International Energy Agency

# The Future of Renewable Energy

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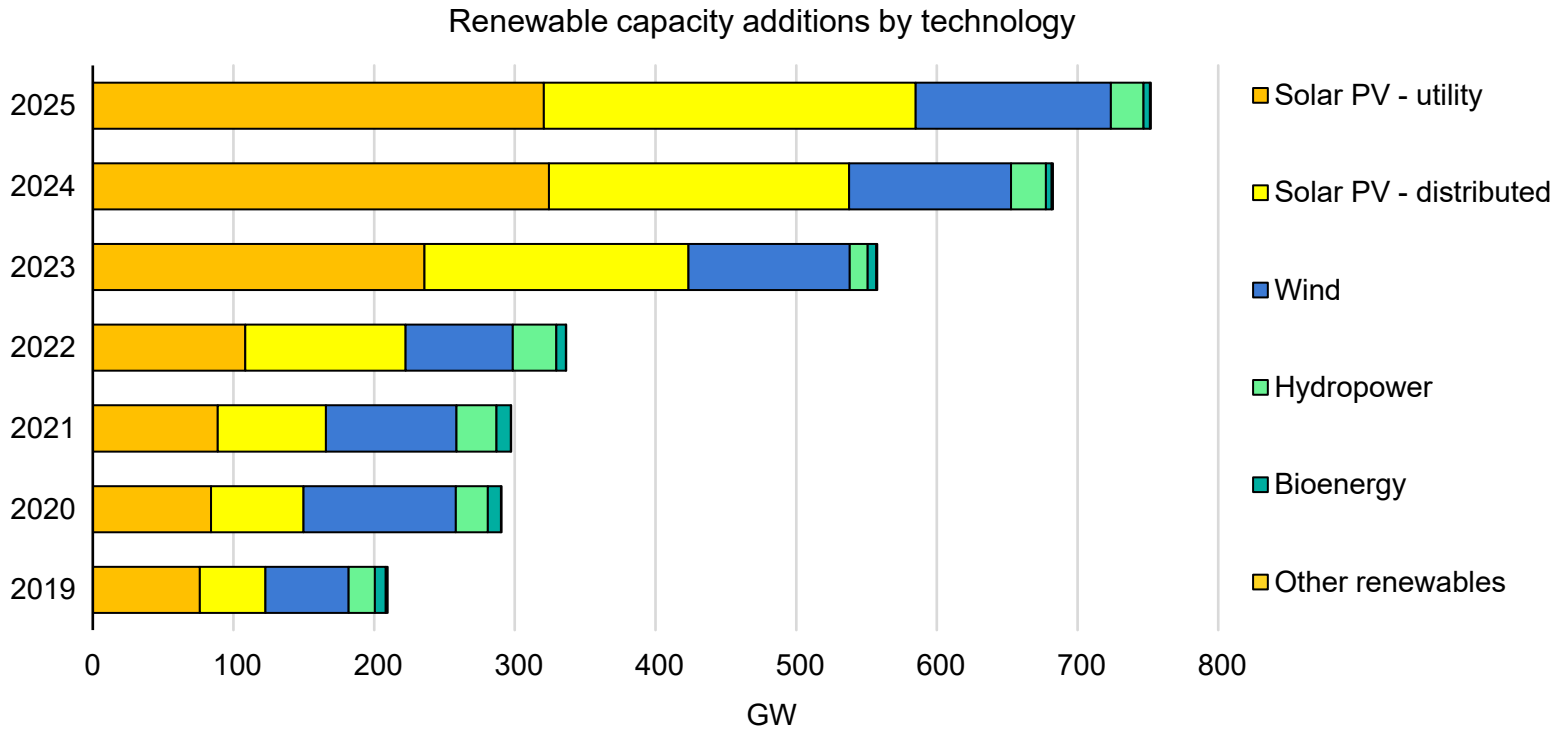
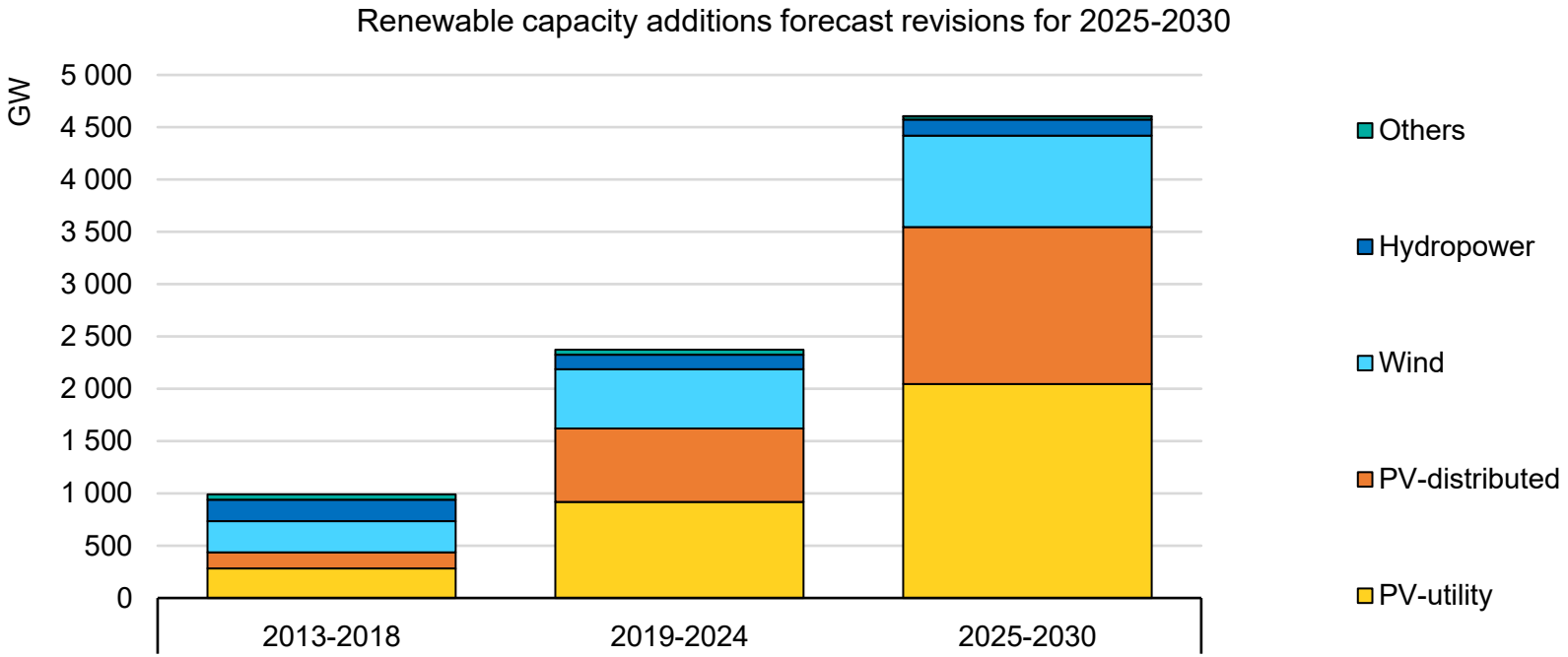
ICEF 2025, Tokyo, 8 October 2025

# 2025: another record year for renewables



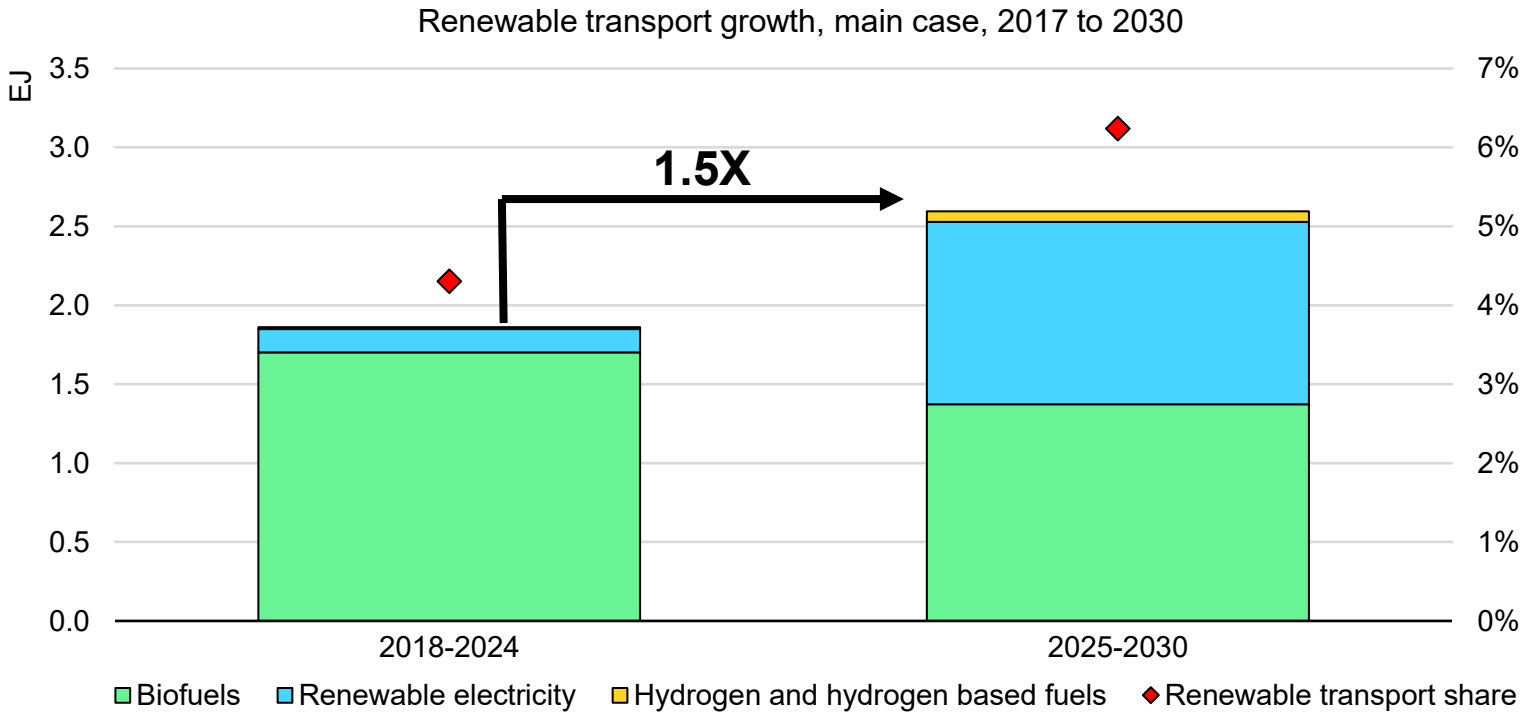

**Developers' rush in China due to policy change in H1 and growth acceleration in India, MENA and Sub-Saharan Africa drives renewables to another record, 23rd year in row.**

# Renewables growth driven by solar PV remains strong amid rising headwinds



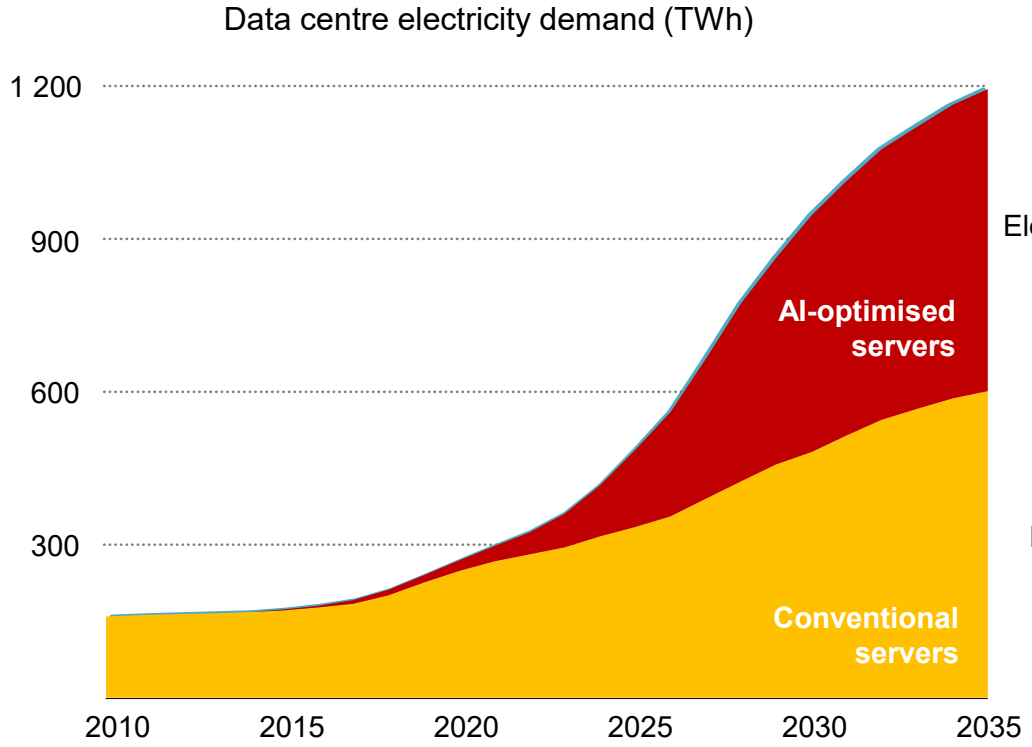

**Low costs, faster permitting & broad social acceptance continue to drive solar PV expansion. Wind capacity doubles despite supply chain issues, rising costs and slow permitting. Pumped storage hydro & geothermal growth accelerates.**

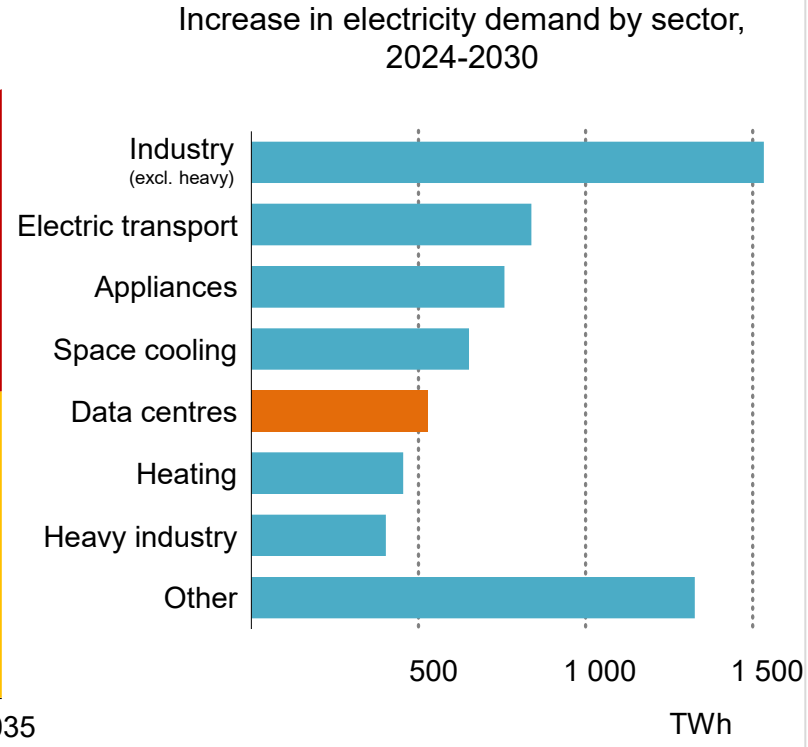
# Renewable transport growth is accelerating




**Electric vehicles powered by renewable electricity are helping to nearly double the pace of transport renewable energy use to 2030, matching biofuels growth. China, Brazil, the EU, Indonesia, India and the US lead expansion.**

# Data centre electricity demand surges



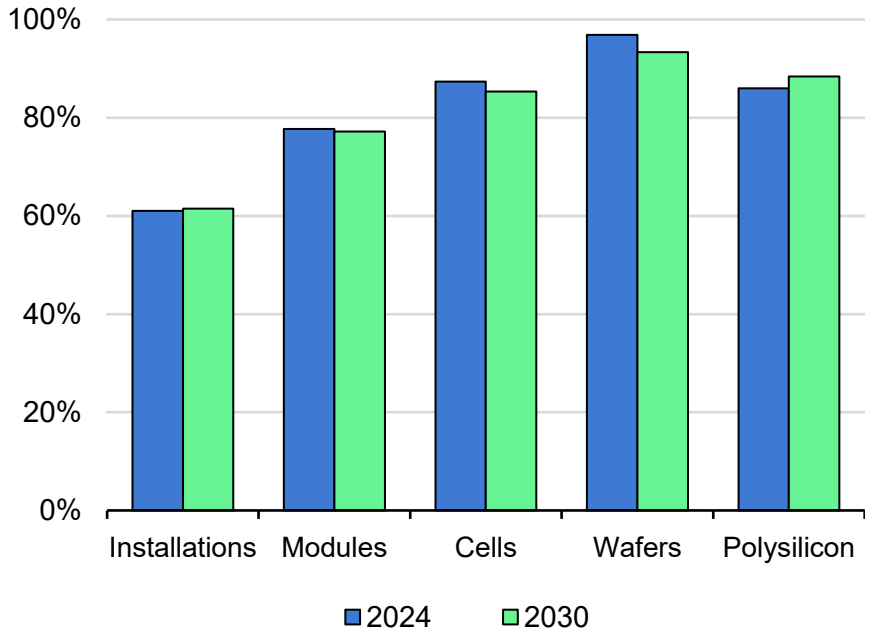

**Data centre electricity demand more than doubles to 2030 and almost triples by 2035, driven by AI, representing almost one quarter of total electricity demand growth in advanced economies and 40% in the United States.**

# Challenges ahead

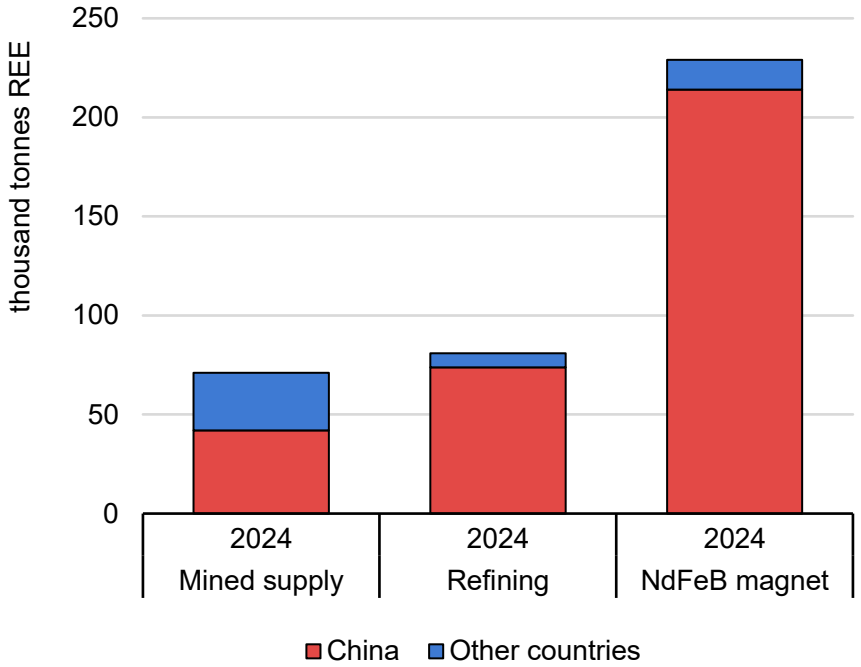
- Long and complex permitting
- Concentration of manufacturing and supply chains
- System integration of rising shares of VRE & slow development of power system flexibility resources
- Cost of capital and financing, especially in EMDEs

# China’s dominance in PV and wind manufacturing remains

China’s share in solar PV manufacturing & installations




Rare earth mining refining and magnet production

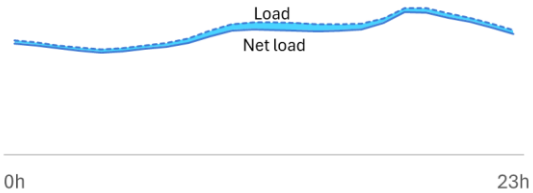



**Despite additional capacity coming online in India, Southeast Asia & the US, China accounts for 80-95% of global solar PV manufacturing. China’s share in rare earth mining, refining and magnet production is above 70-90%**

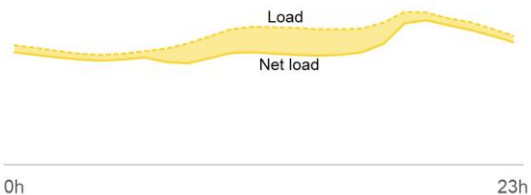
# Six-phases VRE integration framework updated

Low phases

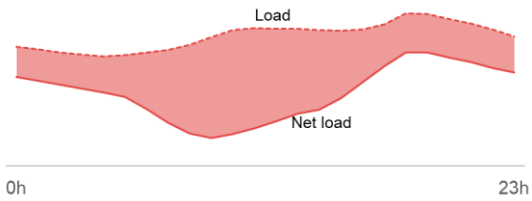
**Phase 1**
VRE has no significant impact at the system level




**Phase 2**
VRE has minor to moderate impact on the system

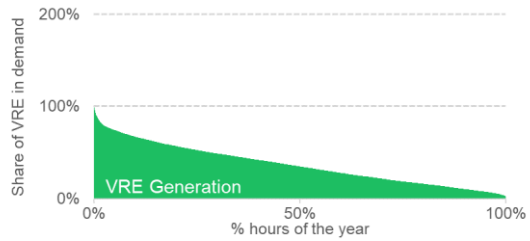



**Phase 3**
VRE determines the operation of the system

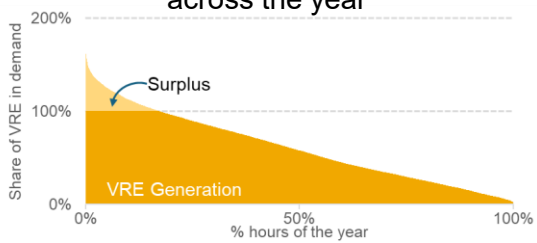



High phases

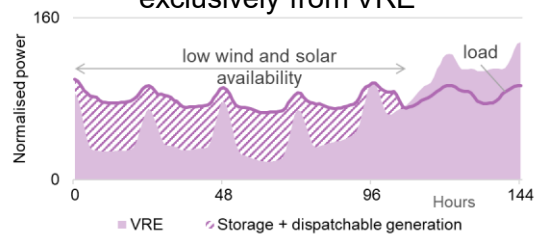
**Phase 4**
VRE meets almost all demand at times




**Phase 5**
Significant volumes of surplus VRE across the year

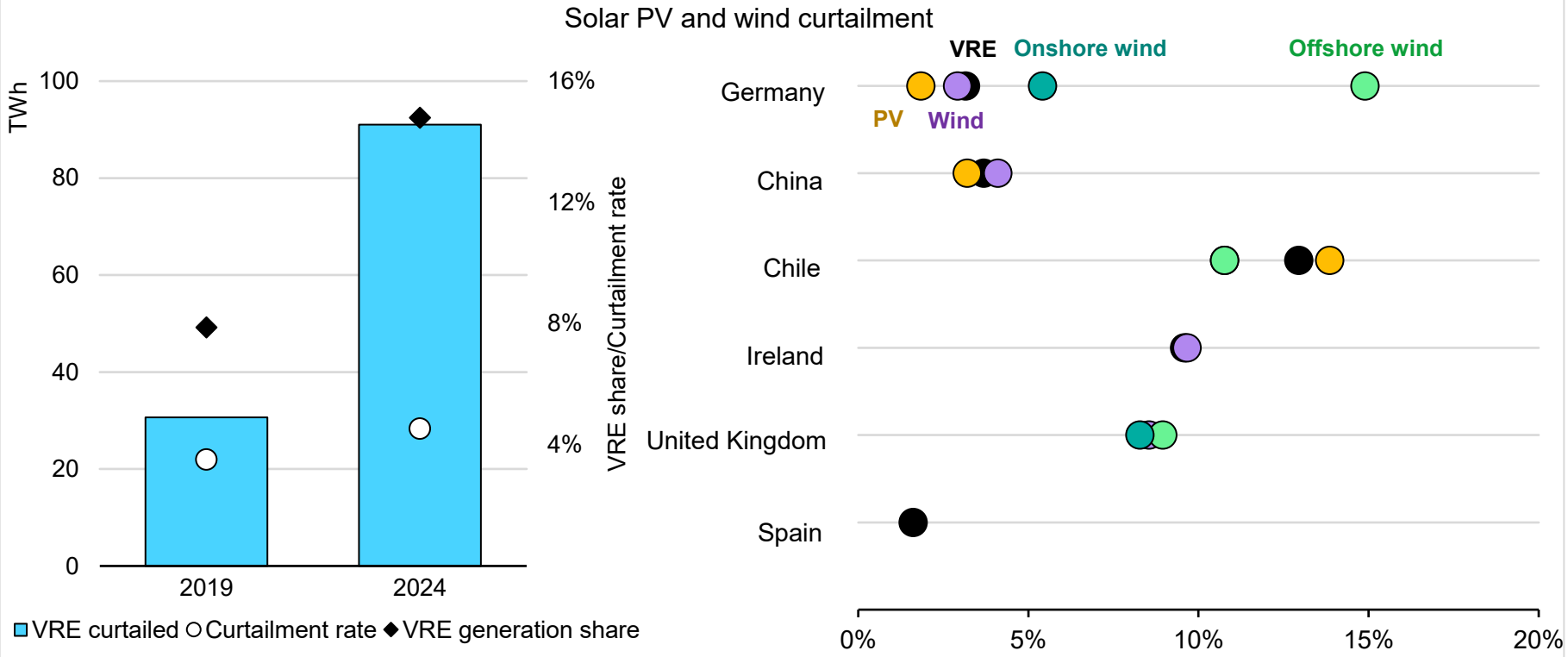



**Phase 6**
Secure electricity supply almost exclusively from VRE



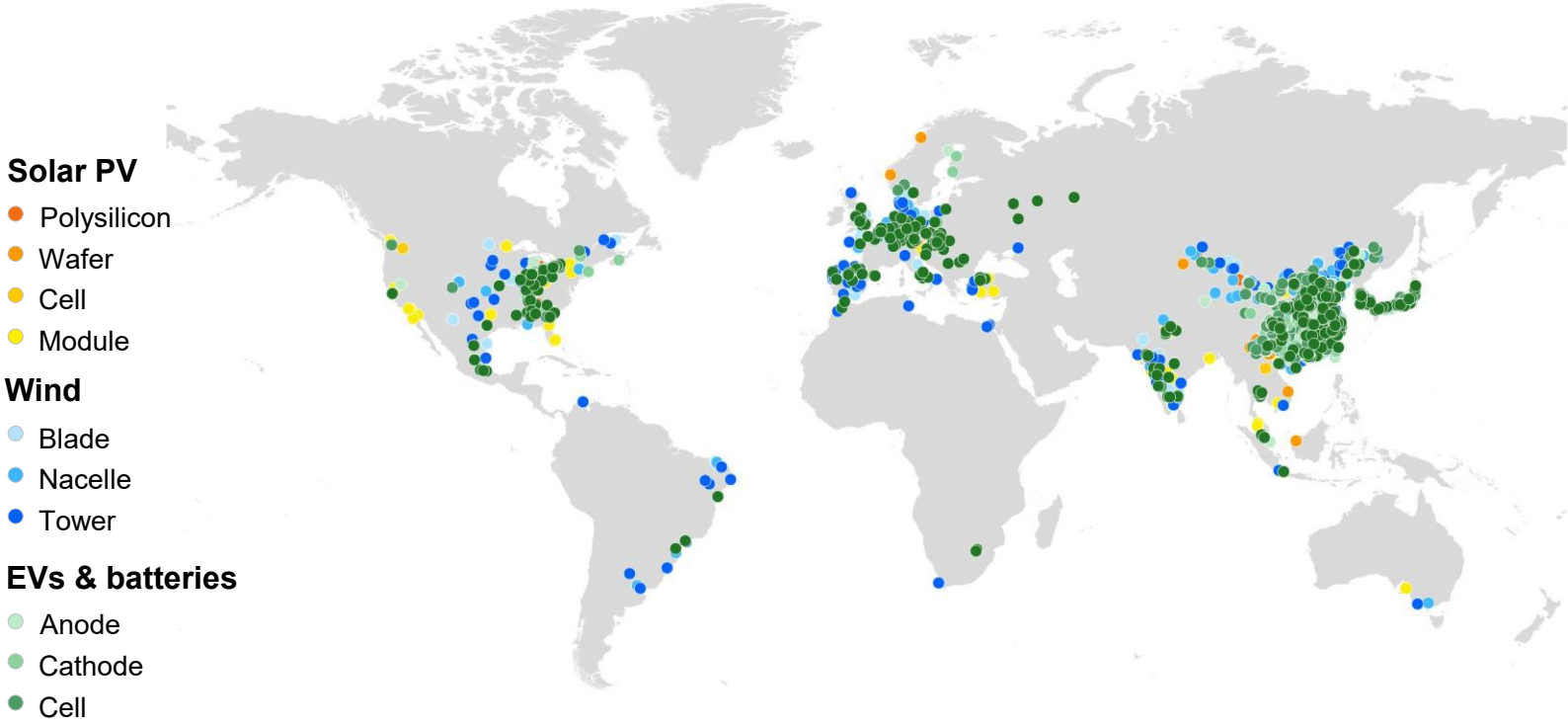

**The framework allows policy makers to identify VRE integration measures that need to be prioritised at each phase to ensure its timely implementation.**

# Grid integration challenges are on the rise




**Curtailment and negative prices signal a mismatch between supply and demand at certain times and/or lack of flexibility in electricity markets, triggering economic inefficiencies and disincentivising investment**

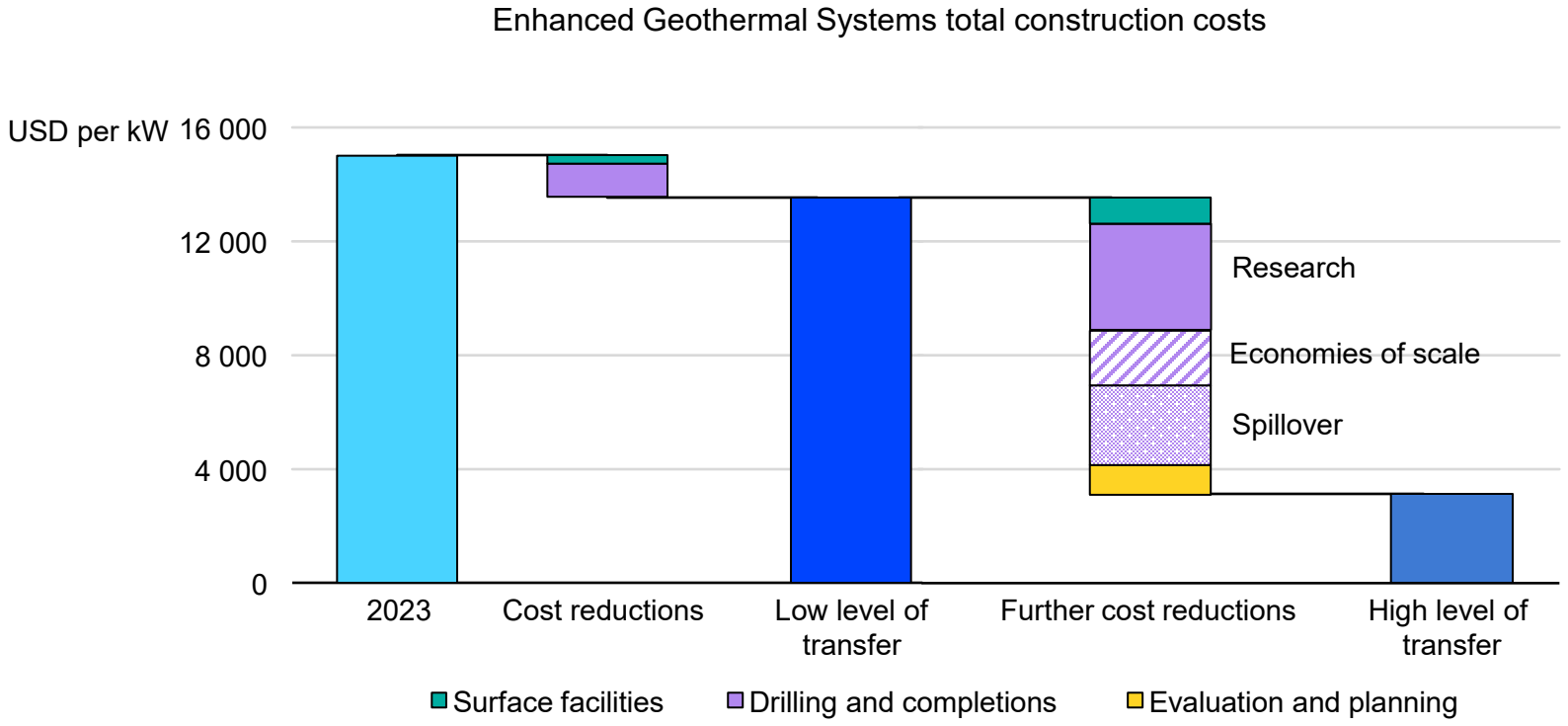
# Investment in clean technology manufacturing is booming



# Emerging technology opportunities

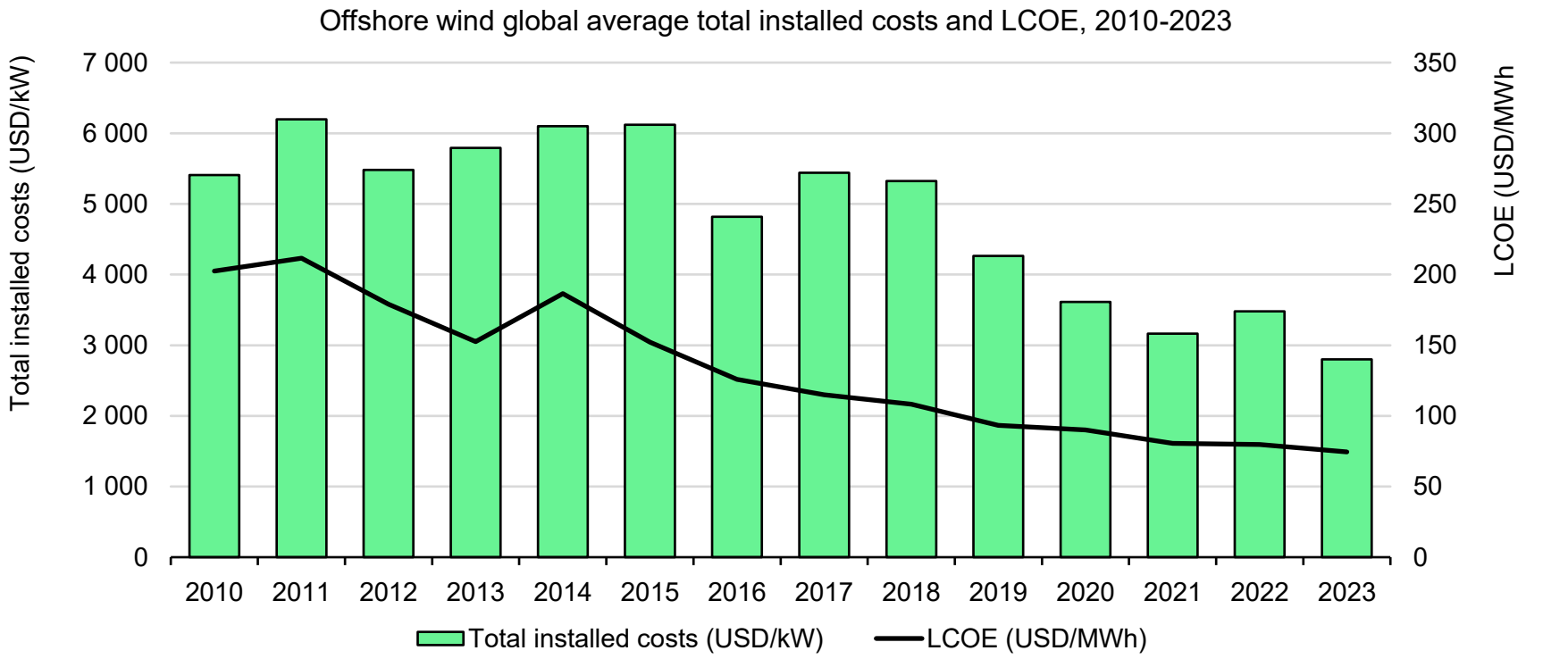
- Solar perovskite PV
- Enhanced geothermal
- Floating offshore
- Storage: electric and thermal batteries
- Advanced biofuels and hydrogen-derived e-fuels

# Oil&gas industry expertise can drive down enhanced geothermal costs



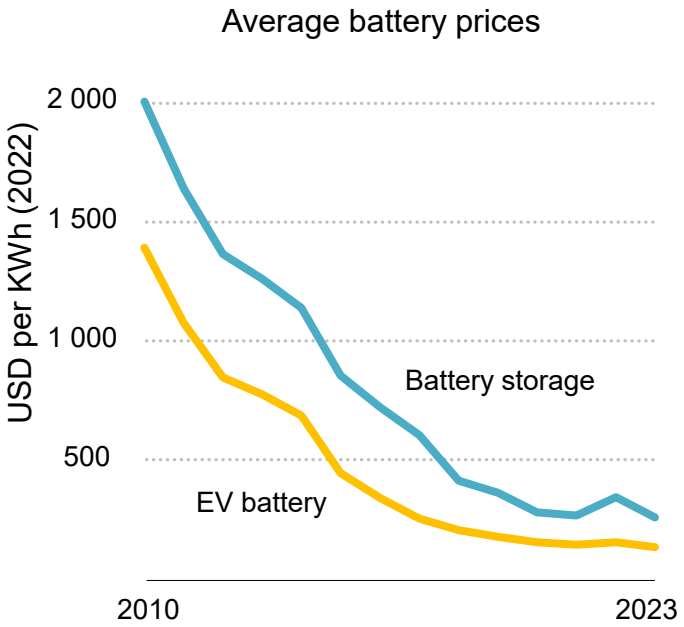

**A high level of knowledge transfer from the oil & gas industry could reduce next-generation geothermal costs by nearly three-quarters down to USD 50/MWh by 2035, unlocking 800 GW of global market potential by 2050.**

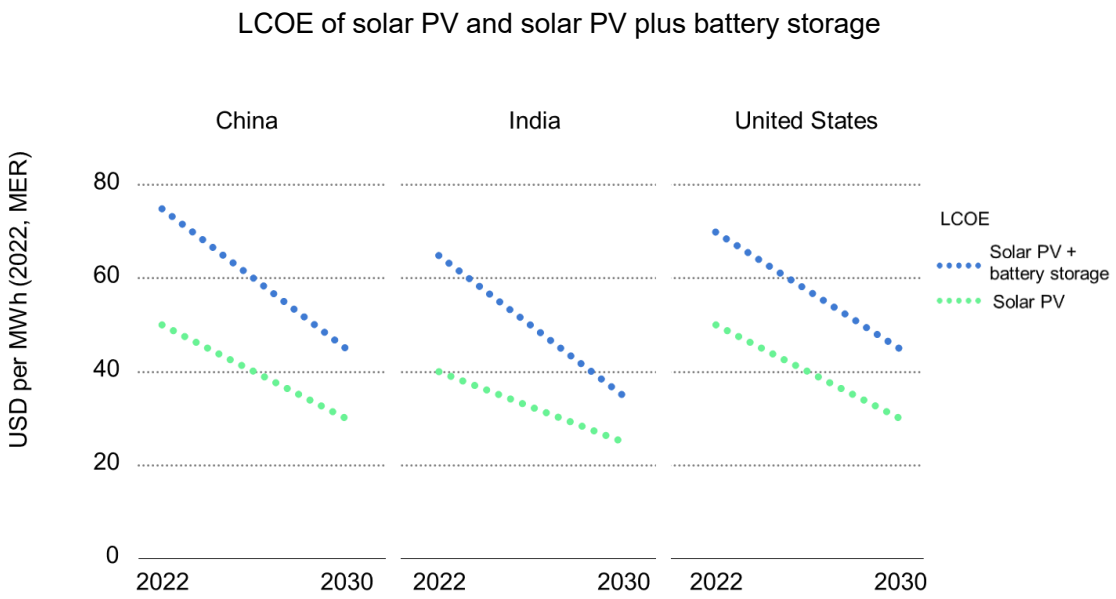
# Turbine size & supply chain improvements have reduced global costs




**Average global LCOE decreased by 50% between 2013 and 2023, reaching 75 USD/MWh. However, for recent small-scale projects in nascent markets in Korea and Japan, it is estimated at more than 200 USD/MWh.**

# Falling costs for energy storage can further enable renewables

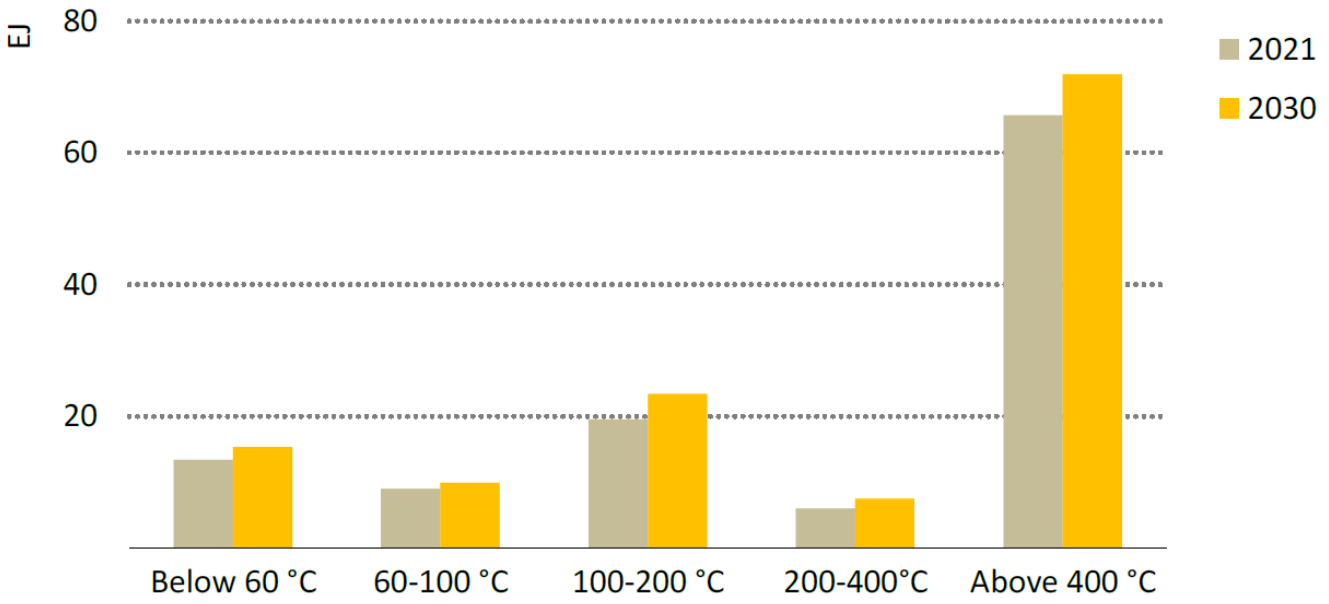



**Battery storage is emerging as a potential option paired with renewables, but appropriate market design and/or incentives are needed to attract investments at scale.**

# Thermal storage solutions are emerging to support electrification of heat

Global industrial process heat demand by temperature in the APS, 2021 and 2030






**Combining thermal storage with electrification of heat can unlock vast amount of flexibility supply. Storage costs are low due to simple construction and cheap materials (steel, water, sand, bricks).**