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Energy transition outlook 2024

World on the edge: net zero by 2050 in doubt without doubling annual investment in energy supply to US$3.5 trillion

October 2024

A strategic perspective of the energy transition

Broad and deep – forming an integrated view of various energy transition scenarios across each segment, commodity, technology and market

Investible market intelligence

- Regional power and renewables markets
- Oils and refining
- Global LNG and gas
- Regional gas markets
- Bulks and metals markets
- Chemical markets
- Hydrogen and ammonia markets
- Bioenergy markets
- Carbon markets

Integrated global perspectives

Energy transition research (global energy and emerging technologies) includes our Energy Transition Outlook (ETO)

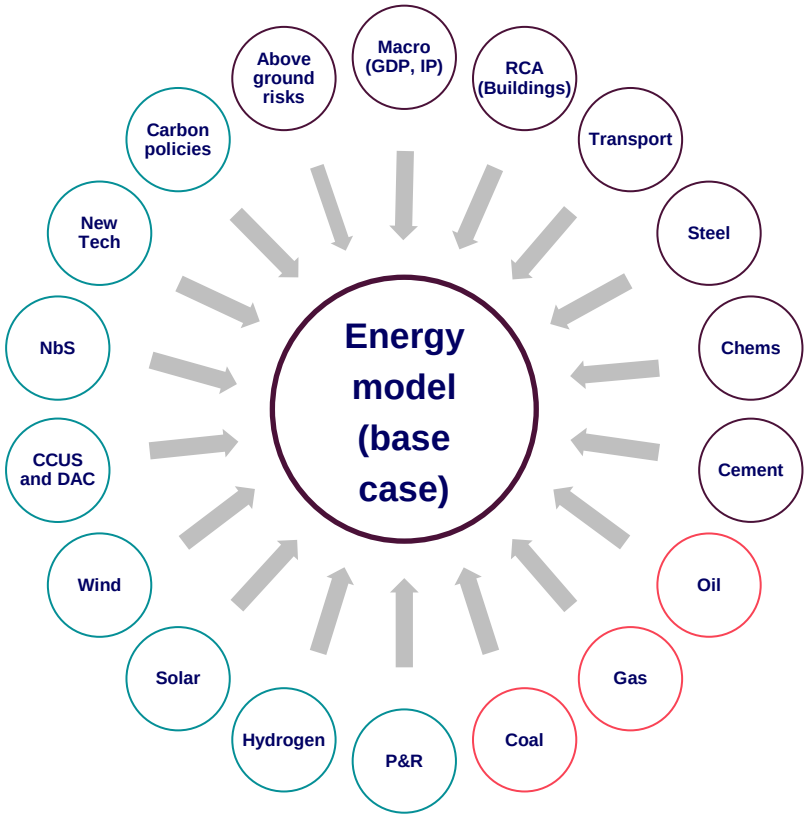
Industry value chain depth: assets, technologies and costs

- Wind
- Solar
- Grid edge
- Energy storage
- Electric vehicles
- Carbon capture
- Hydrogen and electrolyser
- Nuclear
- Geo-thermal
- Oil and gas
- Metals and mining
- Chemicals

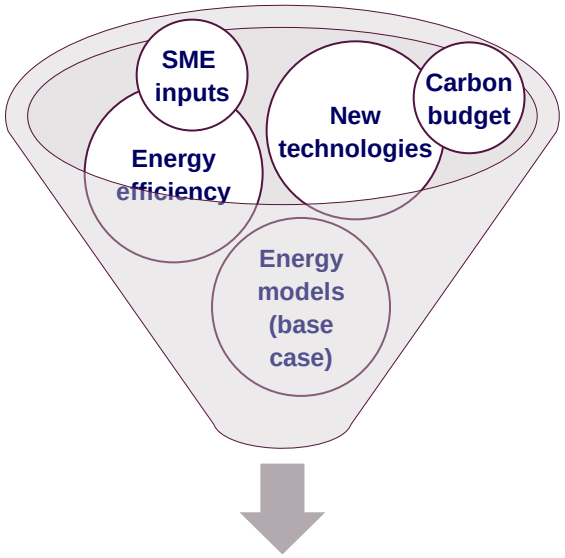
Energy transition model design

Our integrated approach allows us to assess the impact on commodities from climate risks

1) Inputs: base case



2) Inputs: scenarios



Energy model (Scenarios)

3) Outputs: scenarios

Energy Transition Service

- Primary energy supply and end-use demand
- Oil, gas and coal demand
- Bioenergy
- Gross and net carbon emissions
- Power demand
- Power supply and capacity mix
- Solar, wind and energy storage
- SMR nuclear
- Geothermal
- Low-carbon hydrogen supply and demand
- Point-source and direct-air capture volumes
- Nature-based solutions
- Capex outlook by scenario and segment

Commodity research services

- Oil and products
- LNG
- Coal trade
- Copper
- Aluminium
- Nickel
- Zinc
- Lithium
- Cobalt
- Manganese
- Rare earth elements
- Ferro and noble alloys
- Iron and steel

Energy Transition Service

Quantify the energy transition across all commodities, markets, technologies, segments and scenarios

Overview

See how today's fossil fuels-based energy system will shift to lower carbon options through to 2050 and beyond.

Ideal for industry leading strategy, corporate planning, finance, and low carbon ventures teams.

Selected analysis

- Energy Transition Outlook
- Country pledges and net zero scenarios
- Investment needed for the energy transition
- New technologies; bioenergy, nuclear, hydrogen, carbon

Key workflows and questions

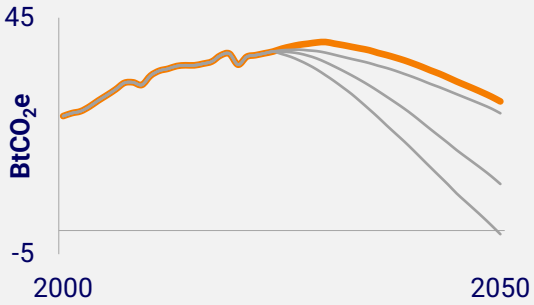
Is further exploration justified under accelerated energy transition scenarios?	How large will hydrogen and CCUS be in the overall energy mix?
What is the outlook for gas & low carbon fuels in power generation?	How resilient is my current business and where do I need to be in 10 years time?
What markets have decarbonisation potential – what sectors and in what fuels?	What is the next big technology in the energy sector?

Use it to:

- Identify US$78 trillion investment opportunities by market segment in a net zero world
- Benchmark 200+ new technologies and use cases that will accelerate the energy transition
- Compare integrated energy transition modelling outcomes from our ETO base case, country pledges and net zero scenarios
- Examine market opportunities in the bioenergy space across solid biomass, liquids and biomethane
- Assess the role green and blue hydrogen and their derivatives will play in reaching Paris climate targets
- Quantify carbon capture and removal by market and scenario across CCUS, BECCS, direct-air capture, and nature-based solutions

Our Energy Transition Outlook explores four possible transition trajectories

Delayed transition 3 °C



Scenario: a cascade of geopolitical crises continue to fragment global trade. Policymakers choose protectionism over cooperation, driving up the cost of alternative energies.

Key 2050 metrics

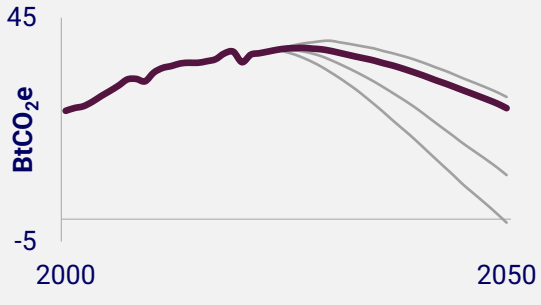
Investment **US$ 52** trillion

EV share: **44%**

Power mix: **79%** renewables

Carbon price: **$68/t**

Base case 2.5 °C



Base case outlook: Steady advancement of current and nascent technologies largely driven by affordability and supply security concerns.

Key 2050 metrics

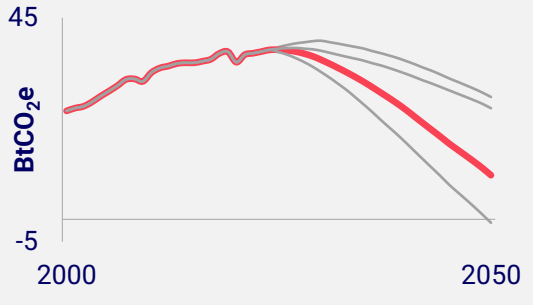
Investment **US$ 55** trillion

EV share: **51%**

Power mix: **82%** renewables

Carbon price: **$84/t**

Country pledges 2 °C



Scenario: coordinated policy responses to the current energy crisis and geopolitical challenges facing the global economy, building momentum in the 2030s.

Key 2050 metrics

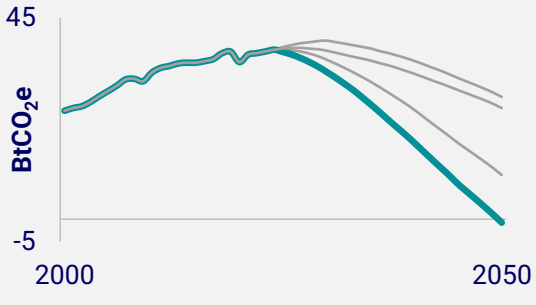
Investment **US$ 65** trillion

EV share: **71%**

Power mix: **91%** renewables

Carbon price: **$133/t**

Net zero 1.5 °C



Scenario: immediate peak energy, rapid deployment of negative emissions technologies, nuclear, long-duration storage and geothermal.

Key 2050 metrics

Investment **US$ 78** trillion

EV share: **91%**

Power mix: **94%** renewables

Carbon price: **$157/t**

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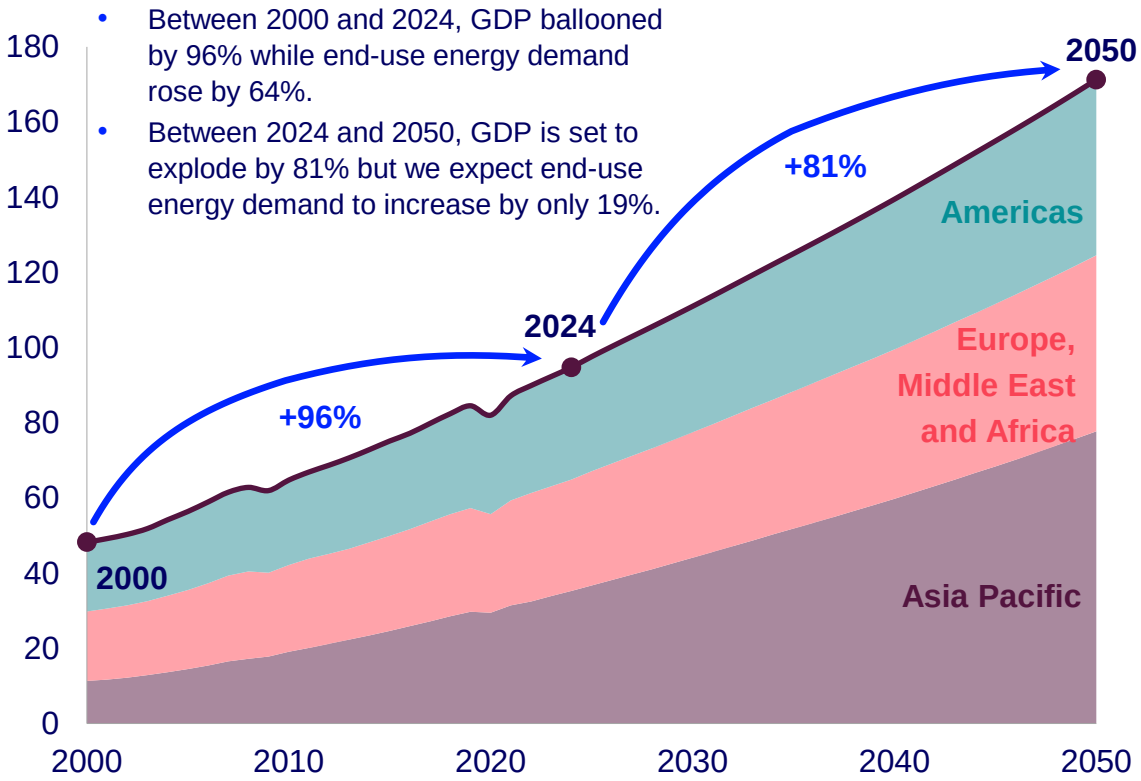
Note: investment amount is cumulative between 2024-2050. Renewables includes solar, wind, geothermal, tidal, nuclear, hydroelectric, bioenergy, and low-carbon hydrogen.

Electrification and renewables temper energy demand from rising incomes

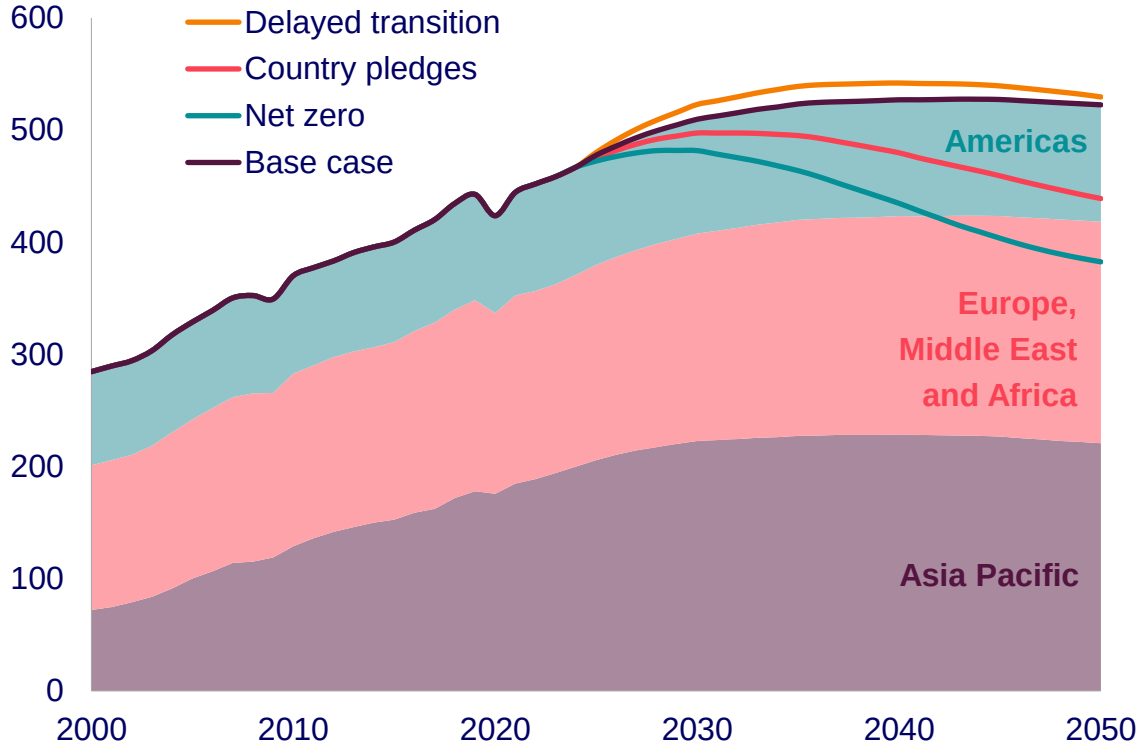
Each unit of electricity generated from renewable sources displaces three times as much in fossil fuel demand

GDP, constant (2015) US$ billion



Source: Wood Mackenzie Macroeconomics service

End-use energy demand, EJ

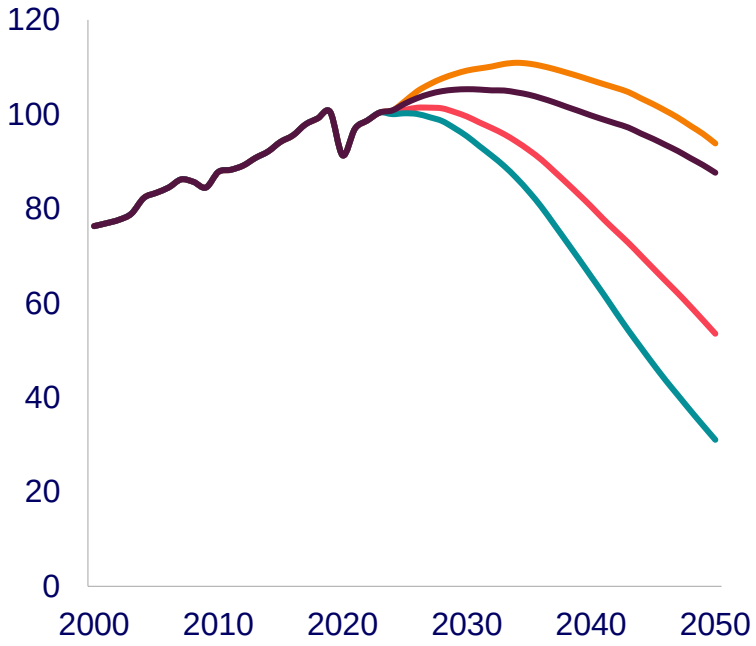


Source: Wood Mackenzie Energy Transition Service

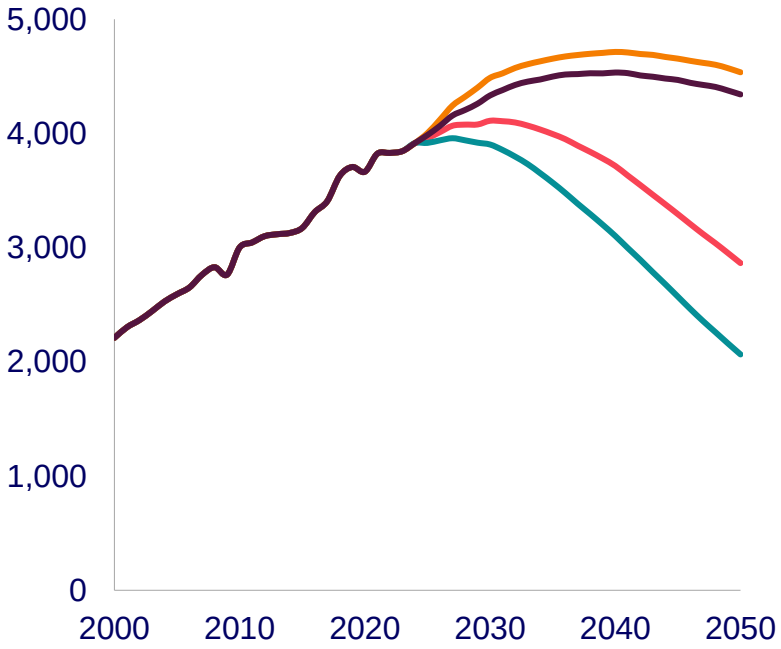
Fossil fuels demand outlook is uncertain, but the long-term direction of travel is clear

Oil may plunge with greater EV adoption while natural gas remains resilient and coal is in structural decline

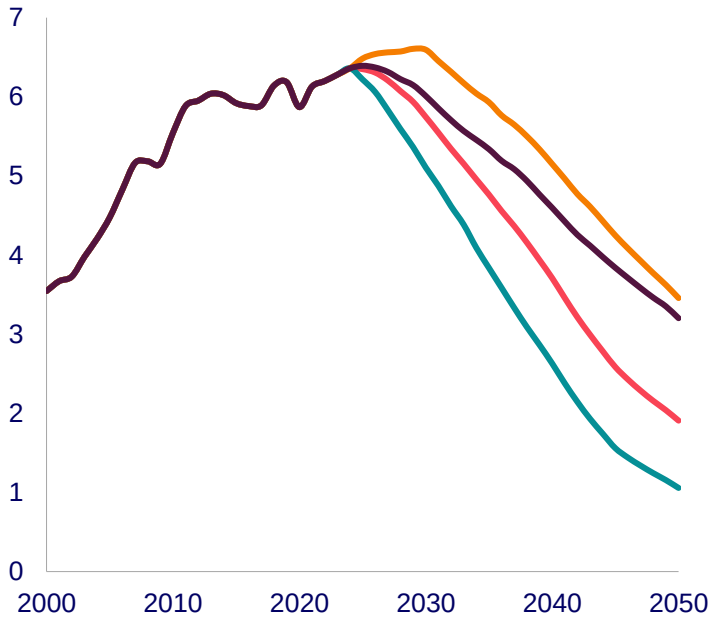
Liquids, million barrels per day



Gas, billion cubic metres



Coal, billion tonnes



Delayed transition Base case Country pledges Net zero

Note: liquids refers to oil and biofuels
Source: Wood Mackenzie Energy Transition Service

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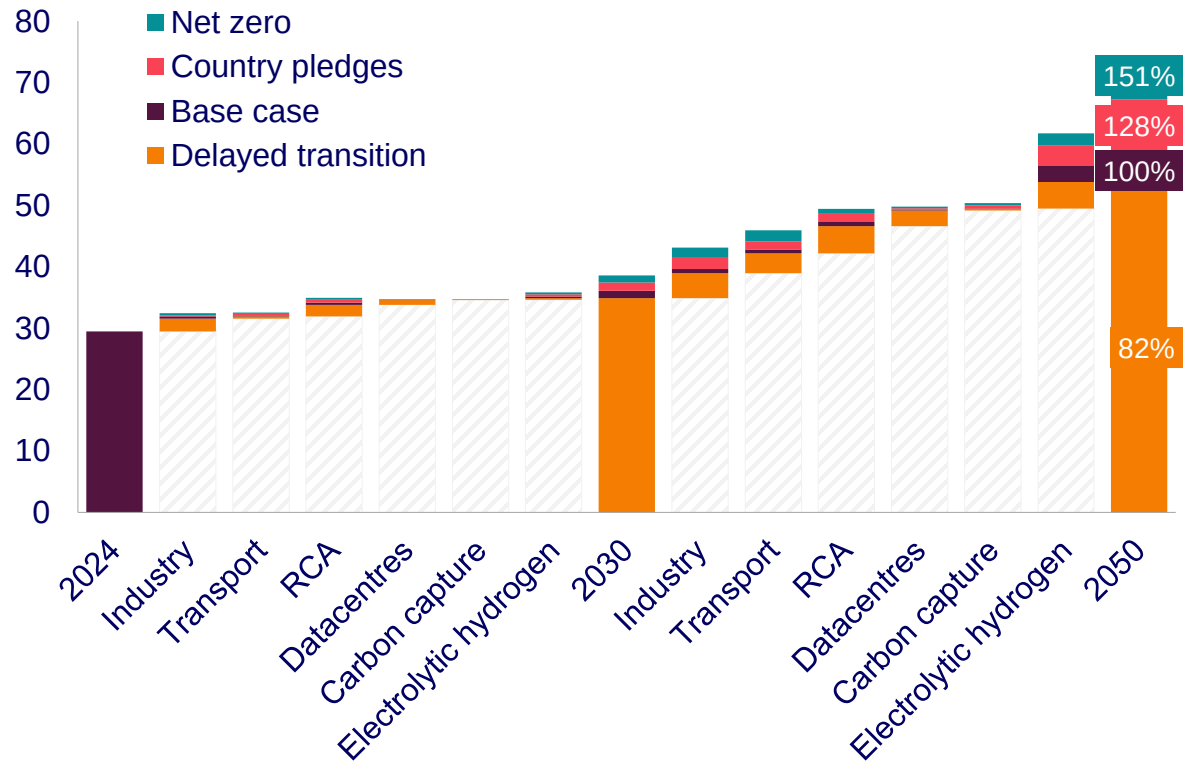
Power demand doubles in base case by 2050 as electrification expands

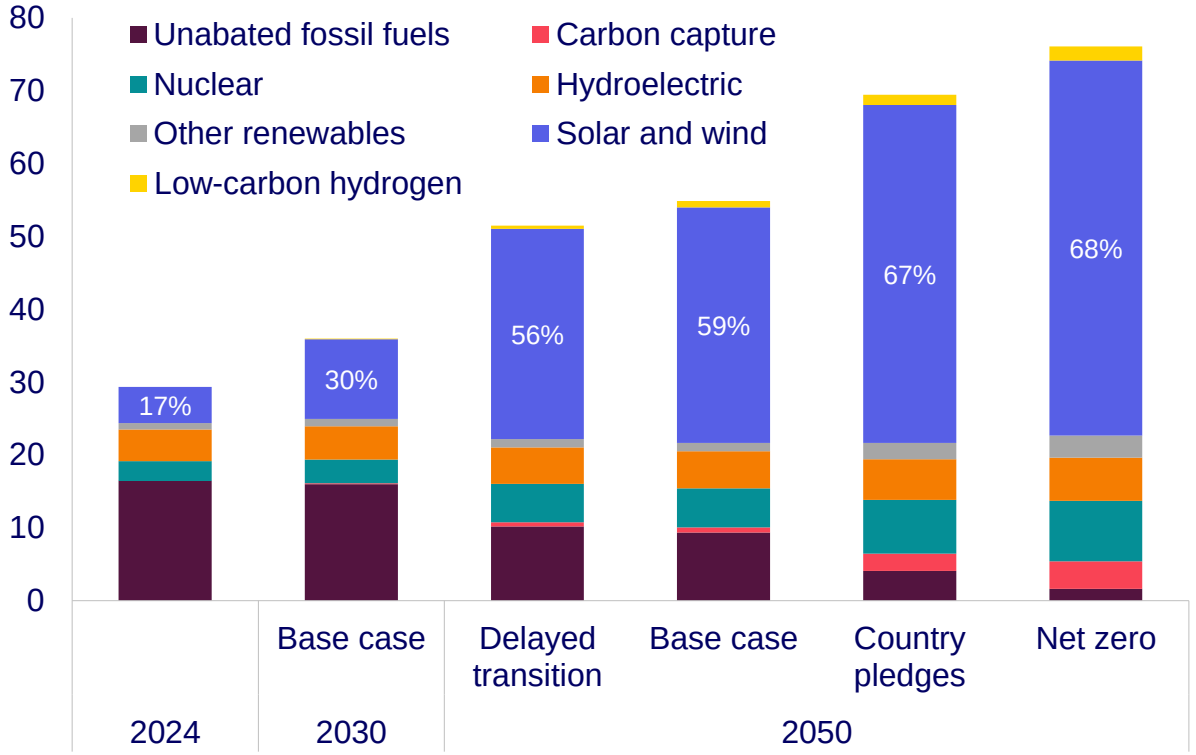
Dispatchable power supply remains steady as solar and wind meet incremental power demand across all cases

Power demand, PWh



Note: percentages based on increase from 2024

Power supply, PWh

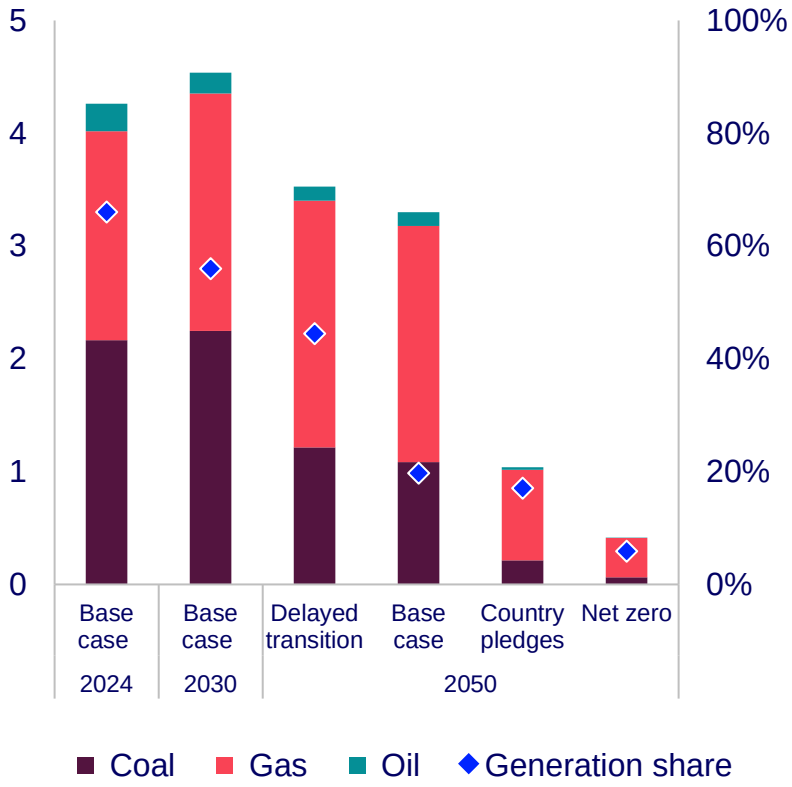


Source: Wood Mackenzie Energy Transition Service

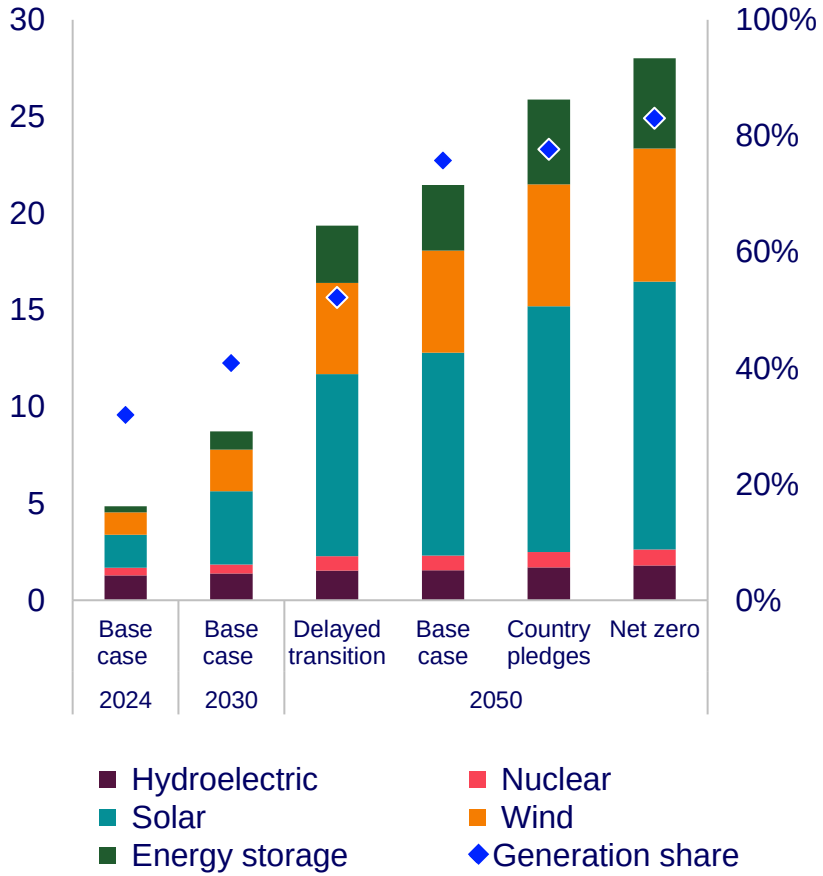
Solar and wind capacity surge to five times existing levels in 2050 base case

Gas into power remains resilient to support variable renewables

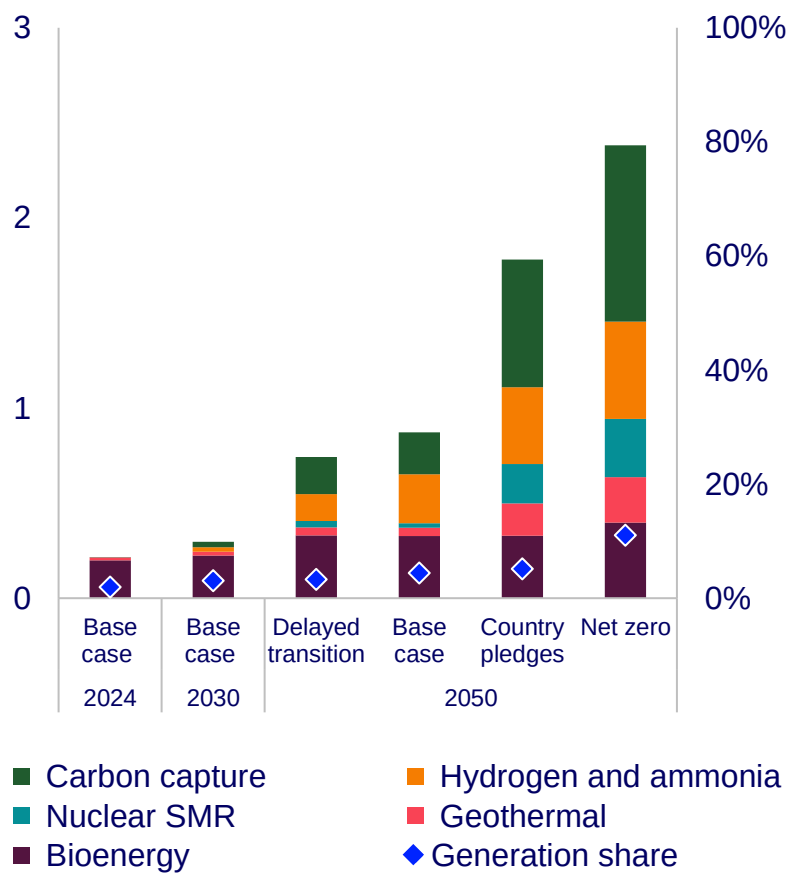
Conventional thermal capacity, TW



Mature low-carbon capacity, TW



Advanced low-carbon capacity, TW

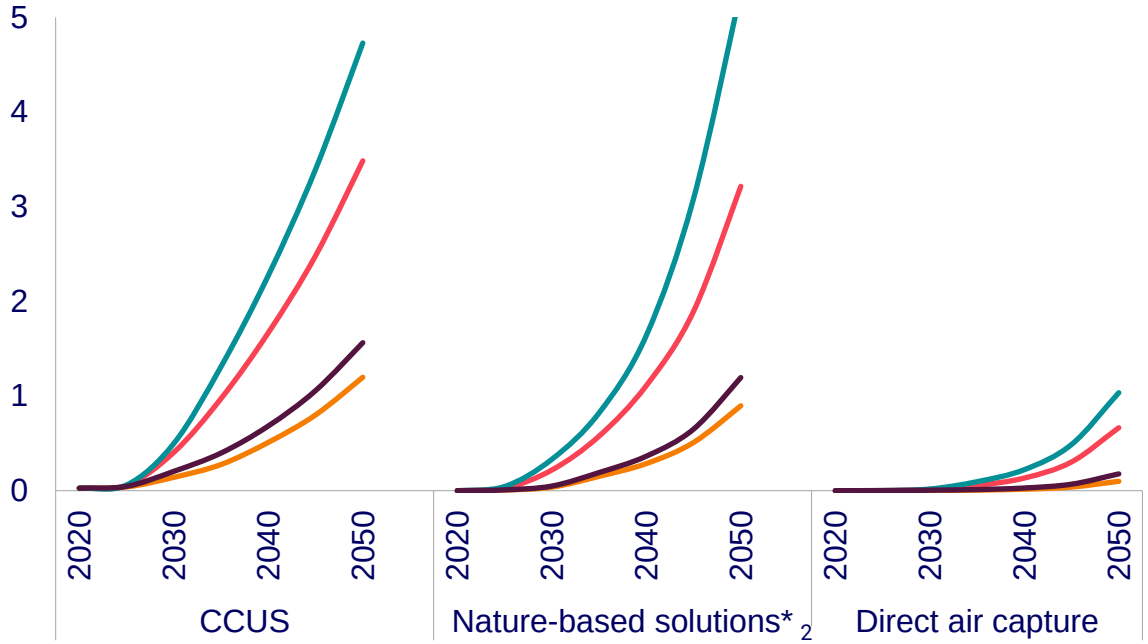


Source: Wood Mackenzie Energy Transition Service

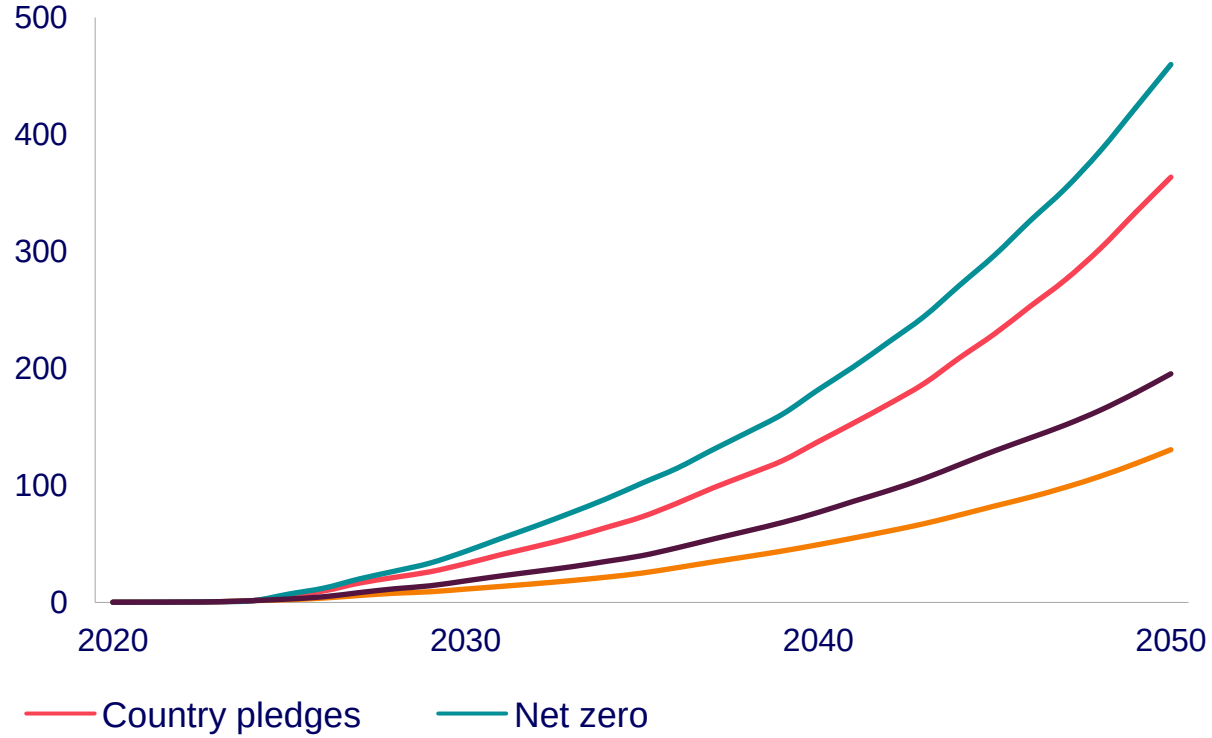
Net zero requires 10 Bt of CO_2 capture and removal and 460 Mt of hydrogen by 2050

Emissions reductions alone are no longer sufficient, removal technologies need to be scaled up

Carbon capture and removals[1], Btpa



Low-carbon hydrogen supply, Mtpa

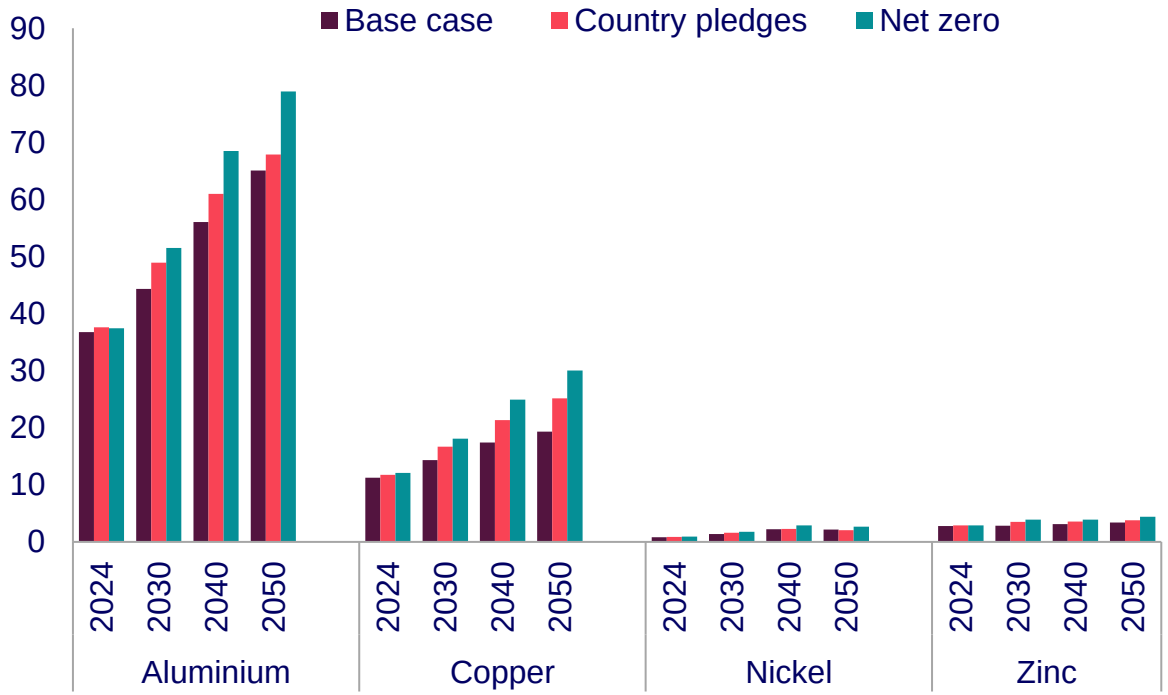


1. Indicates captured volumes, not project capacity.
2. Nature-based solutions (NBS) include both forest sinks and advanced NBS such as geoengineering. NBS values indicate incremental additions only.

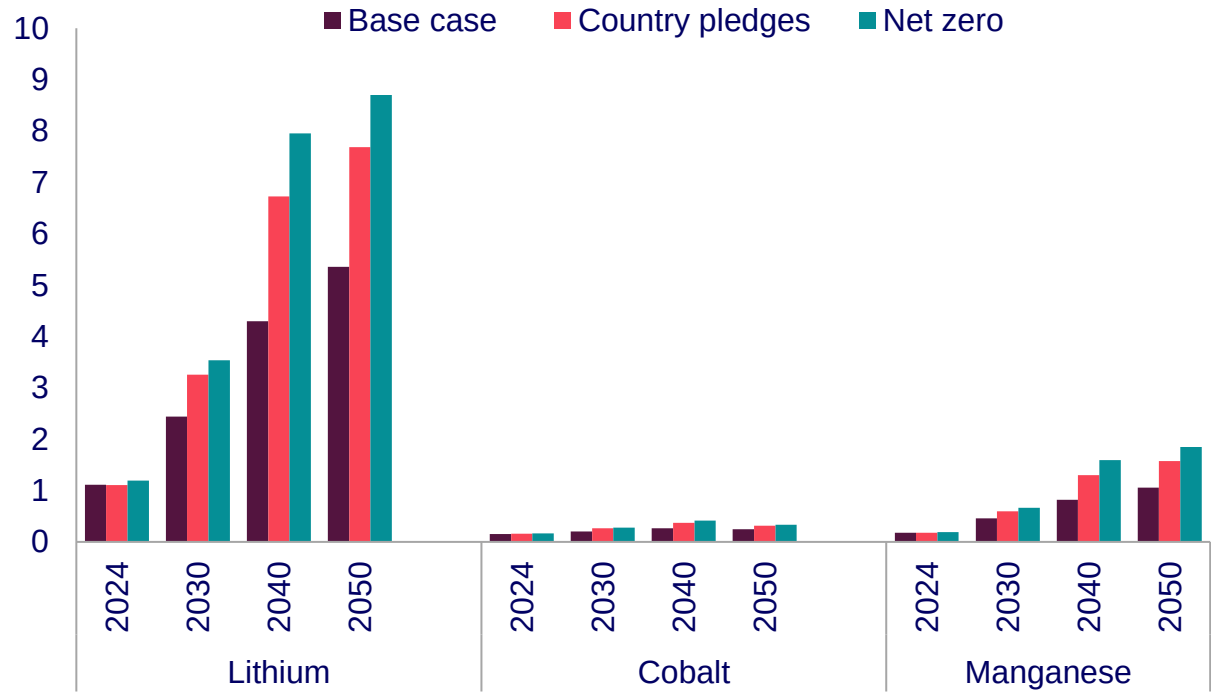
Base metals and battery raw materials supply crucial to support electrification

Urgency of investment underpinned by 7 to 10-year build times for new mines

Base metals demand, Mt



Battery raw materials demand, Mt



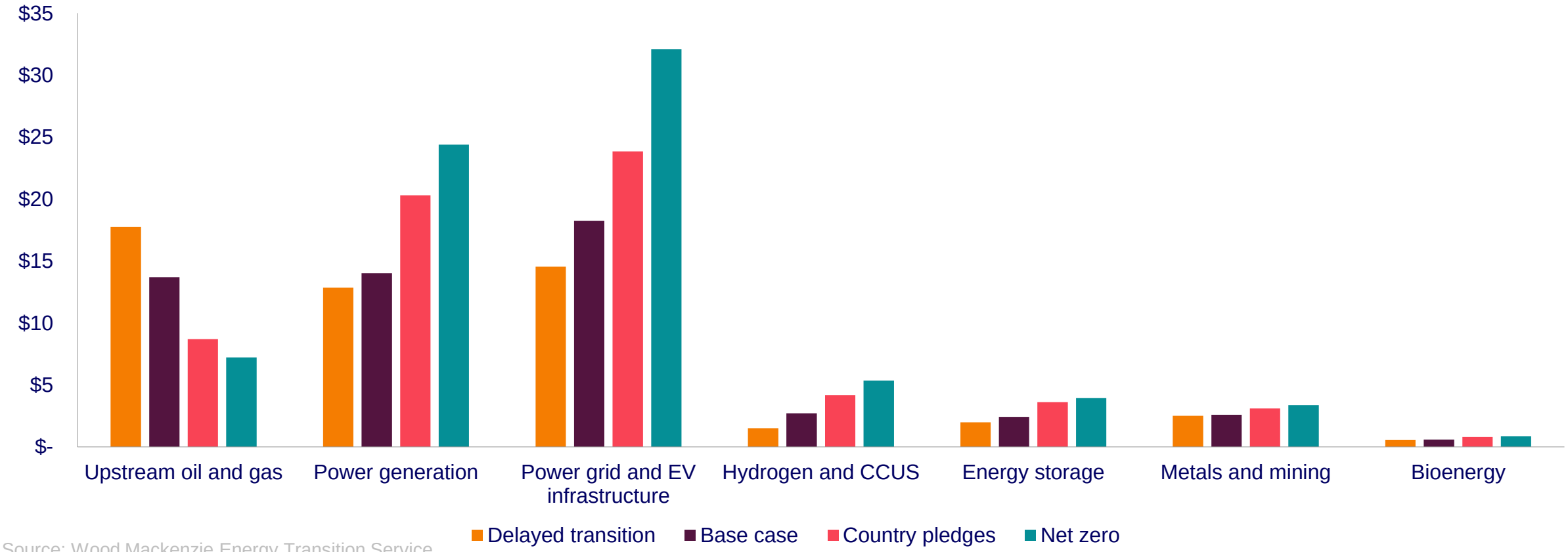
Lithium demand in Lithium carbonate equivalent (LCE)

Source: Wood Mackenzie EVBSC

Energy supply investment to nearly double by 2050 to US$3.5 trillion to reach net zero

Power generation and infrastructure account for up to 80% of total spending

Cumulative capex spend by segment and scenario (2024-50), US$ trillion (real 2024 terms)



Source: Wood Mackenzie Energy Transition Service

The transition is underway but mounting risks could slow it down

Successive shocks to global markets threaten to derail progress and knock the world onto 3 °C pathway

In our base case outlook, **China** has the largest absolute decline in net energy-related emissions. Emissions by 2050 will be 7.8 Bt lower than in 2024 due to electrification targets, the phase-down of thermal coal in the power sector and the country's advanced manufacturing supply-chain for solar and batteries. In **Europe**, compliance markets under the EU Emissions Trading Scheme (ETS), Power Purchase Agreements (PPA) pipelines for wind and solar, and policy support for emerging technologies under RePowerEU result in a 2 Bt decline in net energy-related emissions.

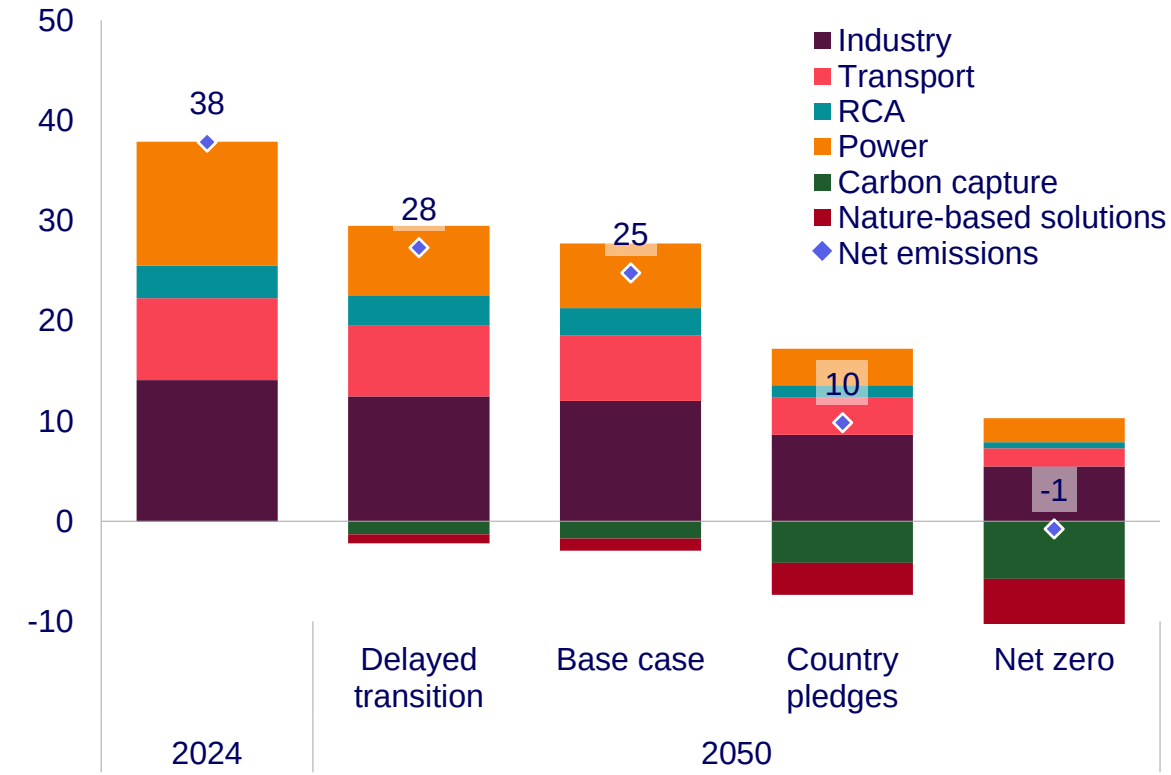
Progress is not as swift elsewhere. With a patchwork of carbon pricing regimes, nationwide infrastructure permitting uncertainty and the incentive-based energy policy of the Inflation Reduction Act, capital is not being deployed fast enough to realise a net zero trajectory in the **United States**. **Latin America**, **Africa**, and **Southeast Asia** face a combination of instability in energy and macroeconomic policies and affordability challenges for emerging technologies.

To support a net zero pathway, the major levers available via the United Nations Framework Convention on Climate Change (UNFCC) include a global climate bank, launching global carbon markets under Article 6 of the Paris Agreement and more ambitious Nationally Determined Contributions (NDCs) in 2025.

National-level permitting reform to support large-scale infrastructure projects, deploying grid-enhancing technologies, greater research and development spending on emerging technologies and improved planning across power generators and regulators are options available to national and local governments worldwide.

Source: Wood Mackenzie Energy Transition Service

Net emissions by sector, $BtCO_2e$



Note: RCA = Residential, commercial, agricultural
Charts show gross emissions as positive numbers and removals as negative.

Signposts for a crucial decade ahead

The first global stocktake (GST), concluded at COP28 in November 2023, required that countries raise their ambitions in the next round of nationally determined contributions (NDC) submissions, due in 2025.

The GST also found that no major country was on track to meet its 2030 goals. That leaves an opportunity both for course correction in the next NDC round and for higher emissions-reduction goals for 2035. The GST emphasised the importance of protecting land ecosystems and addressing biodiversity loss, including halting and reversing deforestation by 2030.

But none of this will be easy without increased cooperation at the COP29 meeting in Azerbaijan in November 2024. Key issues include finalising Article 6 of carbon markets and setting a new global climate finance goal that replaces the existing US$100 billion a year. That figure was not achieved until 2022 and is considered grossly insufficient to meet the needs of developing countries.

Strengthened NDCs and global cooperation will be crucial to mobilising the US$3.5 trillion annual investment into low-carbon energy supply and infrastructure, including critical minerals. But if these challenges are not overcome and emissions continue to rise, then governments and industry could be forced to invest in mitigation and spend much more on adaptation. A delayed energy transition – and all the uncertainty it brings – would mean the world teeters on the edge.

2023

- GST concluded in December that no country was on track to meet the 2030 emissions reduction target.
- Countries must lower emissions and triple renewables capacity by 2030.

2025

- NDCs are due for submission in 2025 before COP30.
- COP29 in Baku and COP30 in Brazil will address outstanding issues – finance, Article 6 and adaptation.

2035

- The UNFCCC requires emissions to fall by 60% by 2035 from 2019 levels to limit warming to 1.5 °C.
- The timeline is significant as the 2030 emissions reduction goals will most likely be missed in major markets.

Source: Wood Mackenzie Energy Transition Service

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The Energy Transition Outlook represents contributions from our global multi-commodity research group, with key authors from our Scenarios and Technologies team

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