

# Megatrends and Long-Term Perspectives on Energy Security

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**Chair of Global Research**

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*Charts are taken from presentations from Global equities, economics, rates, FX, commodities, US fixed income and EM research groups.*

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# Executive Summary

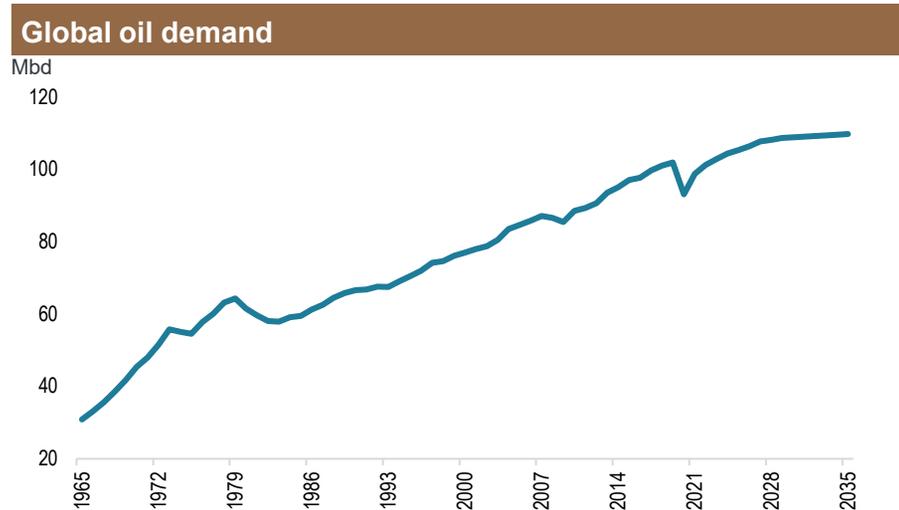
## **Key themes transforming long-term energy security**

- Long-term demand for energy is far from peaking.
- Data centers are driving energy demand, with financing needs of \$5trn to the end of the decade.
- Emerging markets are primary drivers of energy demand.
- Global renewables growth potential remains sizeable.
- China is undergoing one of the most ambitious energy transitions in history.

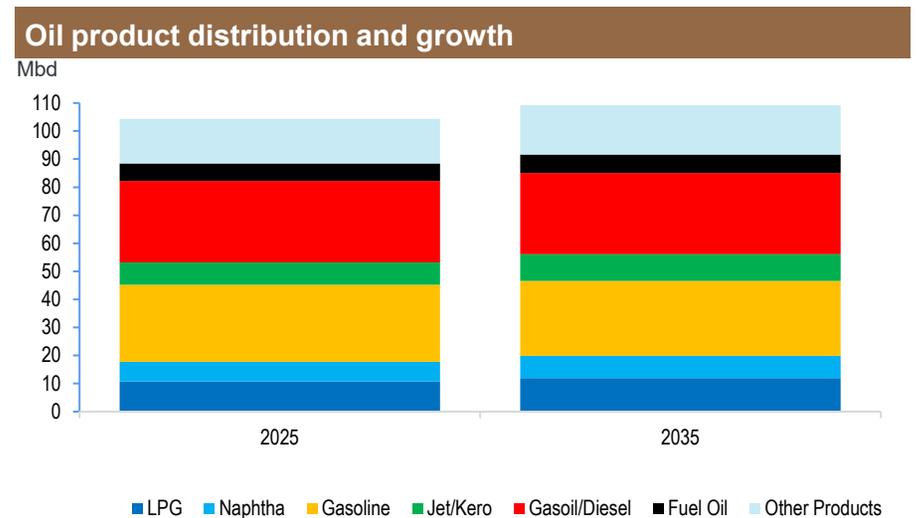
## **Financing challenges remain significant**

- Targets are far from being met and emissions in 2025 could be twice the level required for a 1.5C scenario.
- Investment in low-carbon technologies is below 2030 targets in crucial regions.
- EM countries will need to spend \$2.4trn/year in climate-related and energy transition investments.
- Adaptation financing is lagging with aspirations to triple financing by 2035.

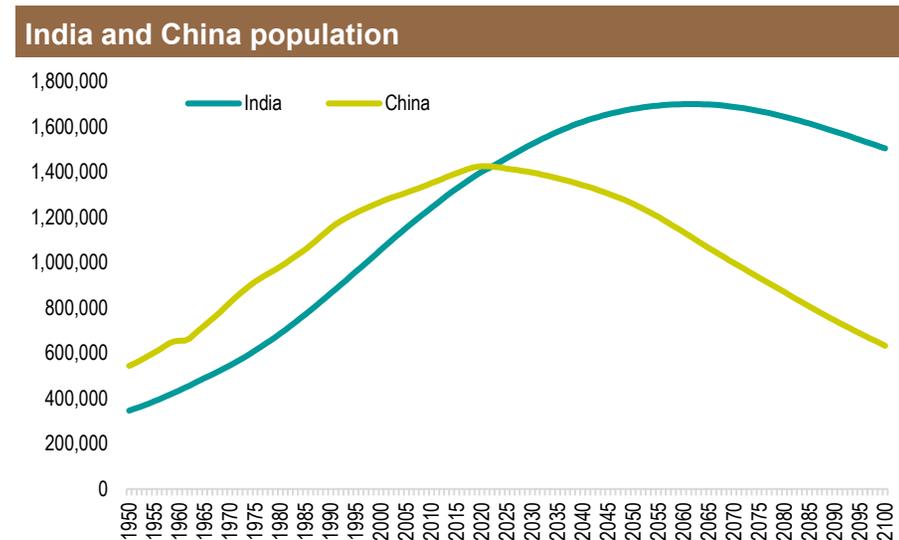
# Long term oil demand will grow through 2035



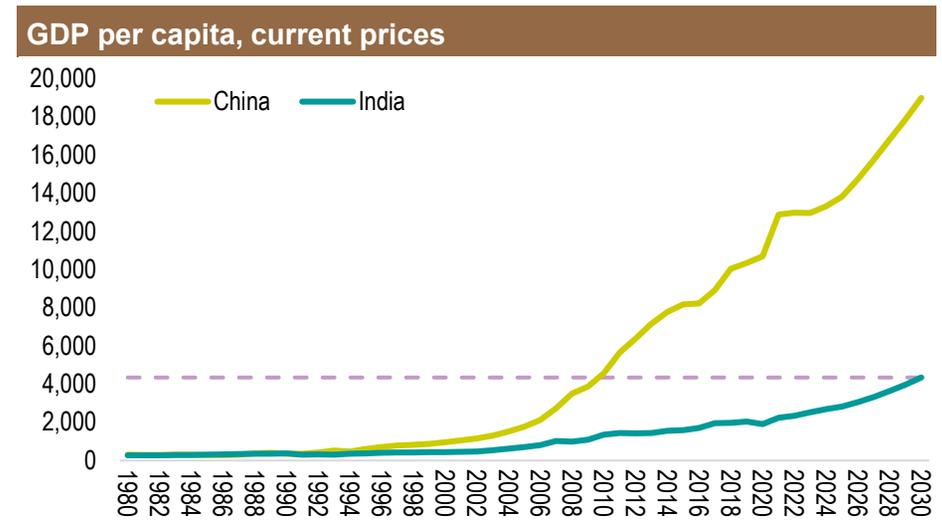
Source: IEA, EIA, Wood Mackenzie, J. P. Morgan Commodities Research



Source: IEA, EIA, Wood Mackenzie, J. P. Morgan Commodities Research



Source: J. P. Morgan Commodities Research, UN



Source: IM, J. P. Morgan Commodities Research

# Elevated risks with higher commodity price volatility since 2020 compared to the previous five decades

## Risks to commodity prices

### Upside risks

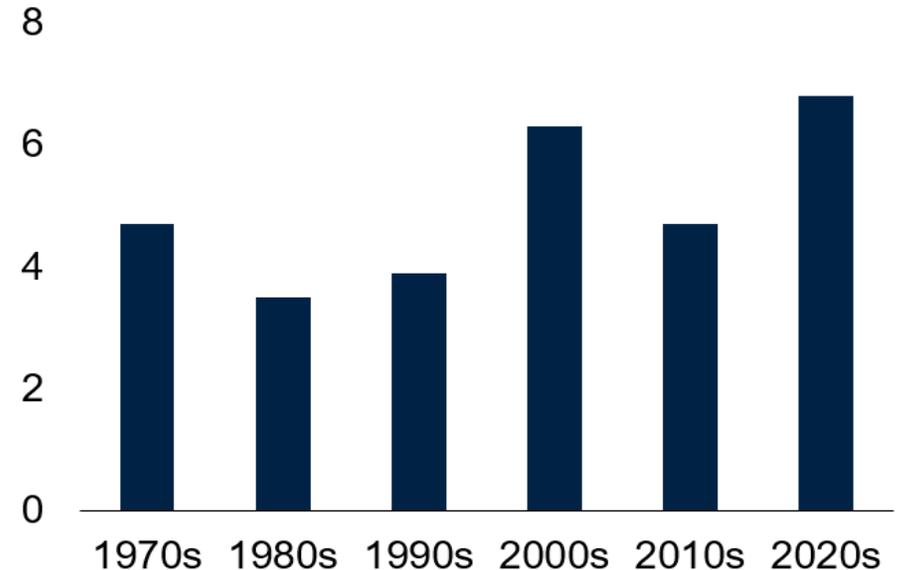
- Additional geopolitical tensions and sanctions
- Additional trade and production restrictions
- Adverse weather conditions
- Faster-than-expected electricity demand and expansion in data centers

### Downside Risks

- Slower global growth
- Oil market oversupply

## Volatility of overall commodity price index

Standard deviation

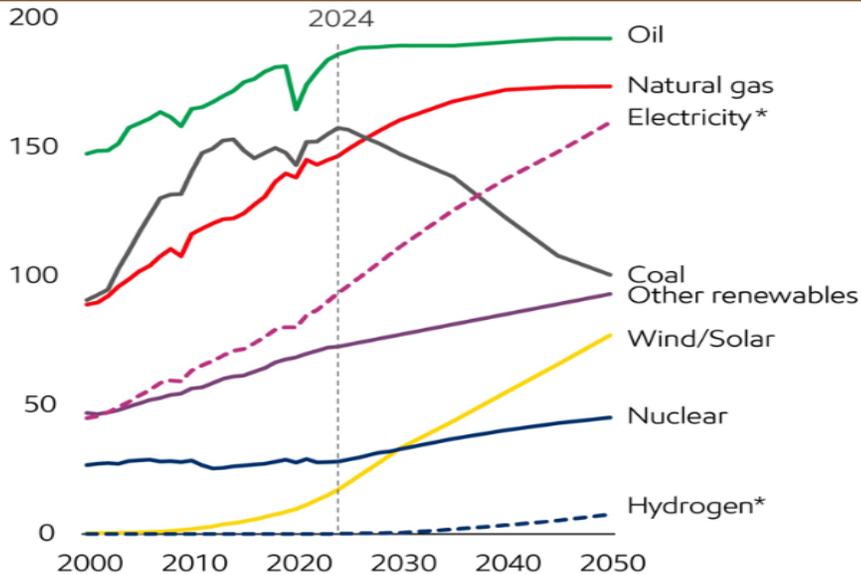


Note: Bars show mean standard deviation of monthly price changes in the composite commodity index by decade, spanning data from January 1970 to September 2025. The commodity index measures prices in U.S. dollars.

Source: World Bank.

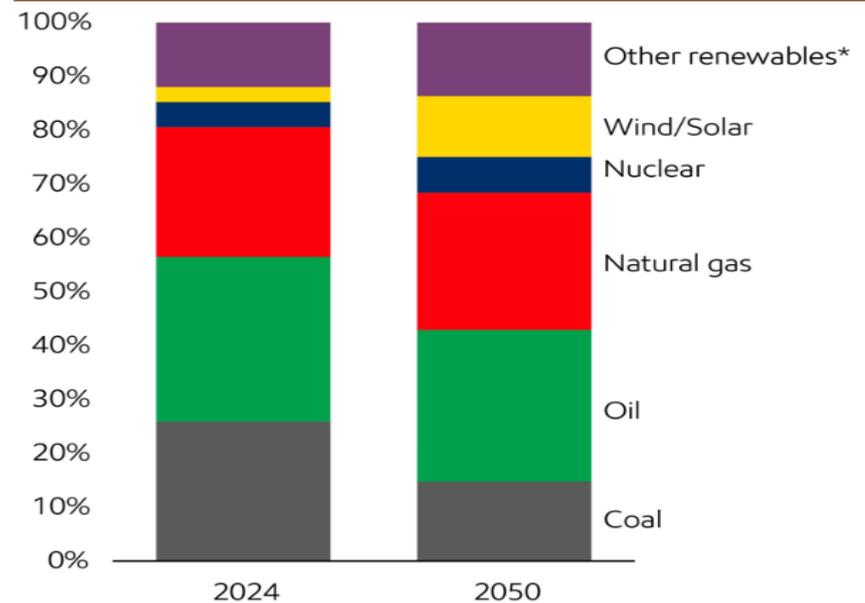
# Hydrocarbons forecast to remain a large share (~70%) of global energy supply in 2050 even as solar and wind capture the biggest increases in the energy mix

## Energy demand growth



Source: Company reports. \*Electricity and hydrogen are secondary energies derived from the primary energies shown

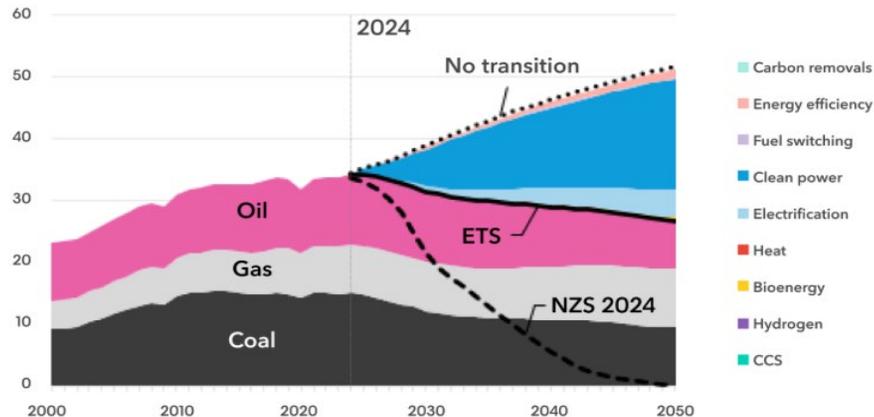
## Percentage of primary energy



Source: Company reports. \* includes biomass, biofuels, hydropower, geothermal

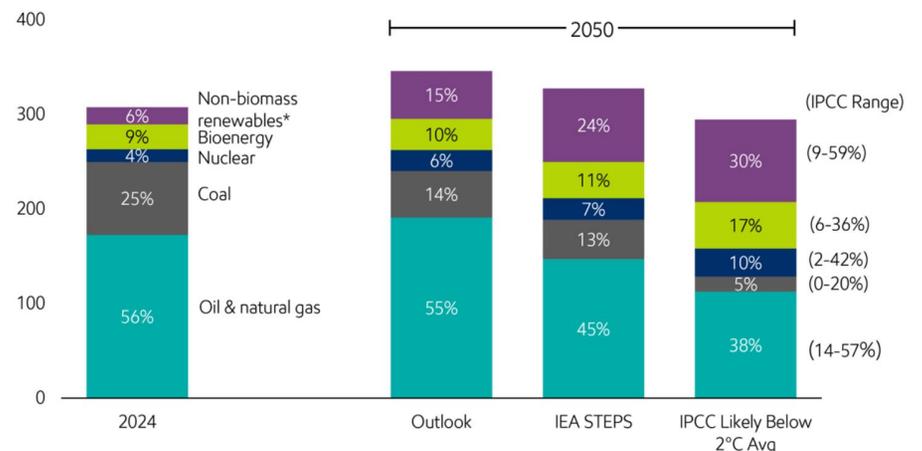
## CO2 emissions reductions via fuel combustion by measure

Economic Transition Scenario versus 'no-transition' scenario and Net Zero Scenario, Billion tons of CO2



Source: BloombergNEF.

## Global energy mix

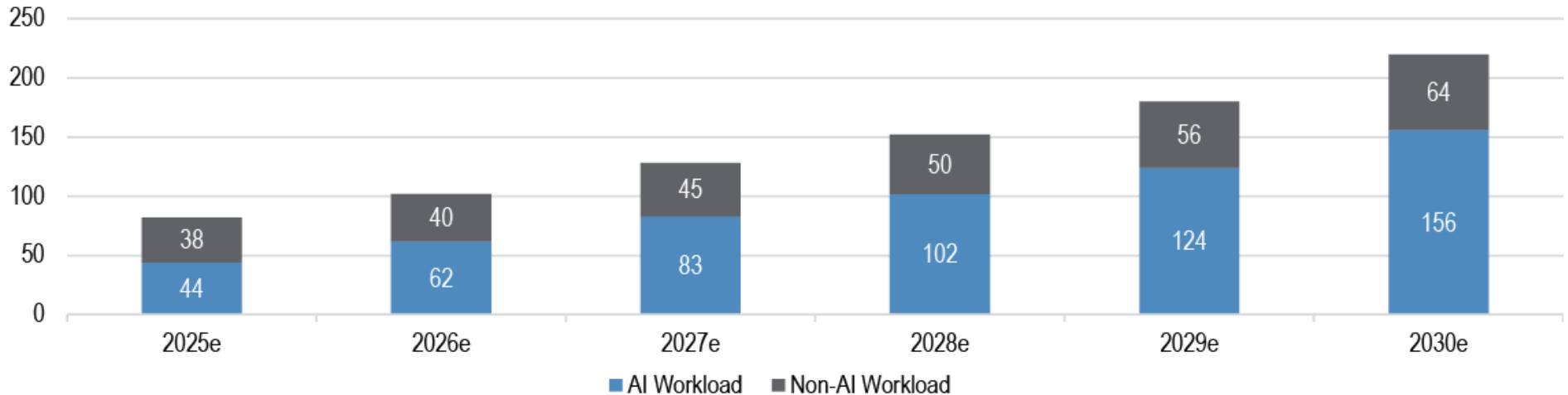


Source: Company reports. \* Non-biomass renewables includes hydro, wind, solar and geothermal

# Data centers are energy intensive and continued growth in the industry will likely increase electricity requirements

## Demand for data center capacity could more than double by 2030...

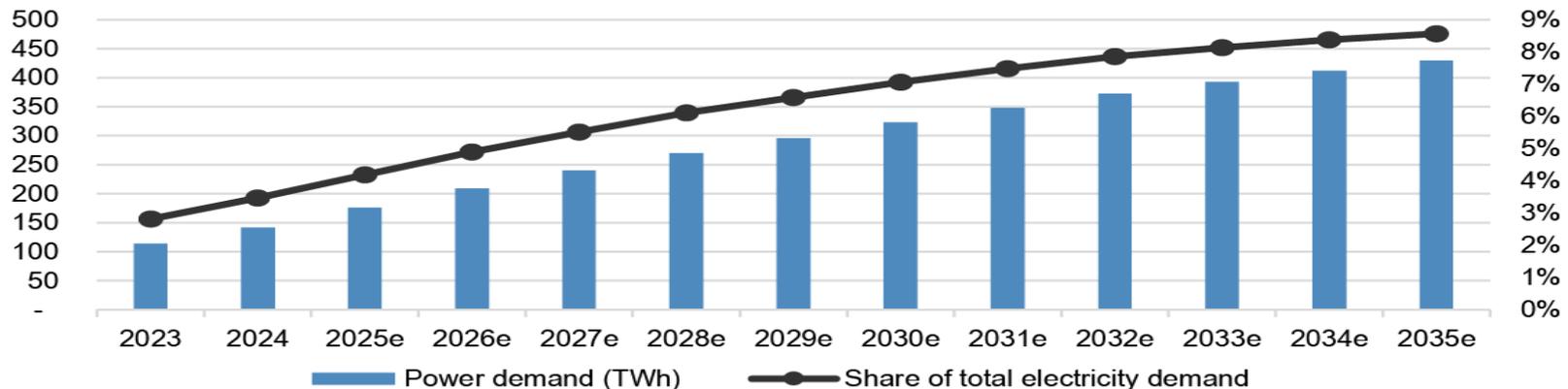
Estimated global data center capacity demand, 'continued momentum' scenario, GW



Source: McKinsey Data Center Demand Model; Gartner reports; IDC reports; Nvidia capital markets reports ([link](#)). The 'Continued momentum' scenario is a balanced energy transition scenario by McKinsey that results in a global temperature increase of 2.3°C in 2100 ([link](#))

## ...putting a heavy burden on electricity supplies, especially in the US

Electricity demand of US data centers, 'Economic Transition Scenario'



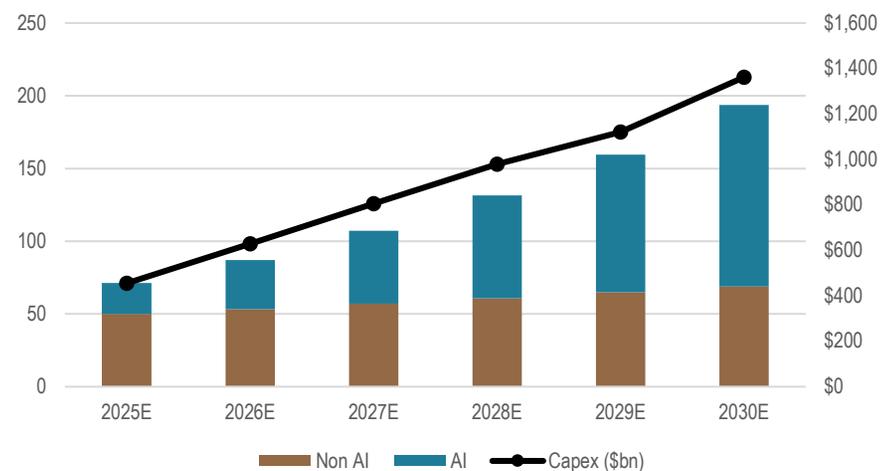
Source: BNEF ([link](#)). The 'Economic Transition' scenario maps out a route to a lower-carbon energy system in a world where cost-competitive technologies drive investment decisions to meet rising energy demand.

# Data center buildout continues to accelerate in the US...

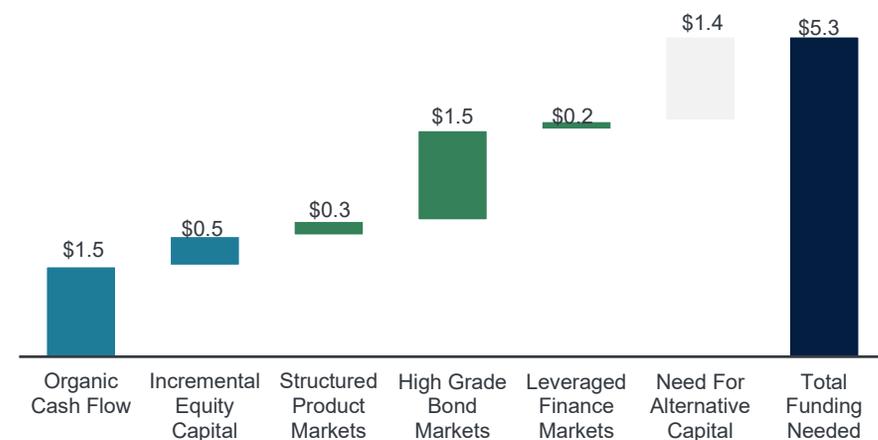
## Bottom-up data center growth constrained by power

	2024	2025	2026	2027	2028	2029	2030	Cumulative 26-'30
<b>Assumed Shipments Given Power Constraints</b>								
High-end datacenter GPU volumes	4,950	6,050	6,683	5,377	5,284	5,564	6,250	29,158
ASIC chip volumes	2,865	3,980	4,378	4,105	4,405	5,066	5,854	23,808
Total datacenter AI chip volumes	7,815	10,030	11,061	9,482	9,689	10,630	12,104	52,966
GPU power consumption per chip (Watt)	740	1,000	1,300	2,000	2,500	2,800	3,000	
ASIC power consumption per chip (Watt)	300	550	800	1,100	1,300	1,400	1,500	
Total GPU power consumption (MW)	3,663	6,050	8,688	10,754	13,211	15,580	18,750	66,982
Total ASIC power consumption (MW)	860	2,189	3,502	4,515	5,727	7,092	8,781	29,618
Total silicon power consumption (MW)	4,523	8,239	12,190	15,269	18,937	22,672	27,531	96,600
Silicon % total data center power consumption	45%	60%	75%	75%	78%	80%	80%	
<b>Total incremental data center power consumption</b>	<b>10</b>	<b>14</b>	<b>16</b>	<b>20</b>	<b>24</b>	<b>28</b>	<b>34</b>	<b>124</b>

## Data center installed base rapidly growing



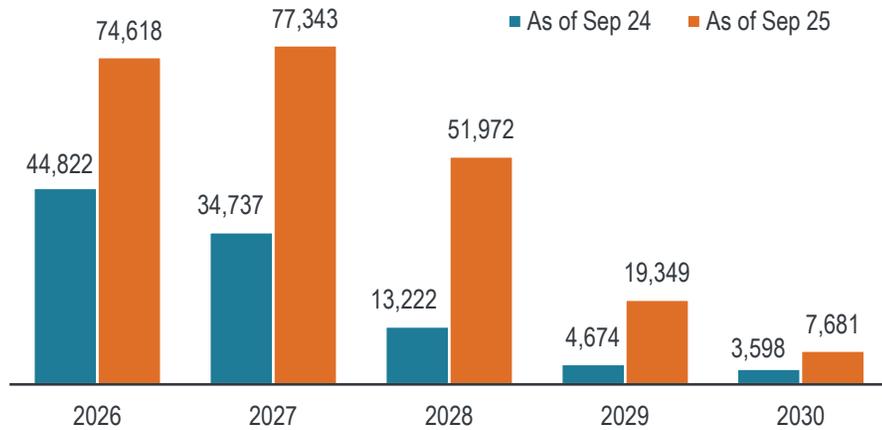
## Expected funding sources



Source for all charts: J.P. Morgan estimates.

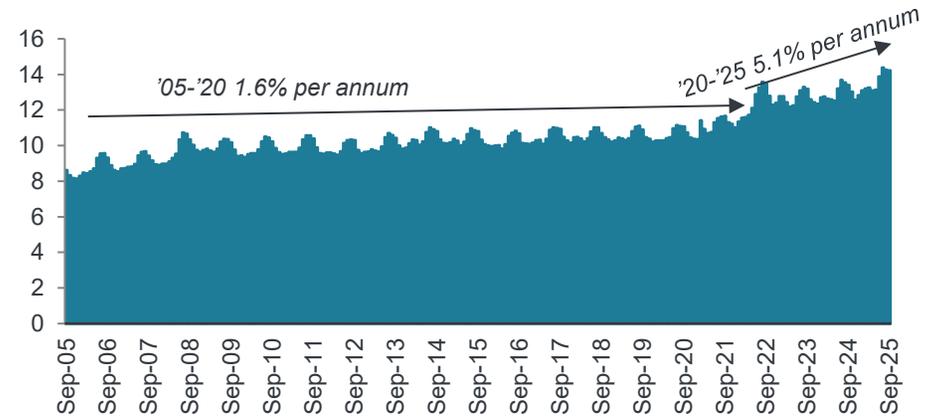
# ...but power remains the key bottleneck

## Total US Planned Generation Capacity (MW)



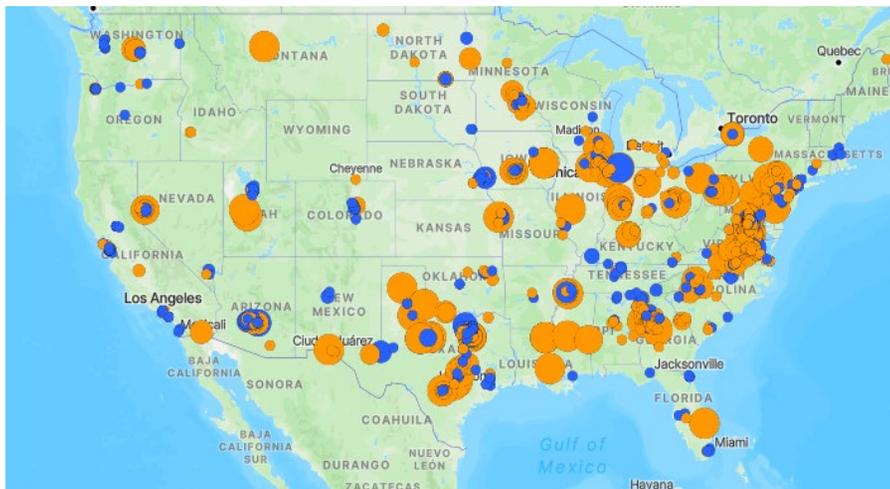
Source: EIA.

## Average Residential price of electricity (¢/KWh)



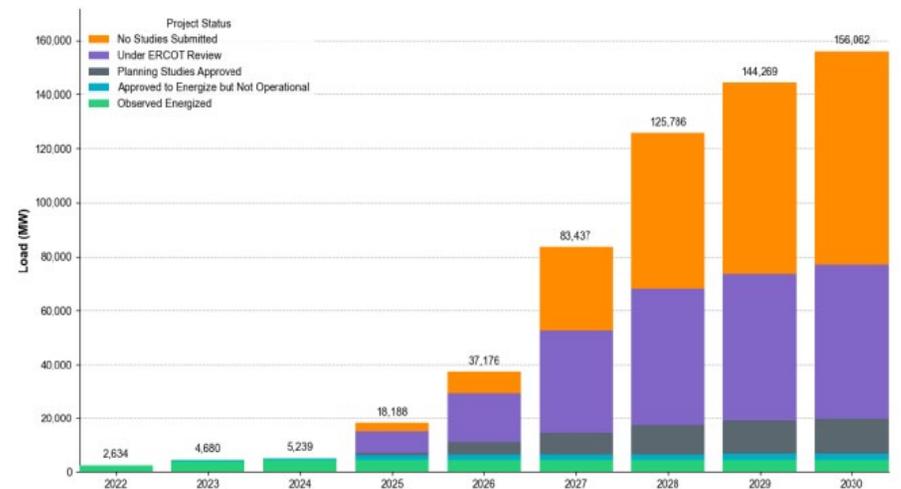
Source: EIA.

## New Data Center Locations prioritizing power



Source: Cleanview.

## Ercot Power Requests vs Approvals

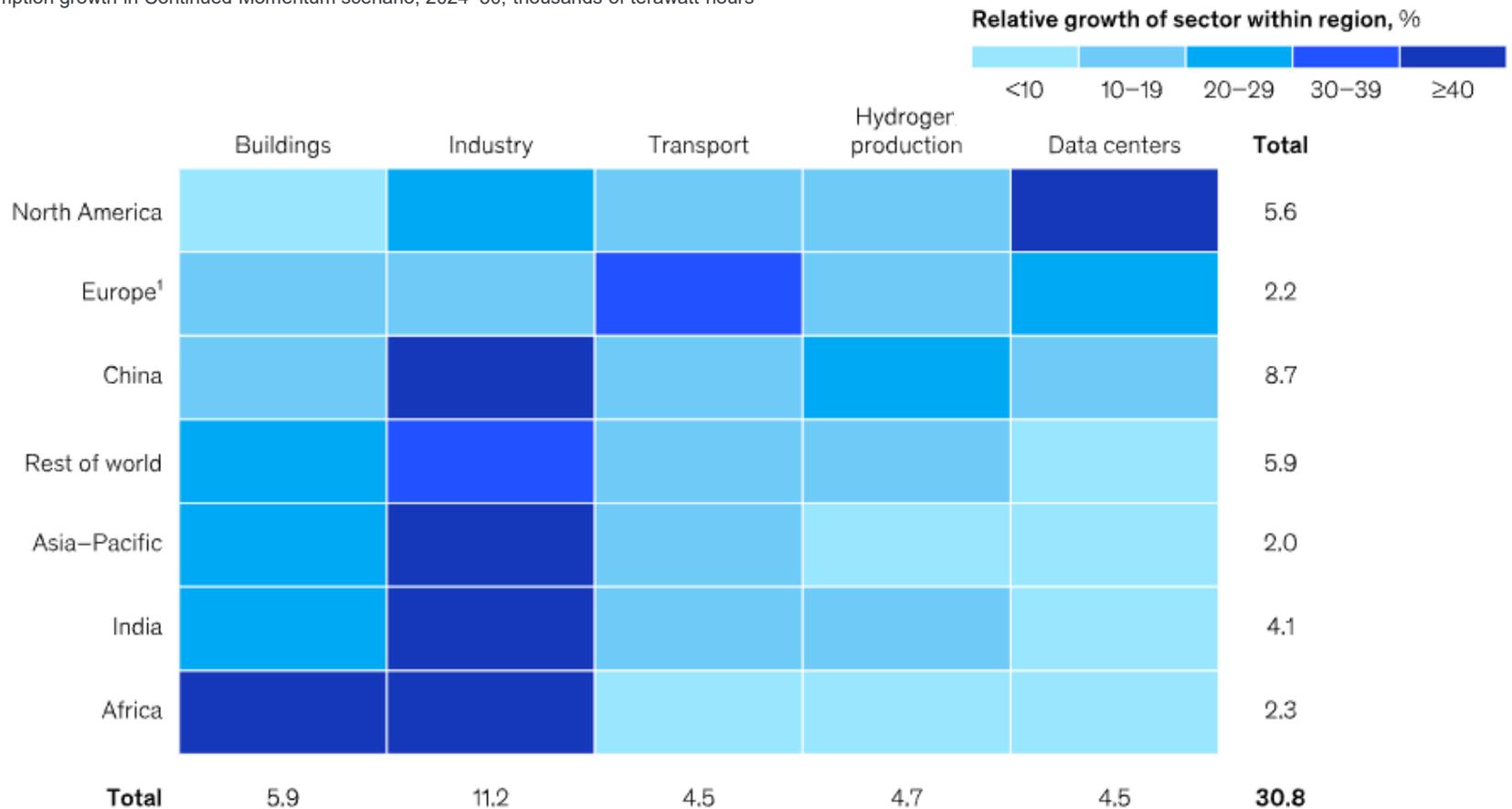


Source: ERCOT.

# Data centers are driving energy demand in North America, while industry & buildings are leading electricity demand growth in the rest of the world

## Industry and buildings are the leading source of electricity demand growth

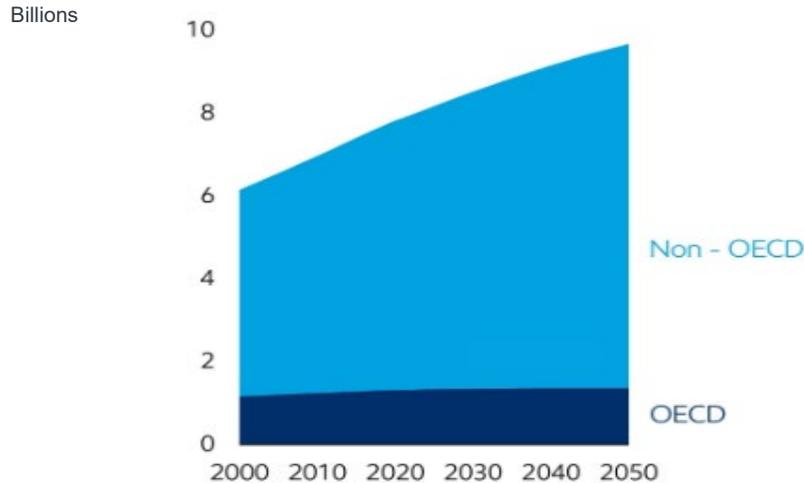
Global electricity consumption growth in Continued Momentum scenario, 2024–50, thousands of terawatt-hours



Source: Energy Solutions by McKinsey  
 Note: <sup>1</sup>EU-27 and UK

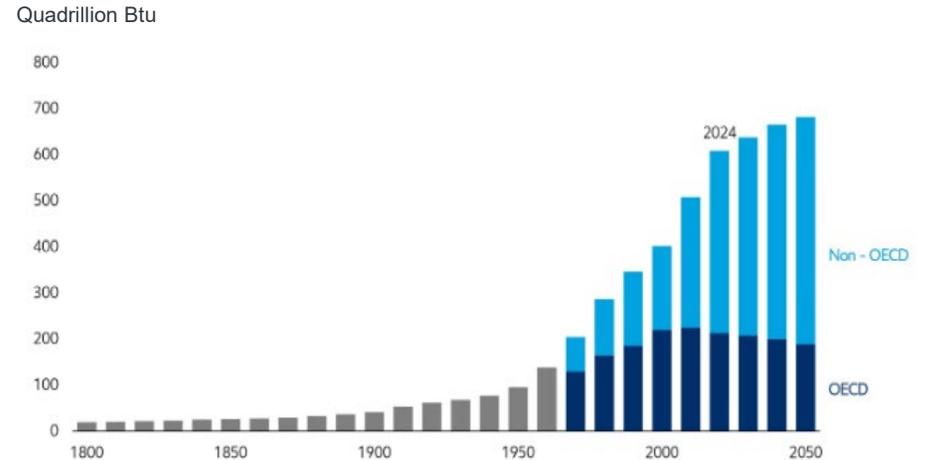
# EM demographic trends expected to drive a 25% increase in energy demand in 2050 versus today

## Population



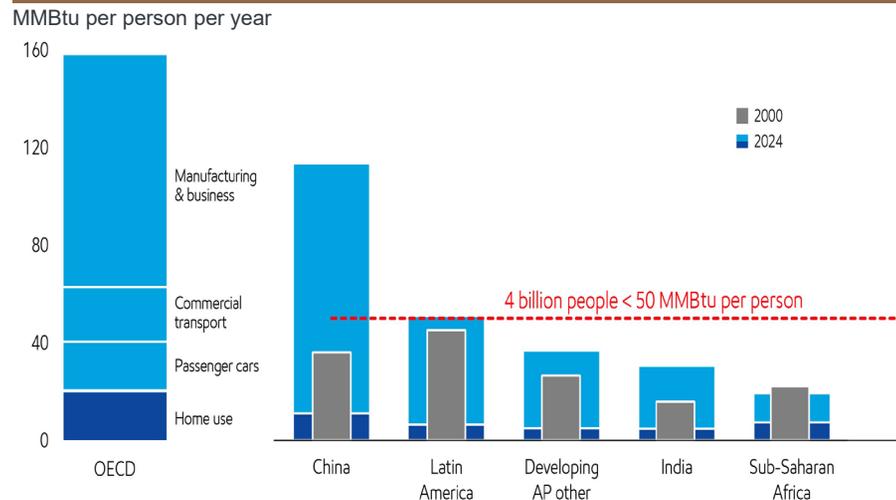
Sources: 2024 ExxonMobil Global Outlook (1970-2050)

## Global energy demand



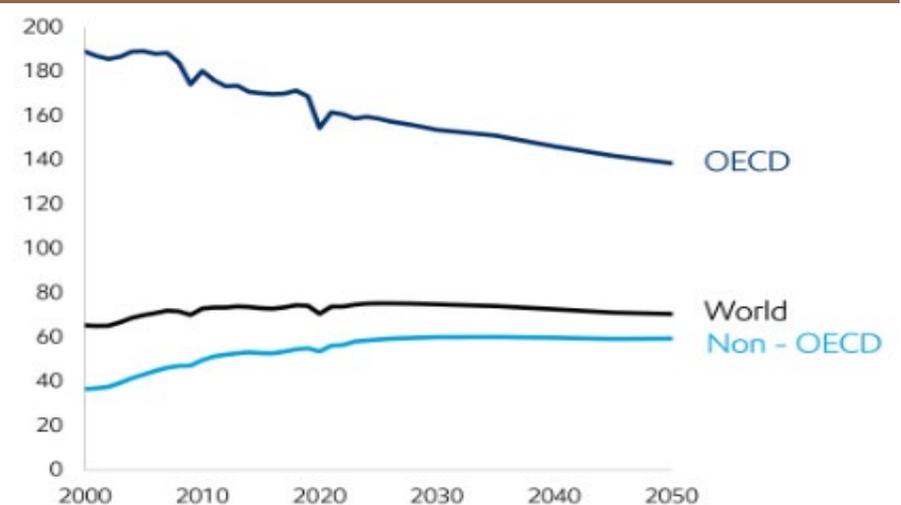
Sources: Smil, Energy Transitions (1900-1960), 2024 ExxonMobil Global Outlook (1970-2050)

## Energy use



Sources: 2024 ExxonMobil Global Outlook (1970-2050)

## Energy per capita

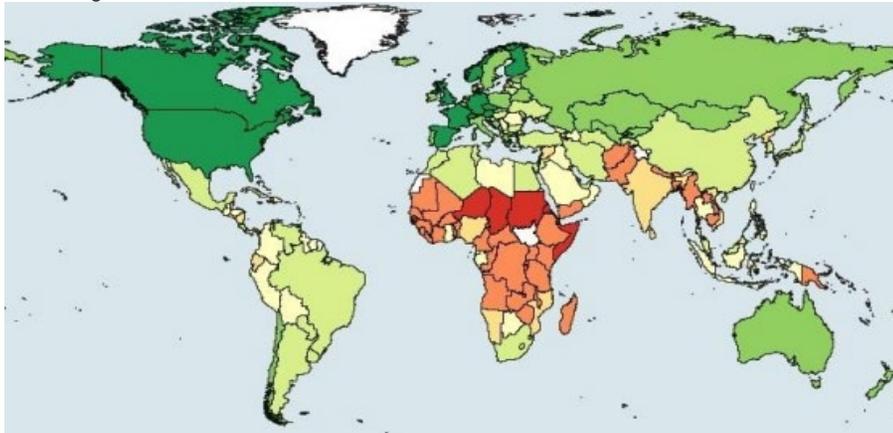


Sources: 2024 ExxonMobil Global Outlook (1970-2050)

# EM more vulnerable to adverse energy supply shocks due to location, economic structure, development and governance

## Climate vulnerability around the world

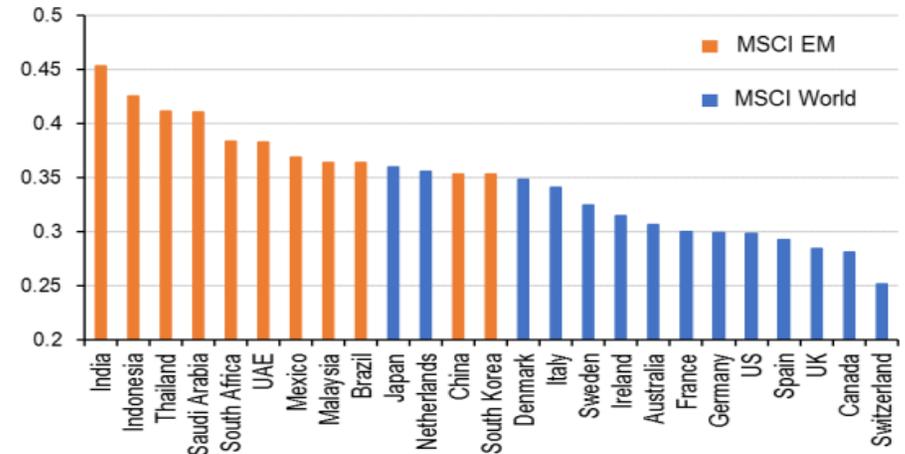
Ranges from lowest vulnerability (green) to highest vulnerability (red). White indicates no data or missing data.



Source: J.P. Morgan, ND-GAIN, UN.

## Climate vulnerability of large equity markets

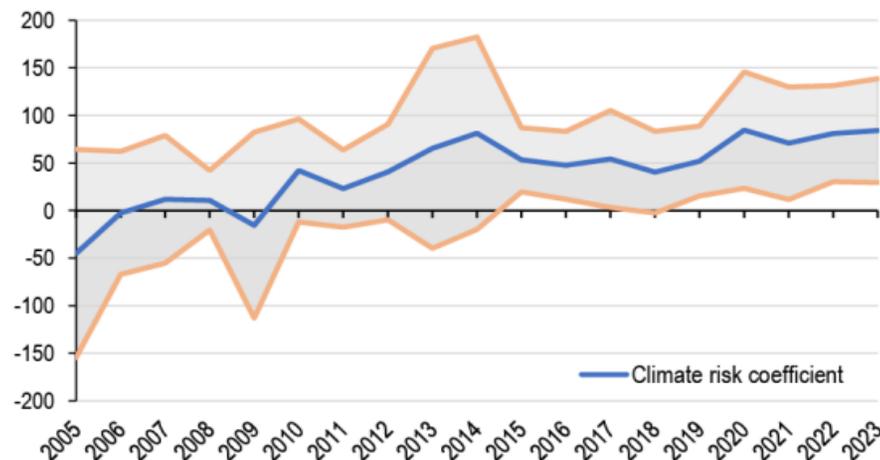
Measure is climate vulnerability from ND-GAIN



Source: J.P. Morgan, ND-GAIN, MSCI, Bloomberg Finance L.P.

## Climate vulnerability of EM against PE ratios

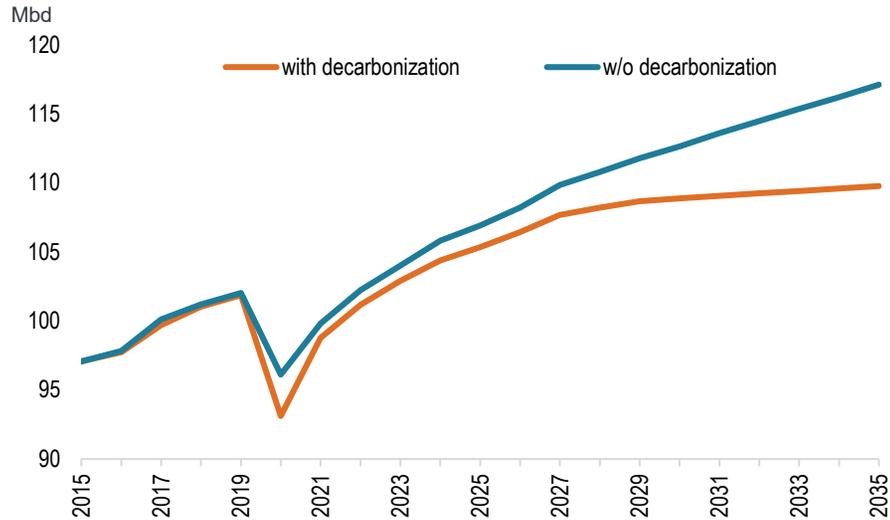
Grey indicates 95% confidence interval around estimates



Source: J.P. Morgan, World Bank, ND-GAIN, MSCI, Bloomberg Finance L.P.

# Global fuel habits are shifting with the pace of oil growth demand slowing

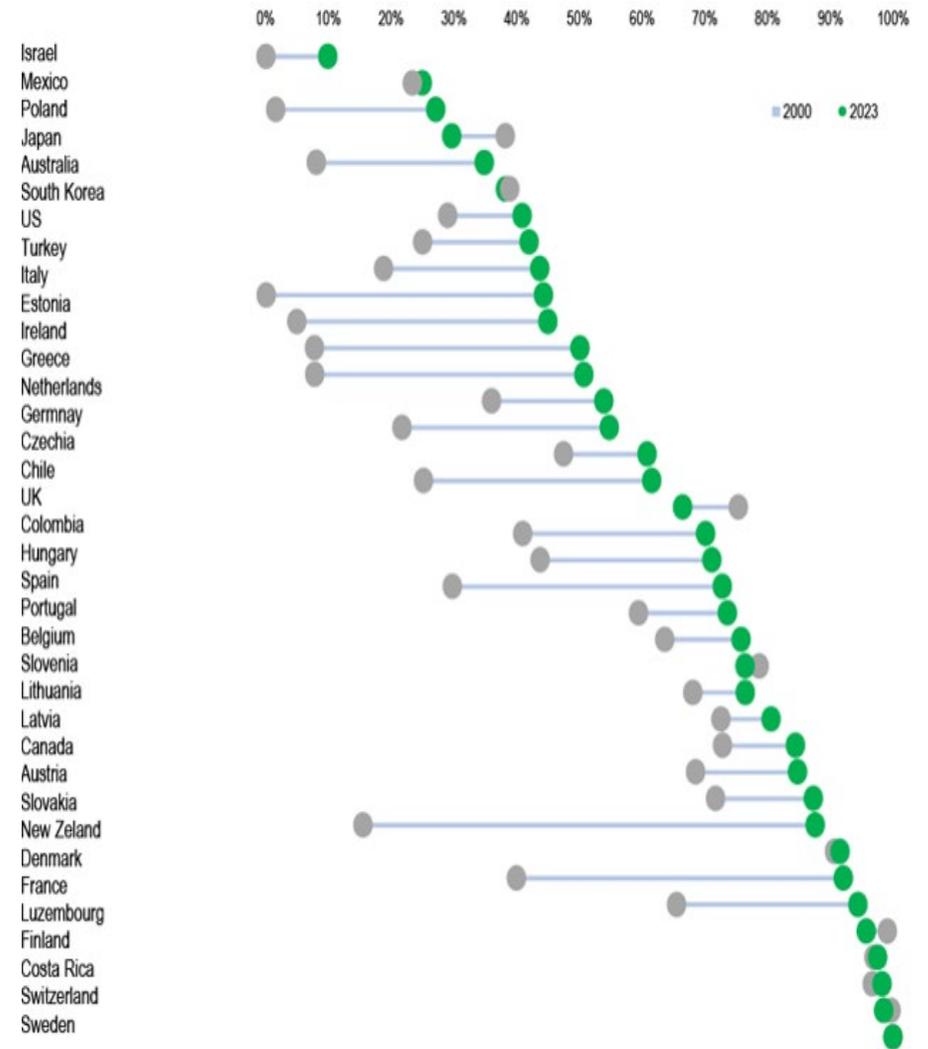
## Oil demand with and without decarbonization



Source: IEA, EIA, Wood Mackenzie, J.P. Morgan Commodities Research

## OECD countries' progress to clean power since 2000

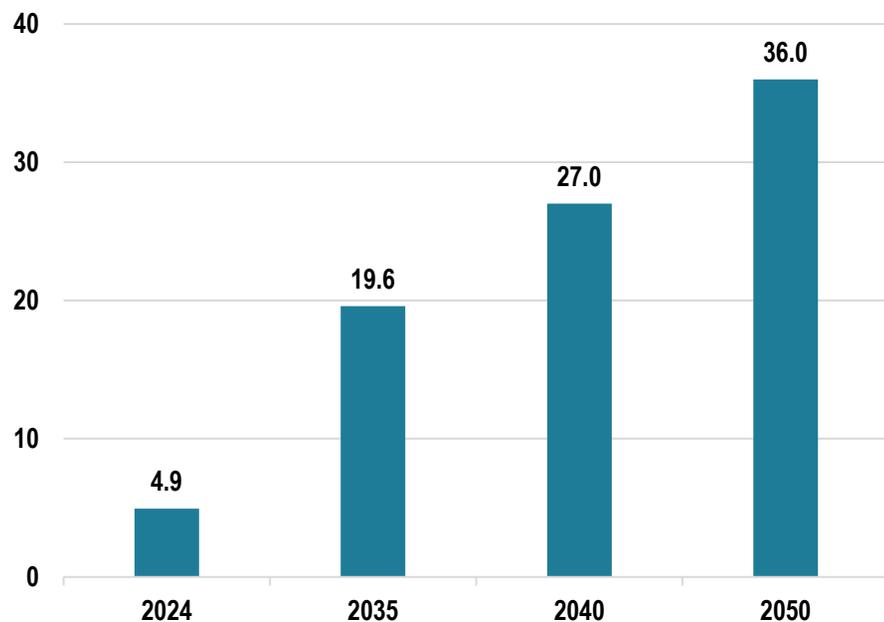
Share of total electricity produced by clean generation sources (RES and nuclear); percent



Source: Ember Climate Org

# Global renewables growth potential remains sizeable

**Global RES Installed Capacity Forecast (in TW), IEA**



Source: IEA 2025

**IRENA forecasts of key metrics to limit warming to 1.5°C**

	Recent Years	2025-2030
RE Annual Capacity Additions (GW/yr)	585 GW/yr	1122 GW/yr
Solar	452 GW/yr	621 GW/yr
Wind	113 GW/yr	387 GW/yr
RE Investments per year (USD bn/yr)	\$699 bn/yr	\$1,610 bn/yr
Grid Investments per year (USD bn/yr)	\$359 bn/yr	\$671 bn/yr

Source: IRENA 2025

**IEA forecasts of key metrics to achieve Net Zero by 2050**

Capacity Additions (GW/yr)	2024	2035	2050
Solar Annual Capacity Additions	539	940	848
Wind Annual Capacity Additions	115	306	264
Average Annual Investments (USD bn/y)	2020-24	2025-35	
RE Investments per year	~700	~1300	

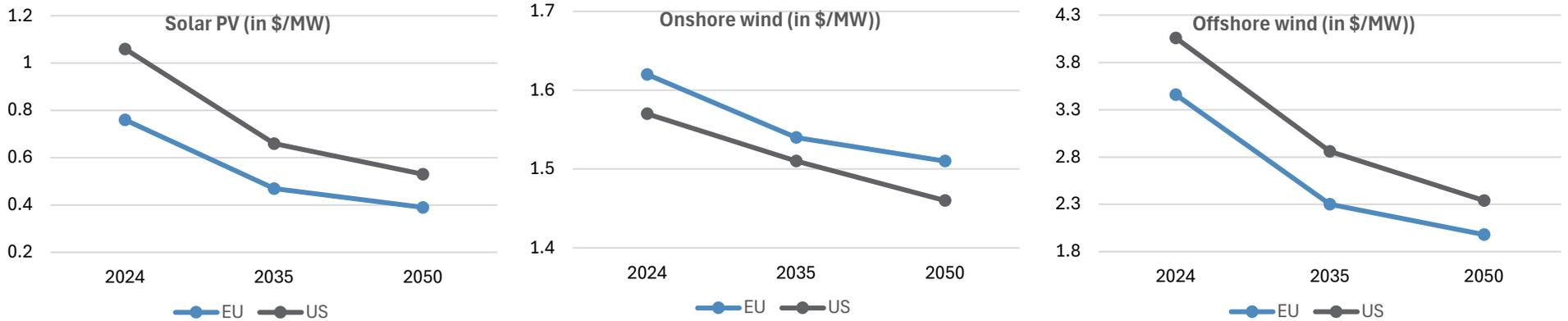
Source: IEA 2025

- Renewable capacity addition rates would need to increase c.3-4x per annum in both solar pv and wind to deliver on 2050 targets.
- Grid Investments to require a sharp uptick vs current status quo globally (c. 2.5x).
- Even if 2050 targets are not reached, there is a very large potential for growth acceleration in the renewable industry.

IRENA Forecasts are for their proprietary 1.5 deg scenario  
 IEA Forecasts are for their proprietary Net Zero Emissions by 2050 scenario

# Renewables growth to gradually regain momentum as cost pressures ease and demand grows

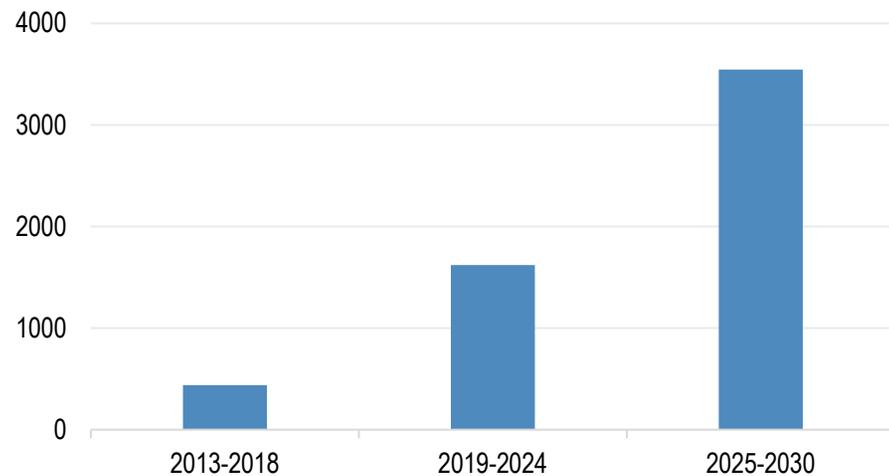
## Capital costs forecasts in European Union and United States (in STEPS scenario)



Source: IEA, IRENA 2025

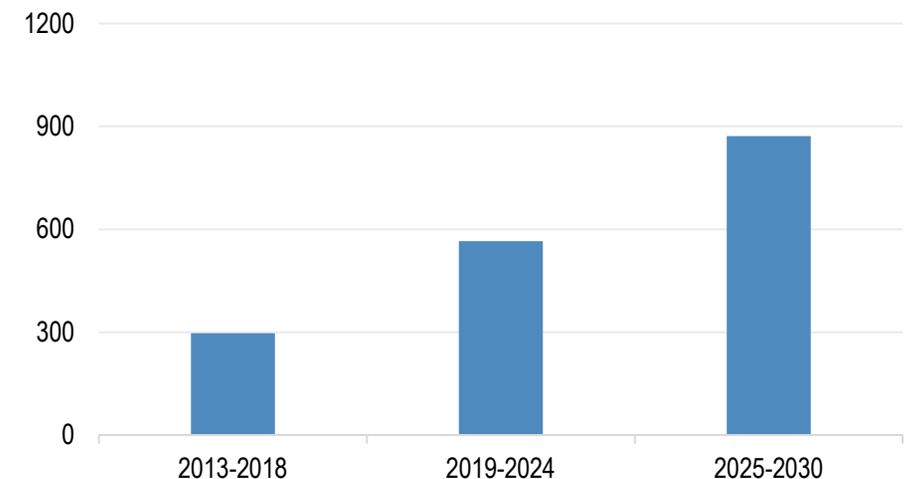
Note: STEPS: The Stated Policies Scenario is a dynamic reading of today's policy settings

## Global solar capacity growth, 2013-2030 (in GW)



Source: Adapted by J.P. Morgan from IEA 2025

## Global wind capacity growth, 2013-2030 (in GW)

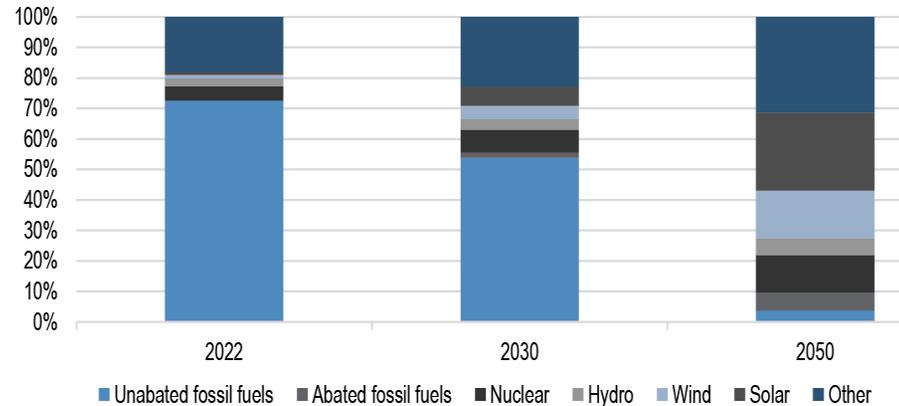


Source: Adapted by J.P. Morgan from IEA 2025

# Solar PV and wind require more critical minerals than fossil fuels, driving higher demand for copper and zinc

## Solar PV and wind power account for 41% of global energy supply by 2050 under the NZE scenario...

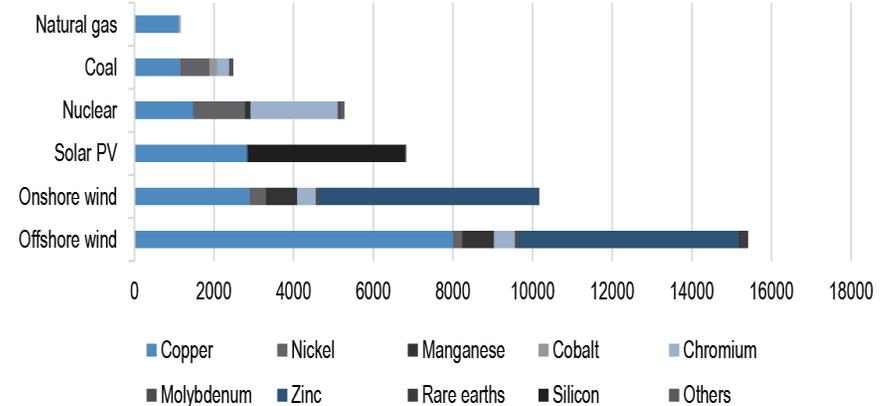
Breakdown of energy supply under the NZE scenario, by source



Source: IEA ([link](#))

## ... and require more critical minerals than traditional sources

Minerals used in clean energy and other power generation sources, kg/MW



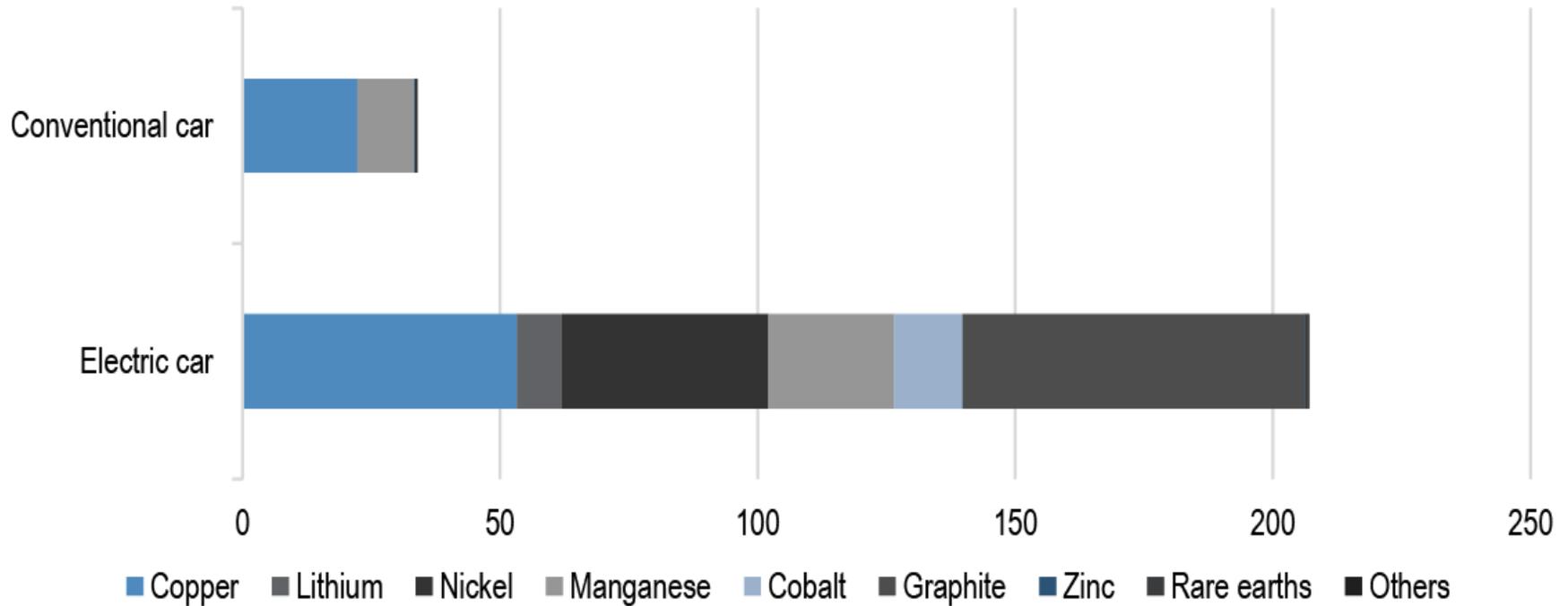
Steel and aluminium not included. The values for offshore wind and onshore wind are based on the direct-drive permanent magnet synchronous generator system (including array cables) and the doubly-fed induction generator system respectively. The values for coal and natural gas are based on ultra-supercritical plants and combined-cycle gas turbines. Actual consumption can vary by project depending on technology choice, project size and installation environment.

Source: IEA ([link](#))

# EVs require significantly more critical minerals than conventional vehicles, driving higher demand in coming years

## Electric cars require 6 times more critical minerals than ICE vehicles

Minerals used in conventional and electric cars, kg/vehicle

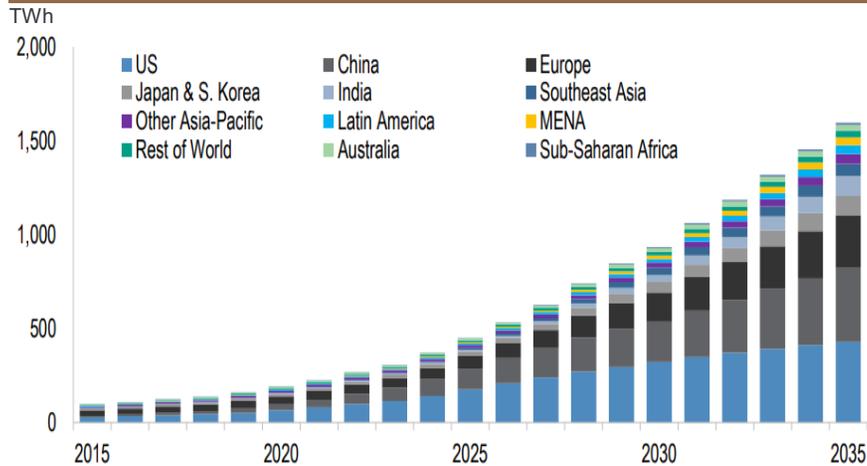


Steel and aluminum not included. The values for vehicles are for the entire vehicle including batteries, motors and glider. The intensities for an electric car are based on a 75 kWh NMC (nickel manganese cobalt) 622 cathode and graphite-based anode.

Source: IEA ([link](#))

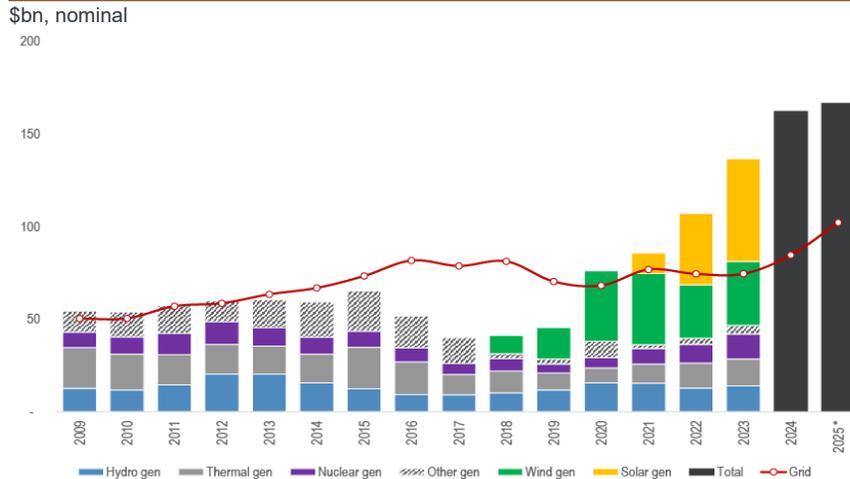
# China is undergoing one of the most ambitious energy transitions in history

## Data center electricity demand forecast (to 2035)



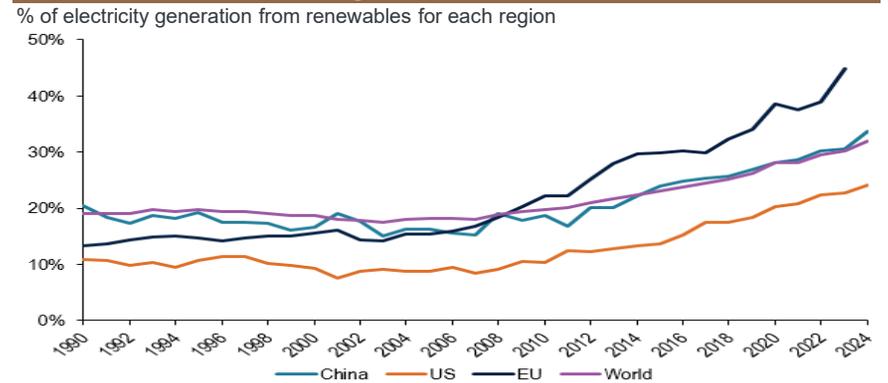
Note: Forecasts (2025-) by BloombergNEF, based on ETS (Economic Transition Scenario)  
Source: Bloomberg Finance L.P., J.P. Morgan

## China investments in power generation and grid infrastructure



Note: 2025 annualized based on 8 months data  
Source: China National Energy Administration, J.P. Morgan Commodities Research

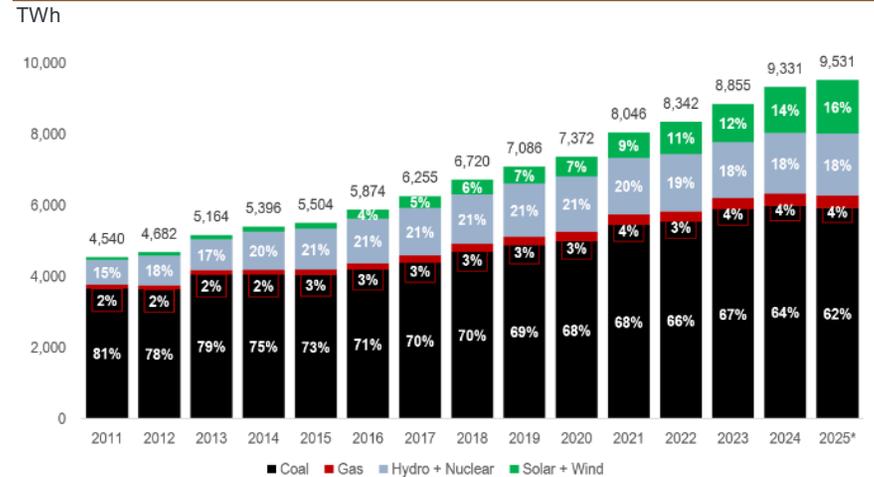
## China's share of electricity production from renewables now exceeds the world average



Note: Calculated as the share of total electricity produced in each region that comes from renewables e.g., 34% of all electricity generated in China was produced from renewable sources in 2024.

Source: Ember (2025), Energy Institute - Statistical Review of World Energy (2025), Our World in Data, J.P. Morgan Strategic Research

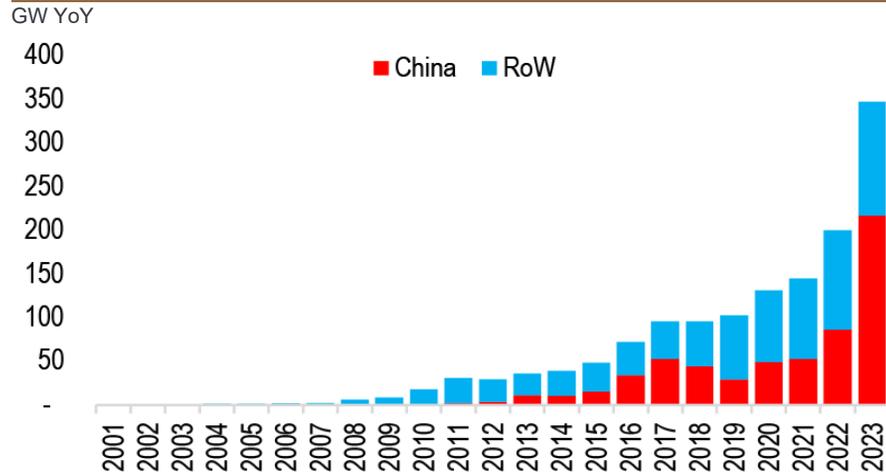
## China power generation mix



Note: 2025 annualized based on last 12 months data  
Source: National Bureau of Statistics, Bloomberg Finance L.P., J.P. Morgan Commodities Research

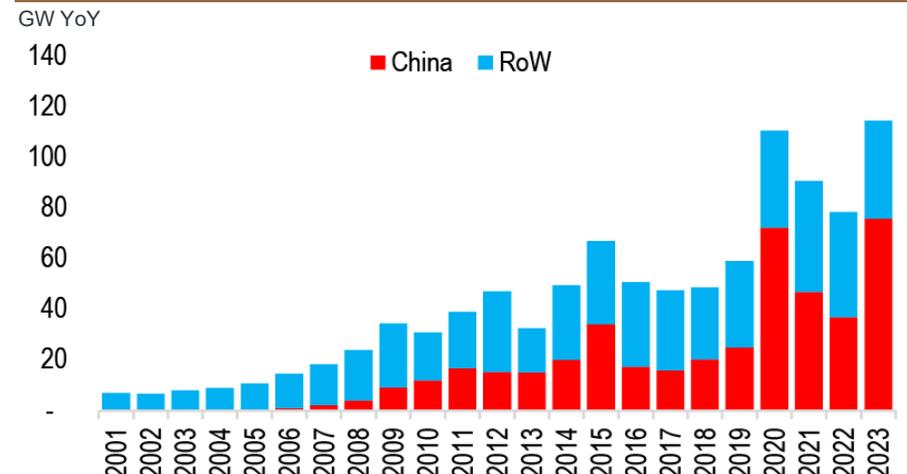
# 'Global' energy transition is happening in China

## Solar capacity installed



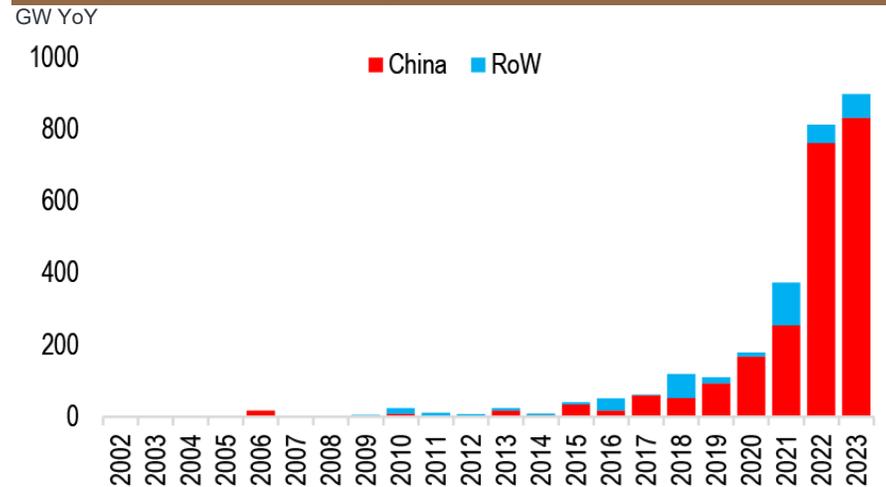
Source: IRENA

## Wind capacity installed



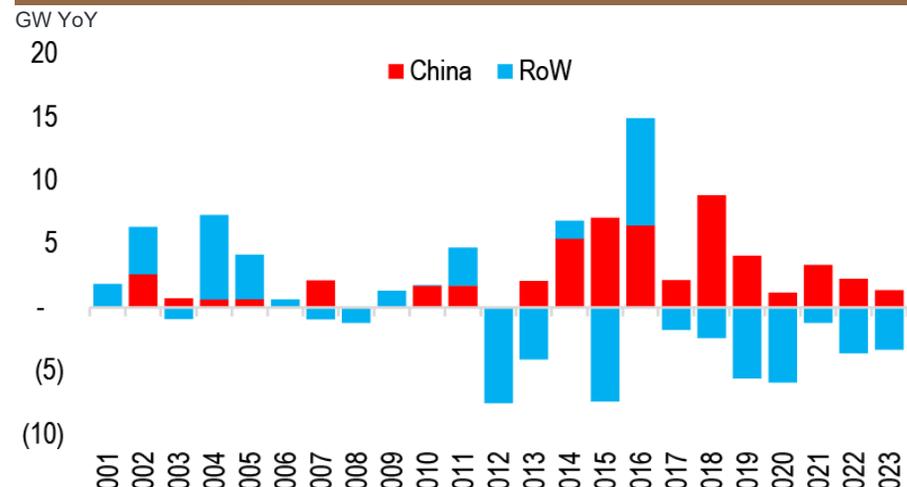
Source: IRENA

## Battery production capacity



Source: BNEF

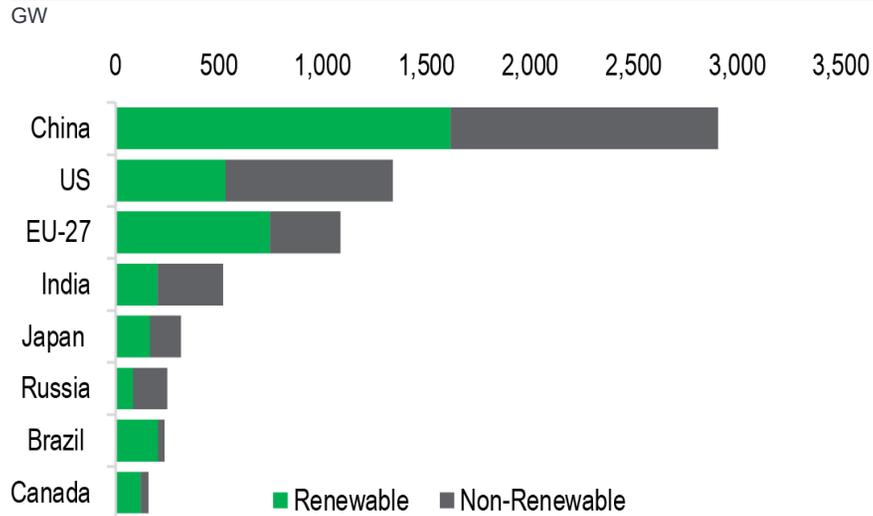
## Nuclear capacity installed



Source: IRENA

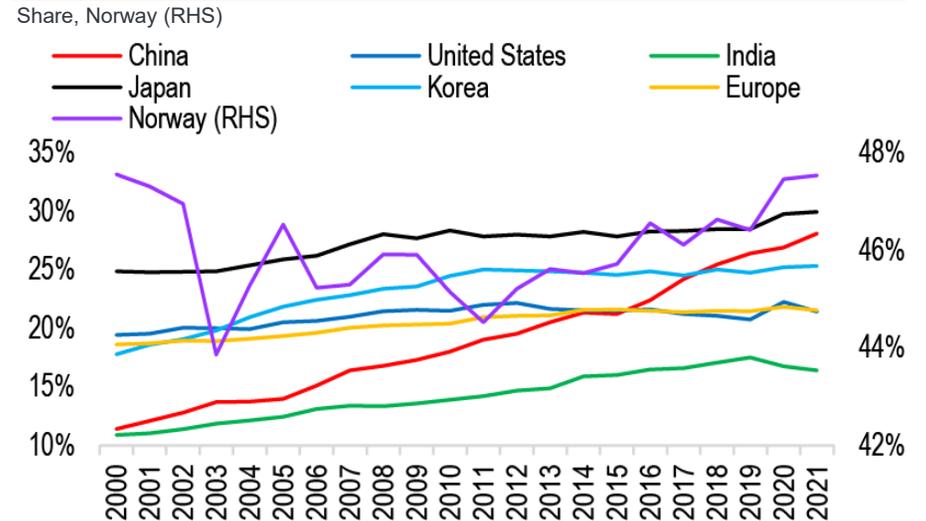
With a shift from hydrocarbon fuels to electricity, China is on its way to becoming the most electrified economy in the world

Installed power generation capacity, by region and type



Source: BNEF

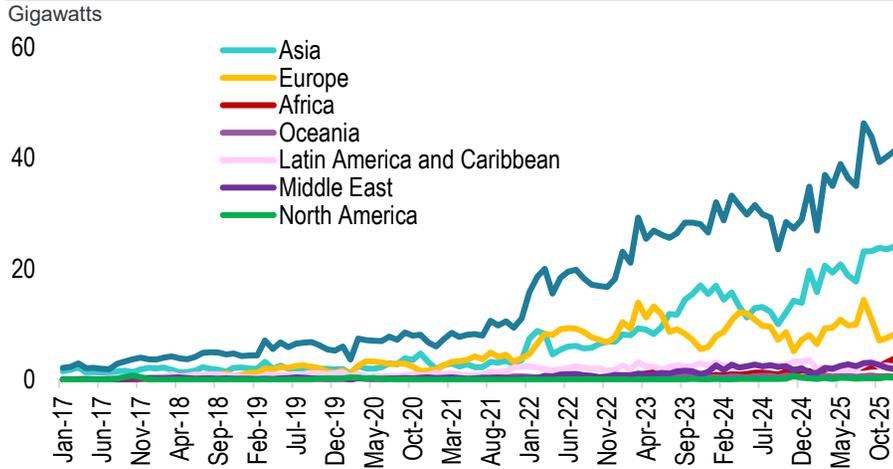
Electricity as a share of total final energy consumption by country



Source: IEA

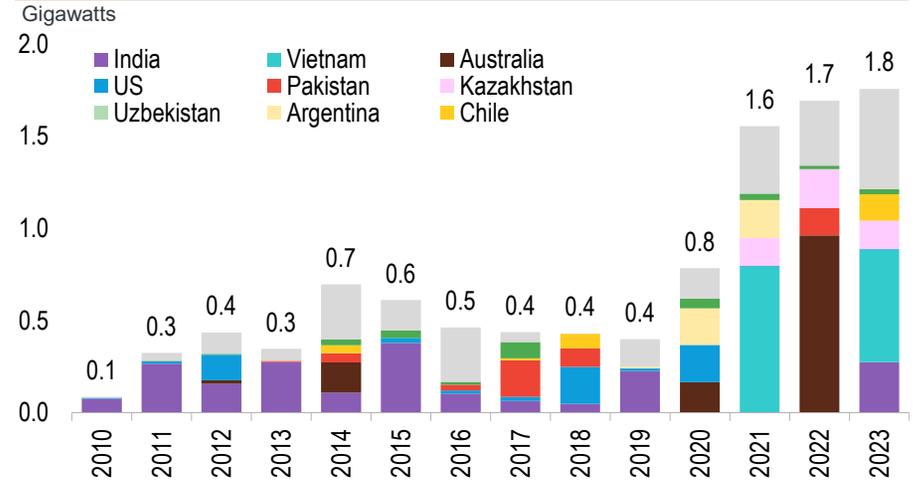
# To the extent that the rest of the world is decarbonizing, China is helping power those transitions

## Monthly exports of solar panel capacity from China



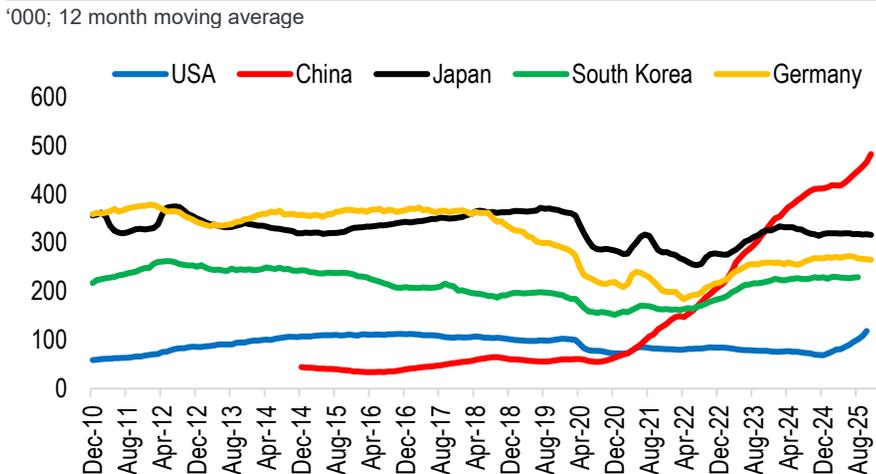
Source: Ember, J.P. Morgan Commodities Research

## Chinese exports of wind turbine capacity by country



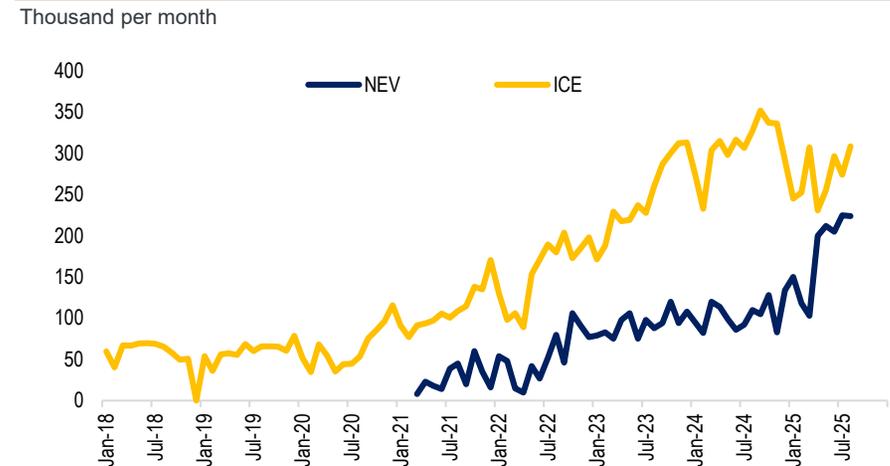
Source: BNEF, J.P. Morgan Commodities Research

## Passenger vehicle exports



Source: Bloomberg Finance LP, J.P. Morgan Commodities Research

## China exports of passenger vehicle by technology type

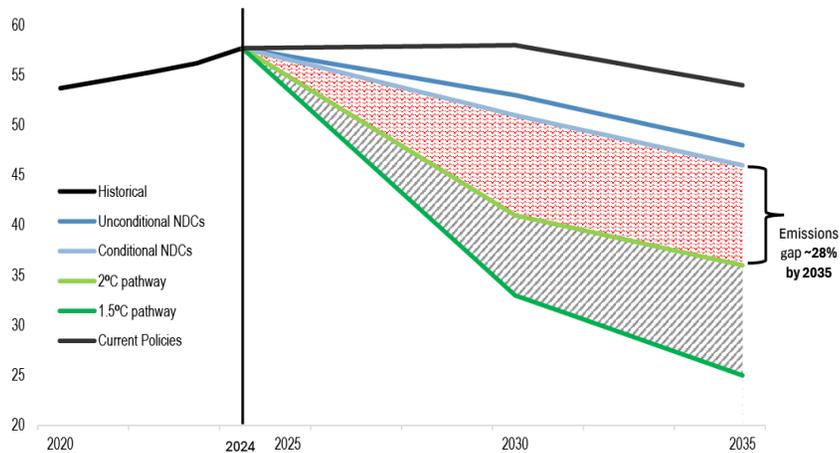


Source: CAAM, China Customs, Bloomberg Finance, J.P. Morgan Commodities Research

# Emissions in 2035 could still be nearly twice the level required for a 1.5 C scenario

## NDCs suggest that emissions in 2035 could still be nearly twice the level required for a 1.5°C scenario

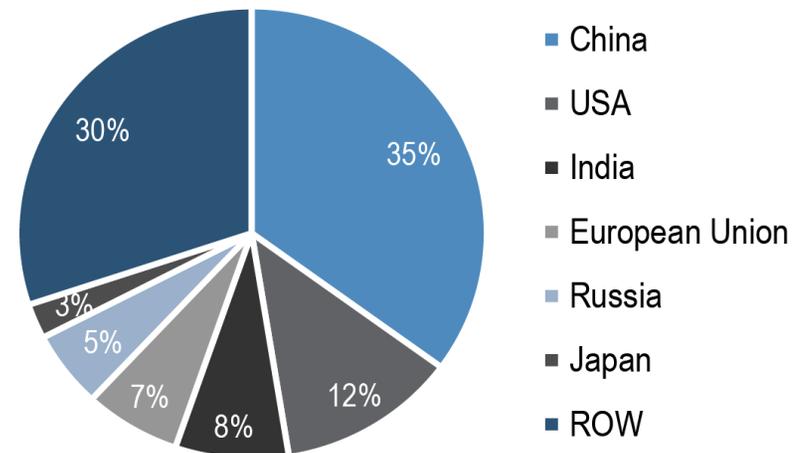
Emissions pathways, GtCO<sub>2</sub>e



Uses reduction figures for 2030 and 2035. Linear reduction pathway assumed.  
Source: J.P. Morgan based on UNEP Emissions Gap Report 2025 ([link](#))

## Emissions around the world

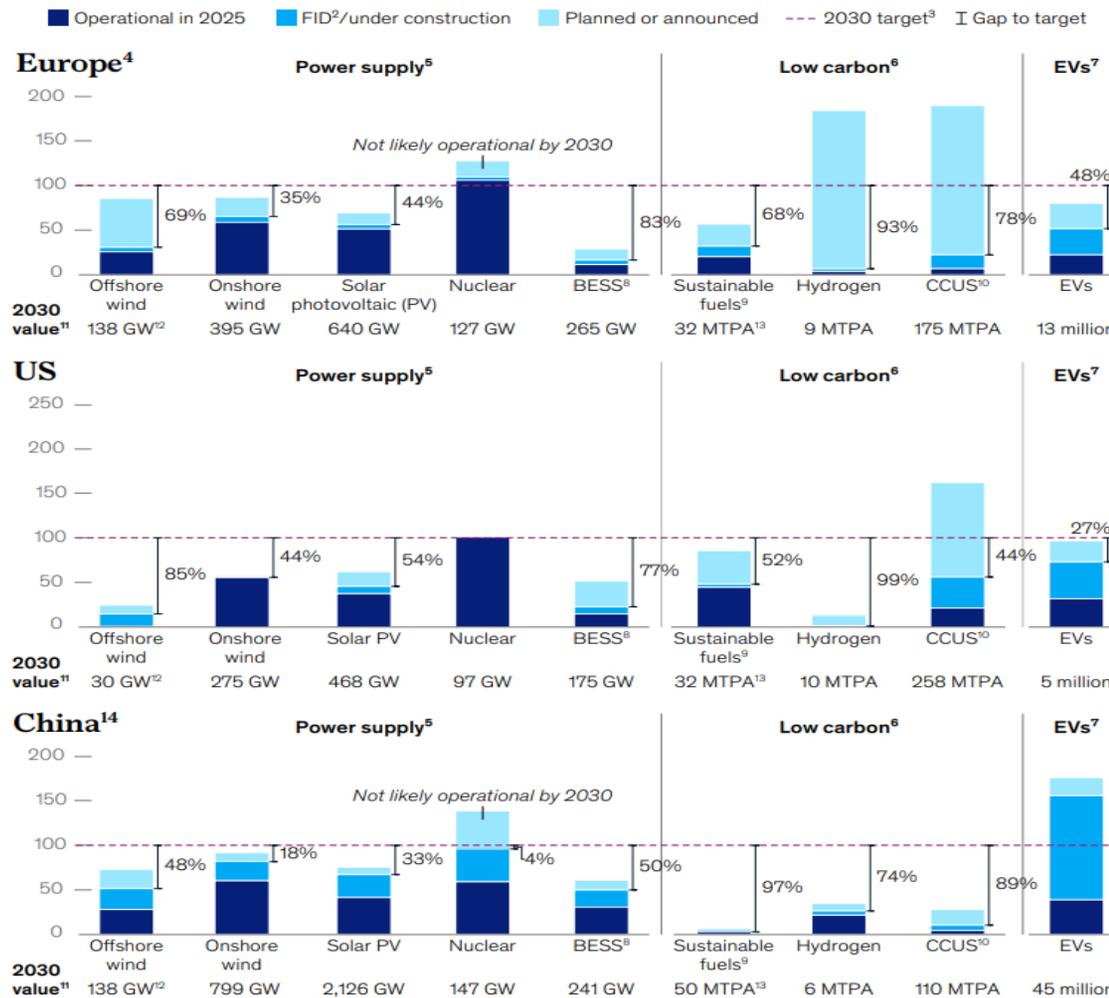
Share of global emissions, 2023



Source: World Bank ([link](#))

# Investment in low-carbon technologies has been considerable but below 2030 targets in crucial regions

## Technology deployment pipelines vs targets, % of 2030 target (normalized)<sup>1</sup>



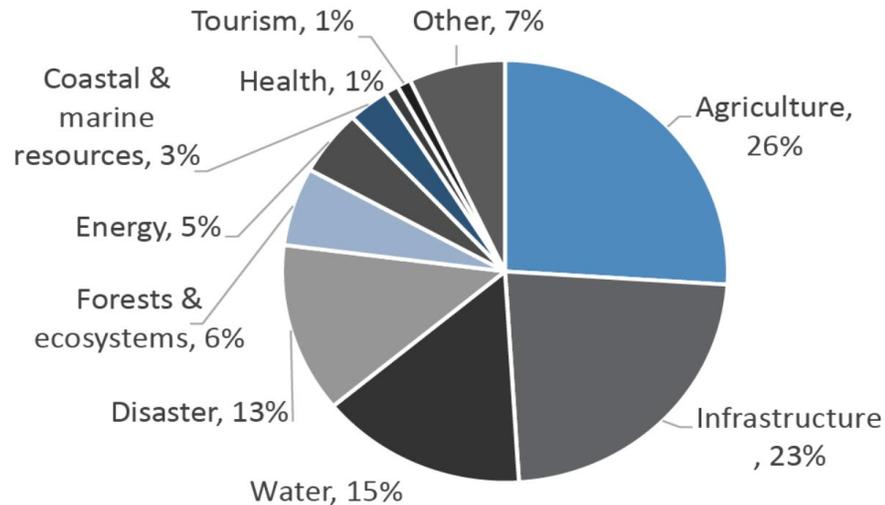
<sup>1</sup>Tech deployment measurement helps in understanding gap between actual and needed deployment. <sup>2</sup>Final investment decision. <sup>3</sup>Target for domestic decarbonization. <sup>4</sup>EU-27, Norway, Switzerland, and UK. <sup>5</sup>Actual build-out of power. <sup>6</sup>Production capacity for low-carbon fuels. <sup>7</sup>Electric vehicles sales. <sup>8</sup>Battery energy storage systems. <sup>9</sup>Includes hydroprocessed esters and fatty acids, hydrotreated vegetable oil, power to liquids, and other advanced biofuels. <sup>10</sup>Carbon capture, utilization, and storage. <sup>11</sup>Local 2030 target or expected level in 1.8° scenario if target is exceeded. <sup>12</sup>Gigawatts. <sup>13</sup>Million tons of CO<sub>2</sub> abated per annum. <sup>14</sup>As China has already reached its official renewable energy sources target (1,200 GW by 2030 combined solar and wind), McKinsey have used a higher range in line with their estimation of a 1.8° pathway.

Source: IRENA; Rystad Energy; Energy Solutions by McKinsey; McKinsey analysis

# Adaptation financing needs for EM remain high at \$310bn annually with aspirations at COP 30 to triple financing by 2035

## Adaptation finance needs by sector

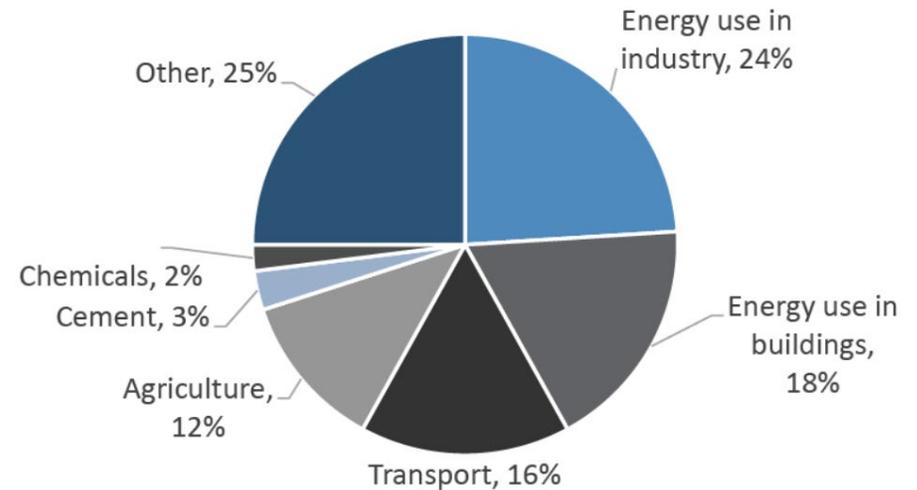
% of annual total



Source: UNEP. \*Based on 26 developing countries' nationally determined contributions and national adaptation plans.

## GHG emissions by sector

% of annual total



Source: World Resources Institute

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## Financing adaptation: Moving from the mundane to the creative

- **Catastrophe (“Cat”) bonds.** Principal is earmarked to cover for specific extreme events, such as tornadoes, hurricanes, fire, etc. with the incidence of such events impacting the principal repayment by the borrower.
- **Adaptation-linked insurance policies.** Premiums can be reduced to reflect investment in adaptation and resilience, or payouts can be increased to fund resilience investments.
- **Debt-for-adaptation swaps.** Similar mechanics to debt-for-nature swaps: countries can restructure debt with a commitment to use the savings to invest in climate change adaptation and resilience.
- **Payments for ecosystem services ([PES](#))** Contribute to climate change adaptation policies by protecting ecosystem services that reduce vulnerability, such as hydrological regulation, biodiversity, or services related to multifunctional agriculture (traditional knowledge, pollination, soil conservation, etc).”
- **Work for taxes** Private company undertakes public works in exchange for a reduction in taxes, such as the system in place in [Peru](#) since 2008, with more than US\$1bn invested through the scheme between 2009 and 2017.
- **“Resilience bonds”** Similar to cat bonds, with the twist that coupon payments could be lowered as the proceeds are invested in projects that enhance resilience, with use of proceeds earmarked for adaptation.
- **Blended finance** where the public sector facilitates private sector involvement through guarantees or by taking first losses.

# Interest rates are structurally higher, increasing financing costs

## Why are real rates likely to move higher?

1. Higher fiscal debt, esp. US
2. Rising elderly cohort dissaving
3. Higher macro volatility
  - a) End of rule-based Global Order
  - b) Pro-active US fiscal policy
4. Climate investment
5. Flattening out of other forces

Structural forces driving real interest rates

	<i>Historical effect</i>	<i>Future effect</i>
<i>Fiscal debt</i>	Higher rates	Higher rates
<i>Climate investment</i>	Neutral	Higher rates
<i>Demographics</i>	Lower rates	Higher rates
<i>Macro volatility</i>	Lower rates	Higher rates
<i>Globalization</i>	Lower rates	Higher rates
<i>Sector composition</i>	Lower rates	Neutral
<i>Financial repression</i>	Lower rates	Neutral
<i>Corporate profits</i>	Lower rates	Neutral
<i>Inequality</i>	Lower rates	Neutral
<i>EM reserves</i>	Lower rates	Neutral
<i>Economic growth</i>	Lower rates	Lower rates

Source: J.P. Morgan

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