS, given that less than one-third of CCUS is expected to be in the money without additional revenue streams

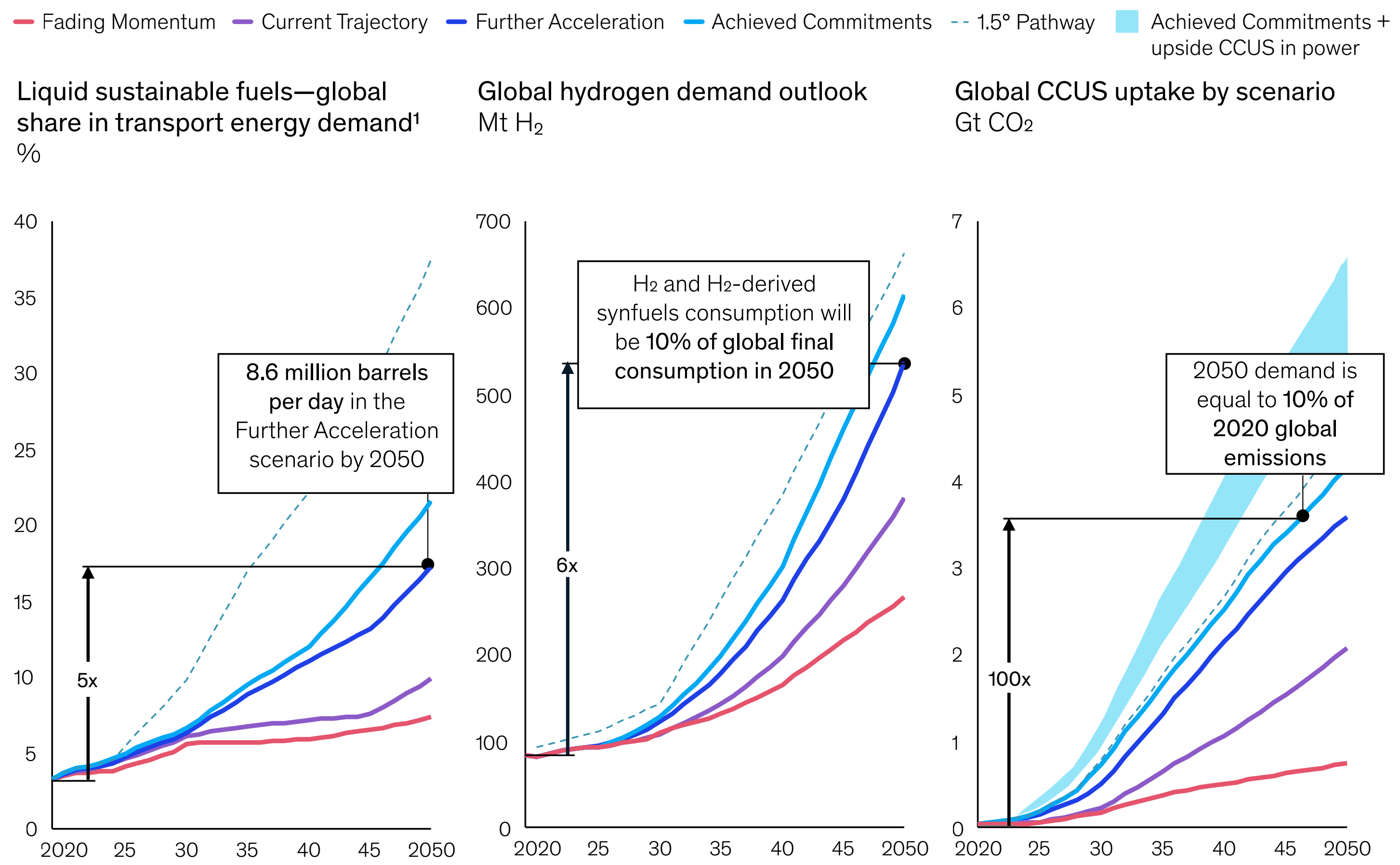
Cost-intensive segments, such as cement, and iron and steel, are projected to take the majority of additional revenues

Source: McKinsey Energy Insights Global Energy Perspective 2022

Analysis conducted before the invasion of Ukraine in February 2022

New energy technologies are growing from niche to significant parts of the energy system across scenarios

Especially after 2030, sustainable fuels, hydrogen, and CCUS are projected to grow significantly



1. Includes bio and synthetic liquids and gases in road transport, rail, maritime, and aviation (not including hydrogen)

Source: McKinsey Energy Insights Global Energy Perspective 2022

The growth in sustainable fuels is driven by the decarbonization ambition in much of the latest regulation, recent investments, and technological advancement. This is expected to include both different types of biofuels as well as power-to-gas fuels. By 2050, the share of sustainable fuels in the energy demand for transportation could be between 6% and 37%, depending on net-zero ambition levels across countries

Similarly, this momentum is helping the uptake of hydrogen. In the Further Acceleration scenario, demand is projected to be mainly in the iron and steel, road transport, and buildings sectors. In maritime and aviation, hydrogen is also projected to be required as input for synfuels

In the Further Acceleration scenario, CCUS uptake will need to increase 100 times by 2050, decarbonizing ~40% of remaining emissions in the industry sector. CCUS is an important decarbonization lever for hard-to-abate sectors, such as iron and steel and cement, and may also be necessary as a kick-starter for blue hydrogen

Investments and Value Pools

Chapter summary

Energy investments may need to grow 4% per annum to support the energy transition, with new technologies capturing ~65% of the investments to 2035

A substantial growth of energy-related investments is triggered by rapid increases in energy demand, with demand for power expected to triple and hydrogen expected to grow fivefold by 2050 in the Further Acceleration scenario, combined with more stringent emission-reduction goals

Renewables are projected to account for more than 30% of the global investments in the next 15 years (excluding transmission and distribution reinforcements). This is twice as high as projected investments in conventional power generation, and almost on par with oil and gas investments

Regional dynamics are projected to persist, with 70% of the oil and gas investments concentrated in North America, Middle East, and Africa to 2035. Europe and Greater China are expected to have a larger spend on decarbonization technologies such as hydrogen electrolyzers and CCUS

Nascent technologies and renewables are likely to consolidate their role and experience a quadrupling in EBIT growth by 2050

Starting from a relatively low EBIT base of ~$300 billion today, power and decarbonization technologies are projected to grow at 5% per annum and reach around $1 trillion in 2050

Profitability is projected to become a challenge for conventional power, as its role shifts from base load to back-up generation, with global EBIT turning negative after 2040 in the Further Acceleration scenario

The exceptionally high returns that characterized oil and gas investments in past decades are unlikely to reoccur, as the demand outlook weakens and the cost of supply increases. Projected EBIT for new technologies, such as clean hydrogen, EV charging, CCUS, and sustainable fuels in 2050 is expected to surpass the 2021 total energy sector EBIT

Business models in a decarbonized system remain uncertain, and will likely be affected by regulations' adjustments

Whereas a strong uptake is projected in decarbonization energy technologies, triggered by cost reductions and rising decarbonization ambitions, revenue streams and support schemes to incentivize these low-carbon investments remain uncertain

To enable a successful transition, regulations mandating a higher share of renewables, CCUS, or sustainable fuels could address the current uncertainties in the business cases of these new propositions, and should stimulate a rapid growth in investments in the short term

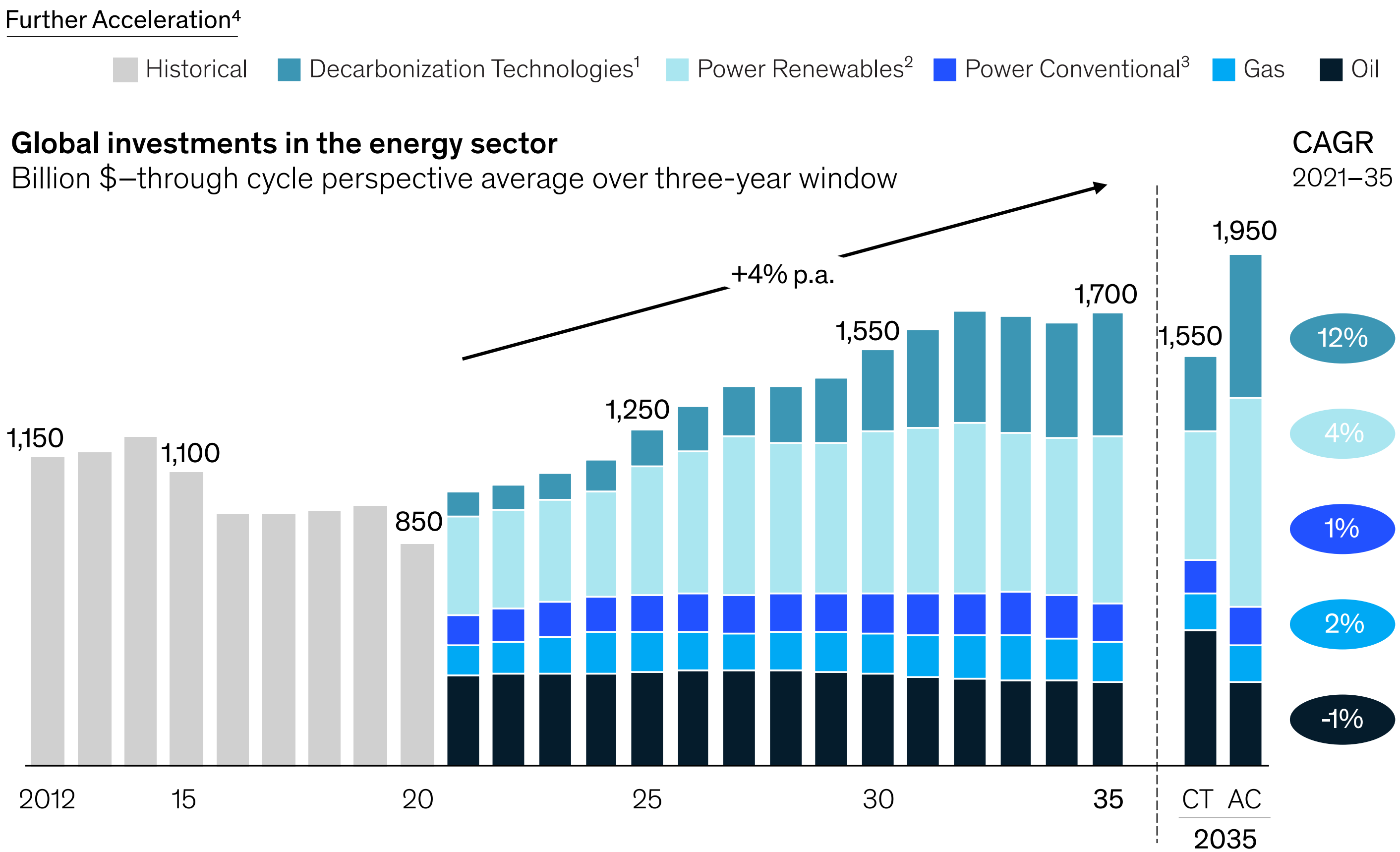
Technologies such as firm thermal power generation are likely to remain in the mix to provide system stability but could see increasing shares of uncertain revenues for which new compensation mechanisms may need to be specified

Source: McKinsey Energy Insights Global Energy Perspective 2022

Analysis conducted before the invasion of Ukraine in February 2022

Energy may attract increasing investment, with most growth being in RES and decarbonization technologies

Despite decline in underlying fossil-fuel demand, investments in O&G are expected to remain stable



Total annual investments in the energy supply sector are projected to grow by 4% per year in the Further Acceleration scenario

Driven by a significant uptake of demand for clean technologies—such as 15% CAGR for renewable power generation and 5% CAGR for hydrogen demand between 2019 and 2035—for the energy transition, almost all growth is driven by renewables power and decarbonization technologies

However, despite the underlying decline in fossil fuel demand and its peak in 2024 in the Further Acceleration scenario, required investments in O&G are projected to stay stable. This is driven by increasing costs, as maintenance capex as well as exploration costs increase, partially triggered by increased environmental requirements

Both trends lead to decarbonization technologies making up more than a fourth of global investments in the energy sector in the early 2030s

1. Includes sustainable fuels, CCUS, hydrogen, and EV charging
2. Includes solar, onshore wind, offshore wind, hydro, and other
3. Includes coal, gas, nuclear, and other
4. For the O&G segments the 2021 Accelerated Transition Scenario is used in combination with Further Acceleration and Achieved Commitments, and the 2021 Reference Case Scenario with Current Trajectory

Source: McKinsey Energy Insights Energy Value Pools Model; IEA World Energy Investments; IEA World Energy Outlook 2021

Analysis conducted before the invasion of Ukraine in February 2022

Emissions

Chapter summary

Global emissions are headed toward 1.7°C to 2.4°C warming, depending on the scenario

Across scenarios, global energy-related emissions are projected to peak before 2030. By 2050, projected levels are expected to be 30–70% below emissions in 2019. In the Achieved Commitments scenario, for example, global energy-related emissions are expected to peak around 2023 and decline by 69% to 11 Gt CO_2 by 2050

However, even though projected emissions reductions have accelerated compared to earlier outlooks, the world remains far from achieving the 1.5° Pathway, even if all countries fulfill their pledges, as in the Achieved Commitments scenario, global warming will likely still exceed 1.5°C

To meet the requirements for a 1.5° pathway, mature economies would likely need to accelerate their annual emissions' decline, on average, by a factor of eight to nine times compared to efforts in the last ten years. Emissions from emerging economies are projected to continue to grow over the next decade; these countries may need to move to lower-carbon growth paths sooner and reach their emissions peaks earlier

Emissions in 2021 rebounded to historic trends alongside the global economic recovery

Following a significant decline in 2020, emissions showed a strong rebound in 2021, almost returning to 2019 levels; emissions in 2021 were only 1% lower than 2019 levels. This illustrates how pre-pandemic trajectories in emissions have largely continued

Emerging economies drove the rebound in emissions. China's emissions grew at twice its pre-pandemic growth rate (3% per annum in 2021) and India rebounded to 2019 levels in 2021

Both coal and natural gas emissions were higher than 2019 levels. The use of coal in power primarily drove the surge in coal emissions, supported by strong industrial growth in China and high gas prices globally. Gas emissions only marginally declined in 2020 and increased beyond 2019 levels in 2021

Oil emissions only partially rebounded in 2021, largely due to the slow recovery in aviation

Meanwhile, 2021 brought a new focus on net-zero commitments and methane-emission reductions

Many countries updated their decarbonization plans in 2021 to have more aggressive reduction targets. Around 91% of global CO_2 emissions are now covered by net-zero targets

In late 2021, as a precursor to COP26, some of the world's largest emitters recognized the GHG methane (CH_4) as a prominent contributor to global warming. They committed to a 30–50% reduction in methane emissions by 2030

Although these pledges would reduce global methane emissions by around 13% by 2030, they remain far from the 34% that is required to achieve a 1.5° pathway. Some large emitters, such as Russia, India, and China have not yet made commitments to reduce emissions

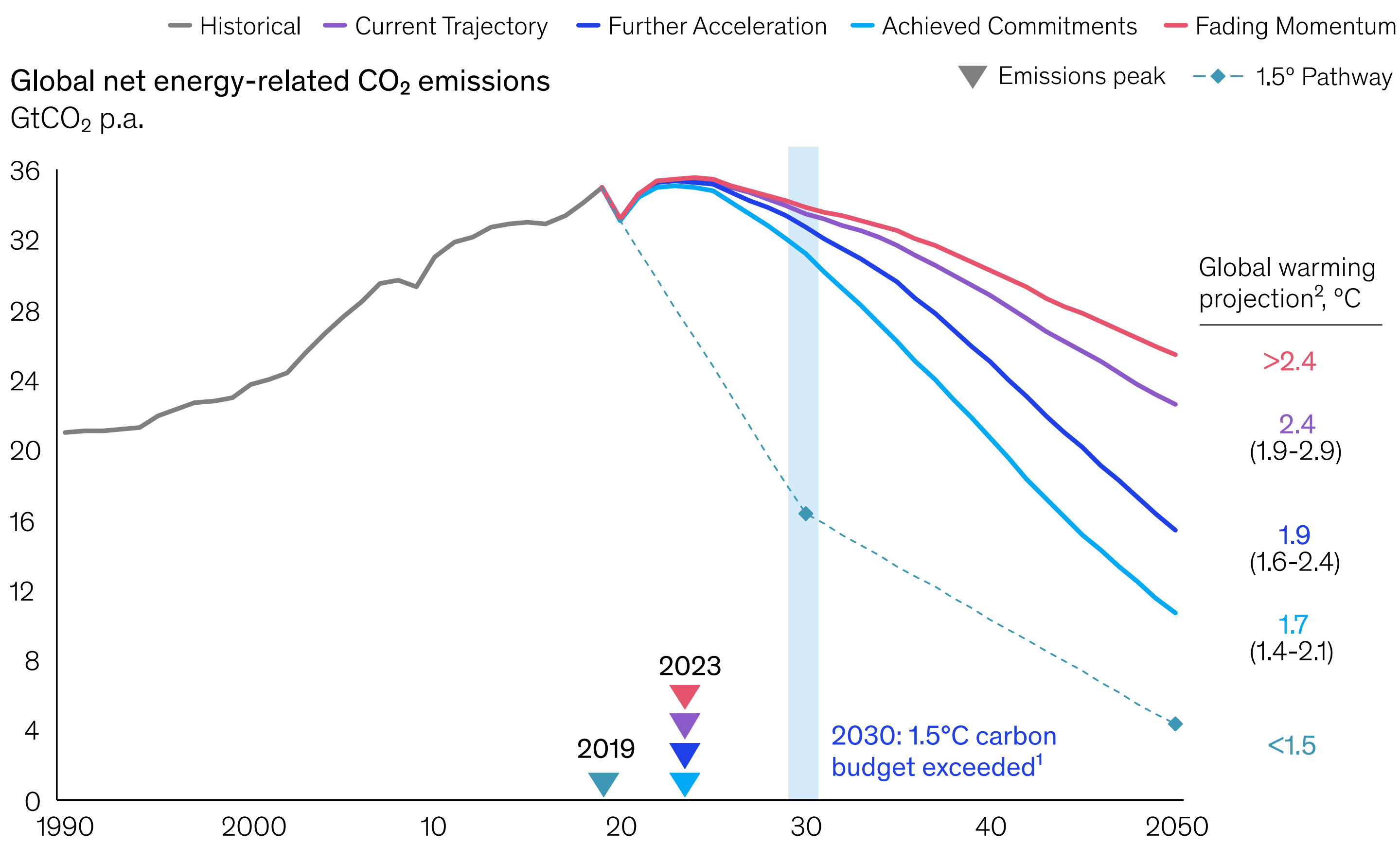
Strong innovation may be necessary to further develop technologies to reduce methane emissions and reach a 1.5° pathway. Such technologies, alongside existing technical levers, will likely be crucial to reduce methane emissions

Source: McKinsey Energy Insights Global Energy Perspective 2022

Analysis conducted before the invasion of Ukraine in February 2022

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

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



COVID-19 triggered a drop in global CO_2 emissions of around 5%. However, emissions have already rebounded and are back to a pre-COVID-19 level. In the Further Acceleration scenario, a flattening of energy-related CO_2 emissions is projected, with a peak in 2023, followed by an accelerating decline

In the Achieved Commitments scenario, expected emissions in 2050 are 30% lower than in Further Acceleration, reflecting a more rapid shift to renewable sources for power generation as well as an accelerated uptake of new, lower-carbon technologies in end-use segments, such as road transport and industry

However, emissions across all scenarios remain far from the requirements for the 1.5° Pathway. Depending on the scenario, the median of expected global temperature increases could reach 1.7—2.4°C or more by 2100. This median global increase implies a 50% chance of exceeding the average on a global level, with stronger increases for specific regions

1. 570 Gt of cumulative CO_2 emissions from 2018 for a 66% chance of limiting global warming to 1.5°C
2. Warming estimate is an indication of global rise in temperature by 2100 versus pre-industrial levels (median - 17th/83rd percentile), based on IPCC assessments given the respective emission levels and assuming continuation of trends after 2050 but no net-negative emissions

Source: McKinsey Energy Insights Global Energy Perspective 2022

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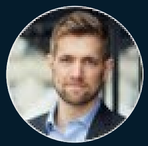

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