Energy Transitions Commission

The role of nuclear and geothermal in clean energy systems

ETC Expert Workshop 3

23rd March 2026

Agenda

"Firm-low carbon power" workstream now entering final stages

CONTEXT

- In many regions of the world, **wind and solar will be the most cost-competitive and scalable** new clean electricity generation sources
- But in some places, fast growing demand, limited land availability, or the high cost of balancing the power grid **could make other clean sources attractive**.

ETC WORKSTREAM WILL EXPLORE

- **What is the role of nuclear and geothermal** electricity in future power systems, alongside wind and solar generation, in different regions of the world?
- Can they be delivered at low cost? Where needed, how can their deployment be scaled faster?

WORKSHOP SCHEDULE

- [x] **Workshop 1 - The role of Nuclear** (2nd October 2025)
- [x] **Workshop 2 - The role of Geothermal** (3rd December 2025)
- [ ] **Workshop 3 -** Key guidelines to scale Nuclear and Geothermal

NEXT STEPS

- [ ] Report drafting and production

Why are we focusing on nuclear and geothermal now?

Clean power technologies	Previous ETC coverage	Other coverage	Expected clean system role
Wind and solar	✔ Clean electrification series	IEA, IRENA, BloombergNEF	Significant – set to dominate electricity generation
Hydro (reservoir / run-of-river)	— Not a key focus (mature, geography-limited)	IEA, IRENA	Large existing but limited expansion
Gas with CCS, hydrogen	✔ Clean electrification series	IEA, IRENA, BloombergNEF	Residual / niche
Bioenergy	✔ Bioresources	IEA, IRENA, BloombergNEF	Constrained
Nuclear; Geothermal	✖ Minimal focus until now	IEA, Sightline climate, U.S. Department of Energy	• Uncertain, potentially material in some regions • Increasing attention: "nuclear renaissance" and "surging next-generation geothermal investments"

This workstream is the first time the ETC has addressed the future role of nuclear and geothermal in detail

Source: ASME (2026), *Nuclear Energy Outlook for 2026*; IEA (2026), *Investment in next-generation geothermal is surging. Policies are key to further growth*

We are planning a joint report covering nuclear and geothermal

Role of nuclear and geothermal in low-carbon power systems (~60 p)

Chapter	Relevance	Theme
Chapter 1: *Context & introduction*	Nuclear, geothermal	Systems context
Chapter 2: *Nuclear costs & technology outlook*	Nuclear	Technoeconomic trends
Chapter 3: *Geothermal costs & technology outlook*	Geothermal	Technoeconomic trends
Chapter 4: *System value*	Nuclear, geothermal	System-level insights
Chapter 5: *Wider benefits and risks*	Nuclear, geothermal	System-level insights
Chapter 6: *Considerations for country deployment*	Nuclear, geothermal	Guidelines and strategies for selected countries

Focus of this workshop (→ Guidelines and strategies for selected countries)

Notes: ☢ is relevant for nuclear; ♨ is relevant for geothermal

Objectives for this workshop

Stress-test our thinking on:

1. **Guidelines and strategies** for future nuclear and geothermal buildout by country, based on selected criteria spanning system benefits and deliverability
2. **Investment levels** needed over time, to align with net zero by 2050 pathways
3. **Guidelines for decision makers** based on emerging conclusions from the analysis

Agenda

Criteria-based country classification selected to guide nuclear and geothermal deployment

Key objective: Develop country-level guidelines and strategy frameworks for nuclear and geothermal deployment aligned with energy transition pathways

Method selection

1. Archetype mapping (not selected)

Approach:
- Categorise countries into archetypes based on expected nuclear/geothermal roles
- Policy actions by archetype

Advantages:
- Clear actions by archetype

Limitations:
- Too generalised / prescriptive

2. Criteria classification by country (selected approach)

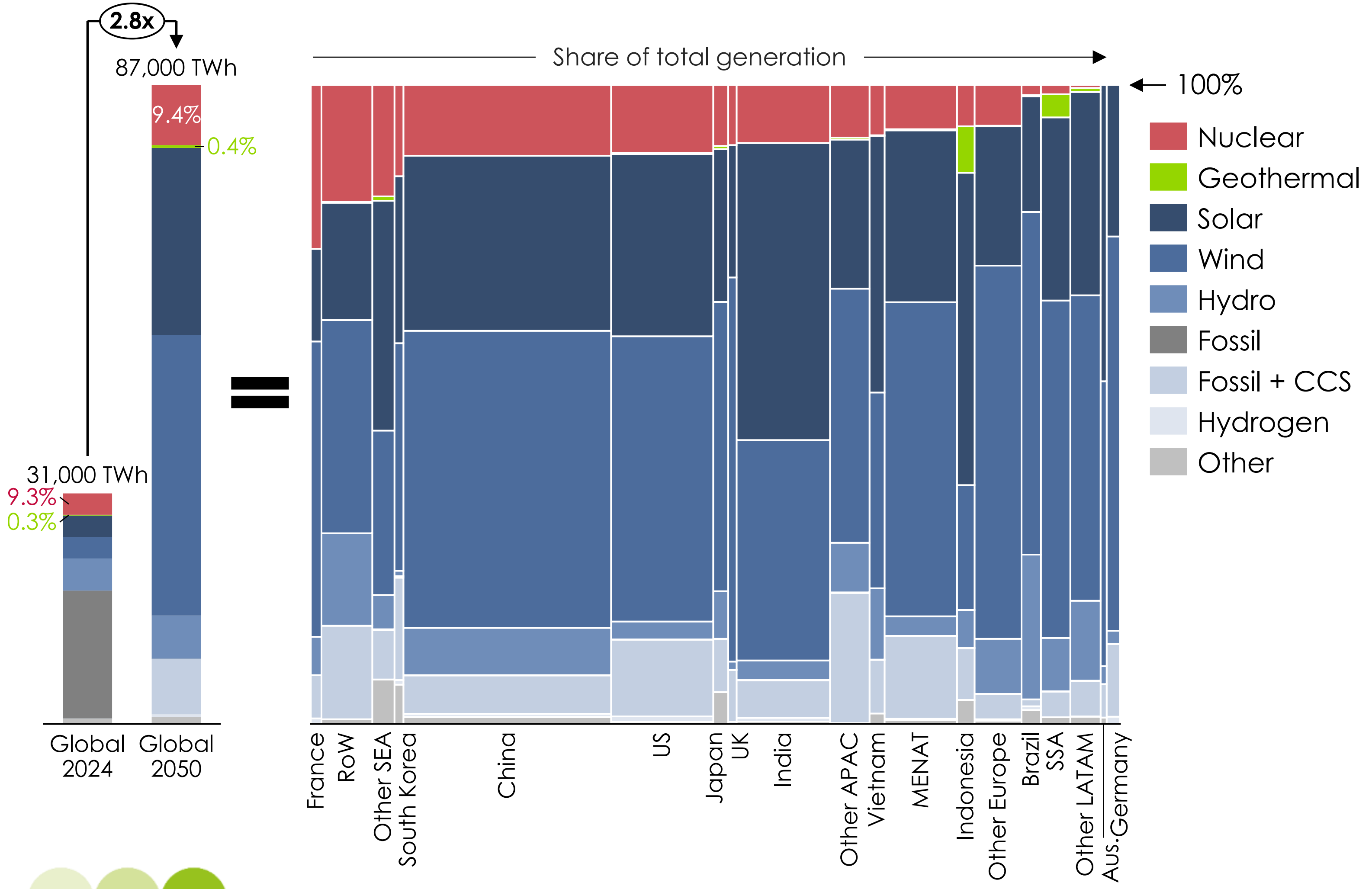
Approach:
- Define key criteria
- Score countries against them
- Develop decision frameworks

Advantages:
- Captures country constraints on a sliding scale rather than fixed archetypes

Limitations:
- Less prescriptive, so country actions may be less explicit

Nuclear and geothermal could maintain a ~10% share of global generation in 2050, even as the global power system expands by ~3x

Share of nuclear and geothermal vs other technologies in BNEF's 2050 Net Zero Scenario
%



- ~10% of global generation by 2050 – maintaining today's share despite a ~3x system expansion
- Regional shares vary widely (0-25%)
- New nuclear deployment depends on system benefits, grid requirements, and deliverability constraints

Notes: RoW = rest of world, SEA = Southeast Asia, APAC = Asia-Pacific, MENAT = Middle East and Northern Africa, SSA = Sub-Saharan Africa, LATAM = Latin America
Source: BNEF (2025), *New Energy Outlook*

The role of nuclear depends on system benefits and deliverability

Six criteria determine the role of nuclear and geothermal by country

1. System benefits – when are nuclear/geothermal most valuable?

a) Power system benefits	→	High value where wind/solar potential and alternative secure firm capacity are limited, increasing the need for reliable firm supply
b) Energy system benefits	→	Attractive where heating demand is large and alternative solutions are constrained or costly

2. Deliverability – what enables rapid, low-cost deployment?

a) Delivery capability	→	Experienced suppliers and workforce capable of standardised repeat build to deliver projects on time and on budget
b) Resource availability	→	Secure nuclear fuel supply and cost-competitive geothermal resources
c) Regulatory capacity	→	Credible, proportionate and predictable regulatory and siting frameworks across the project lifecycle
d) Financing availability	→	Access to low-cost capital and credible risk allocation and revenue frameworks

System outcomes: Total system cost and resilience

Financial risk: Time and cost overrun exposure

Political durability: Institutional stability and public support

We have assessed a range of countries against these system benefits and deliverability criteria

Six criteria determine the role of nuclear and geothermal by country

	Nuclear	Geothermal
1. System benefits		
a) Power system benefits	Wind and solar availability and cost; import and risk exposure to fossil; need for reliable firm supply	
b) Energy system benefits	Scale and growth of low-carbon heat and energy demand; value from hybrid applications; integration with existing energy infrastructure	
2. Deliverability		
a) Delivery capability	Experienced owner–operator and standardised repeat build capability or ability to upskill or import capability	Presence of an experienced geothermal or oil and gas workforce and supply chain, and the ability for standardised repeat build capability
b) Resource availability	End-to-end nuclear fuel cycle security	High cost-competitive resource availability for conventional or next-gen. technologies
c) Regulatory capacity	Credible, proportionate and predictable regulation and full lifecycle regulatory and siting capacity	
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System benefits for nuclear and geothermal depends on power system and energy system benefits

Six criteria determine the role of nuclear and geothermal by country

1. System benefits	Nuclear	Geothermal
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Power system benefits spans renewables resource, alternative firm capacity, and “base load” demand share

1. System benefits

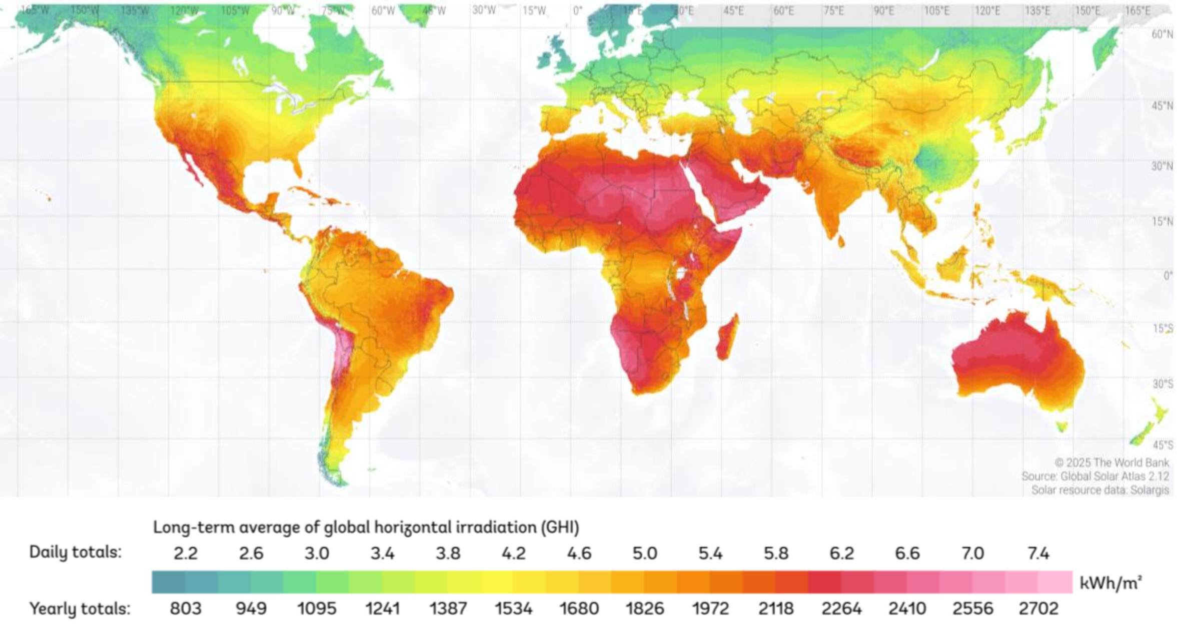
a) Power system benefits

Criteria	*Justification*
Wind and solar resource quality and land constraints	Where strong wind and solar resource is available and land constraints are minimal, these will typically be faster and cheaper sources of clean generation
Cost, scalability, and security of alternative firm capacity	Where domestic firm power generation sources including hydro and fossil are limited, a shit to alternative supply, including nuclear and geothermal
High-load-factor demand share	High “base load” aligns with increasing nuclear and geothermal shares in the generation mix, as these technologies typically operate with high capacity factors and limited (economic) flexibility

Wind and solar resource quality varies significantly around the world, impacting the need for alternatives

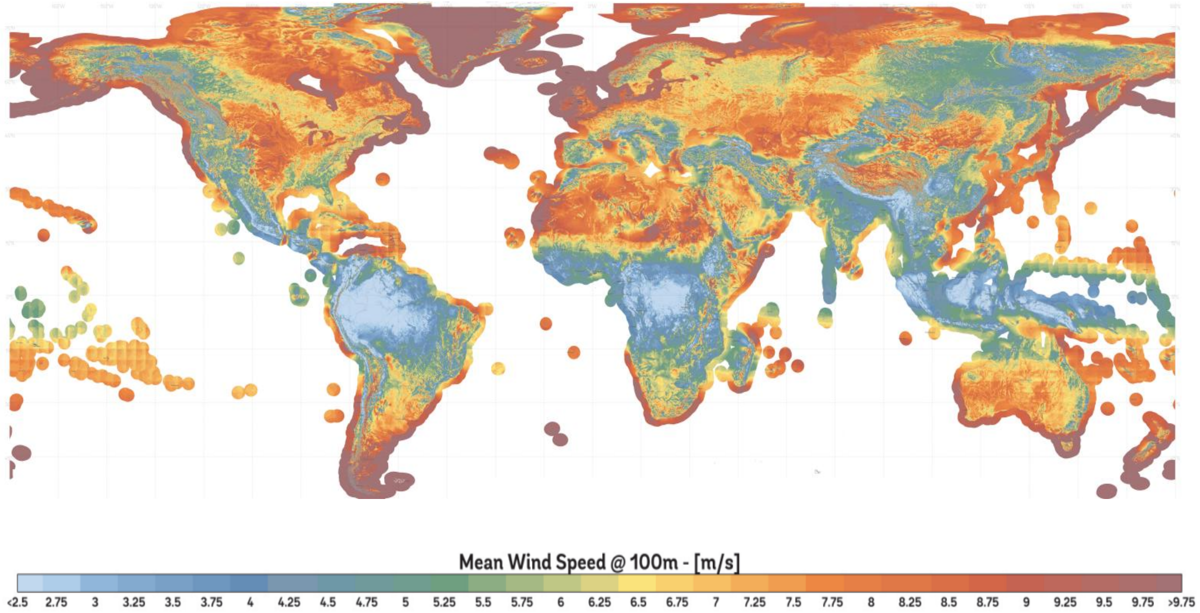
Solar global horizontal irradiation variation across the world

kWh/m² (long-term yearly average)



Wind speed variation across the world

m/s (mean speed 100m above surface level)

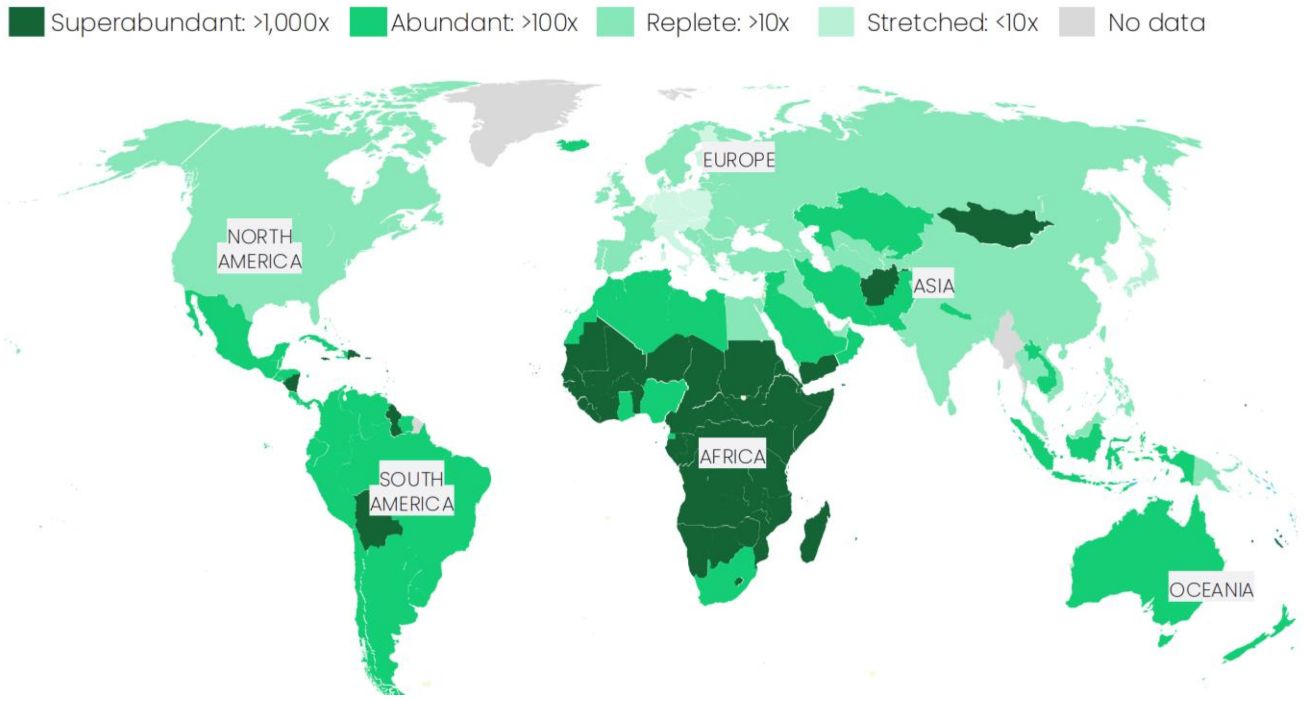


- **Countries with limited wind and solar resource development potential could have a higher need for nuclear & geothermal**
- **In countries with vast wind and solar resources, alternative clean generation may play a more limited role**

Note: GHI refers to Global Horizontal Irradiance - the total amount of solar radiation received on a horizontal surface.
Source: The World Bank (2025), *Global Solar Atlas: Global horizontal irradiation*, available at https://globalsolaratlas.info/download?c=11.523088,8.613281,3. World Bank (2023), *Global Wind Atlas*, available at https://globalwindatlas.info/en/.

Wind and solar technical potential relative to demand depends on resource and land availability; both impact the need for nuclear and geo.

Wind and solar technical potential as a multiple of energy demand (Ember)
Wind and solar technical potential / 2022 energy demand



Super-abundant.
- Most of Africa, Bolivia, Mongolia.
- Many of these countries currently have low demand but energy access will increase significantly

Abundant.
- Chile, Australia, Morocco.
- Resource-rich with well developed infrastructure and governance systems.

→ **Low Firm Low-Carbon Need:** Countries in the "Sunbelt" have less need for firm low-carbon (as renewables-dominated grids will typically be cheaper and fast to develop

Replete.
- China, India, the US, Western Europe.
- Countries in this group in the most part have enough renewable energy to satisfy their energy requirements.

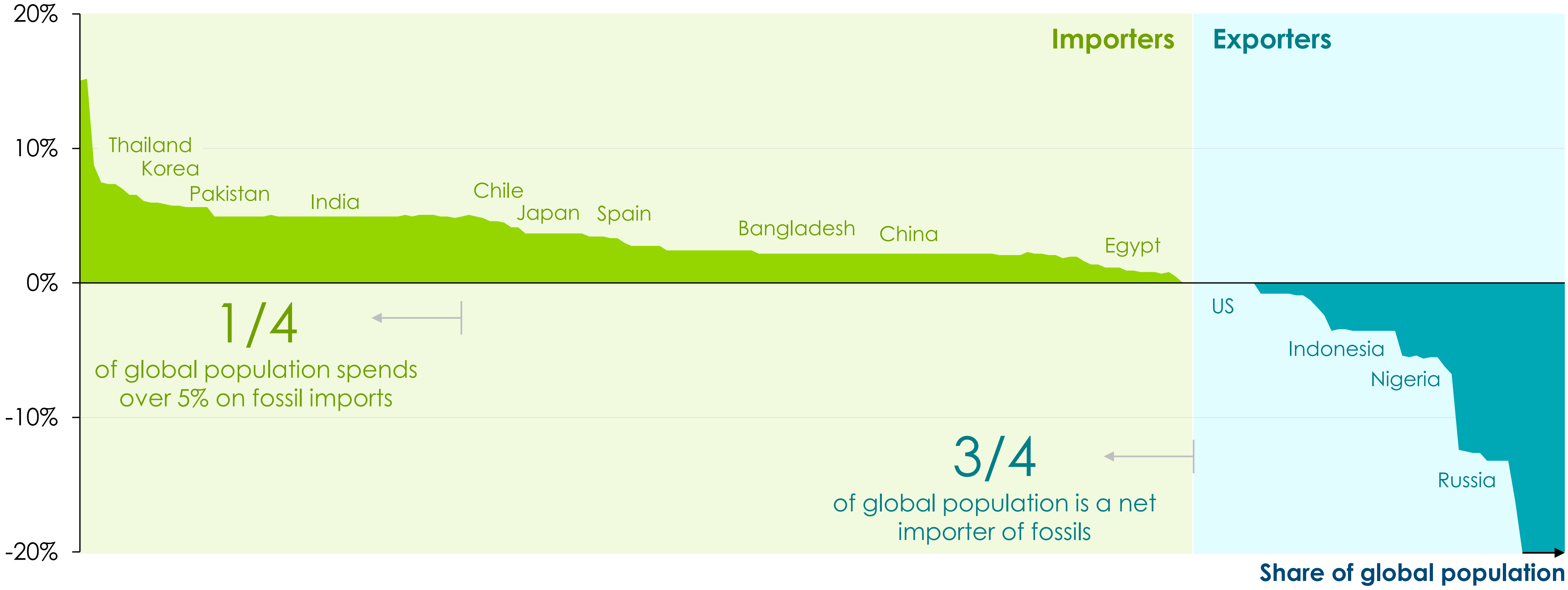
Stretched.
- Much of Eastern Europe
- Limits on wind and solar resource, developable land availability, and high demand limit the scalability

→ **Higher Firm Low-Carbon Need:** The "Windbelt" and "Mixed Climate" have a higher need for nuclear driven by resource constraints, though the role could generally be limited compared to VRE.

Source: Ember (2025), The Electrotech Revolution, Carbon Tracker (2021), The Sky's the Limit

Fossil fuels have high energy security risks in many geographies – a key driver to shift from fossil fuels to renewables or nuclear

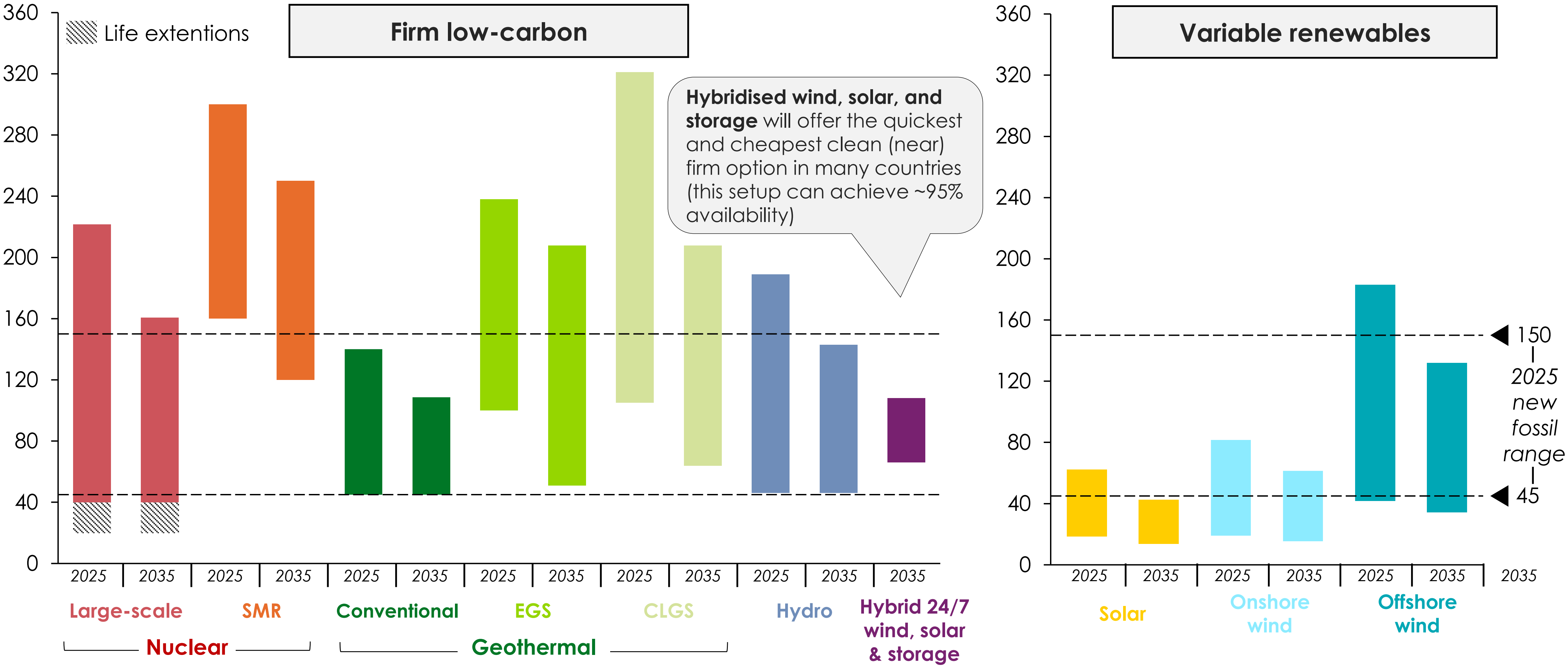
Fossil fuel net imports (-) and exports (+) value as share of GDP, 2022 (Ember)
%



Note: GDP balance based on energy trade balances in EJ from 2022, multiplied by typical commodity prices from IEA.
Source: Ember (2025), The Electrotech Revolution, Carbon Tracker (2021), The Sky's the Limit

Nuclear power generation costs vary; in many cases, higher cost vs alternative clean firm solutions

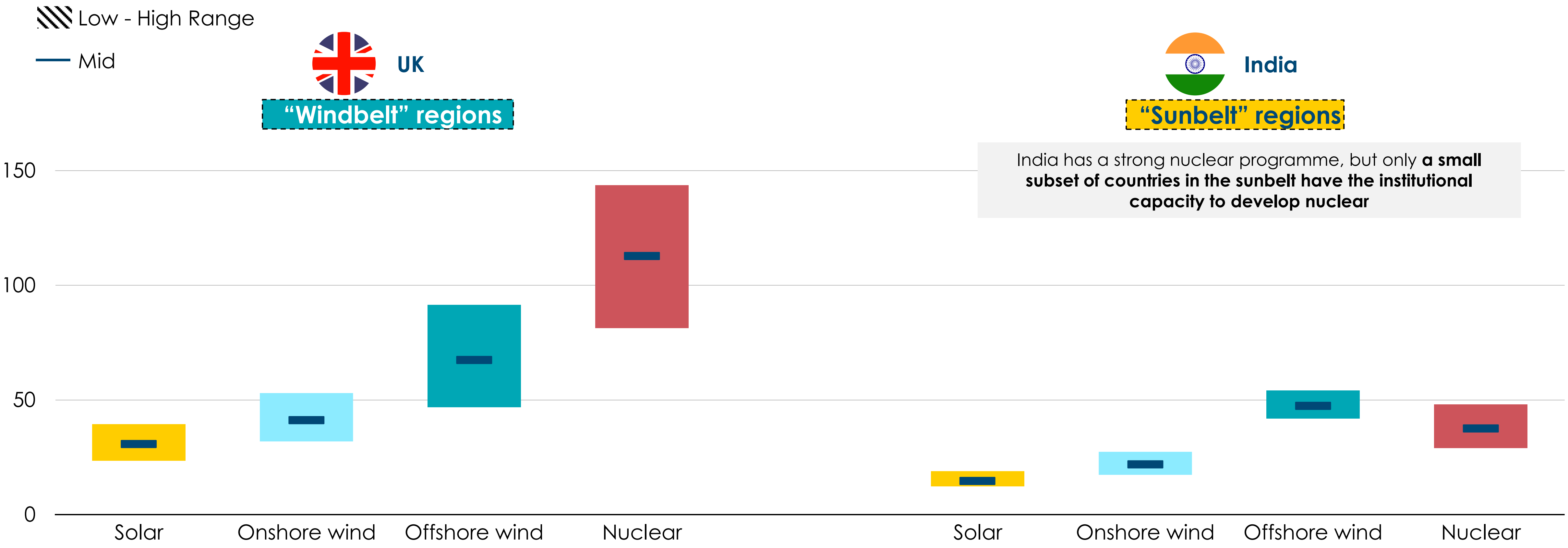
Levelised cost of energy estimated ranges in 2025 and 2035 for selected clean energy technologies
$/MWh (real 2024)



Notes: EGS = enhanced geothermal systems, CLGS = closed loop geothermal systems, SMR = small modular reactor. Life extensions only included for nuclear due to the large opportunity based on the ageing plants. Hybrid 24/7 wind & solar based on IEA 2035 STEPS estimates from China (lower bound) to the EU (upper bound), with hybridized systems achieving ~95% availability. Source: BNEF (2025), LCOE Data Viewer; BNEF (2025), *US Next-Generation Geothermal Makes Unsung Progress*; IEA (2025), *World Energy Outlook 2025*

"Sunbelt" vs "Windbelt" technology costs divergence is evident for wind and solar; nuclear costs also diverge where delivery capability exists

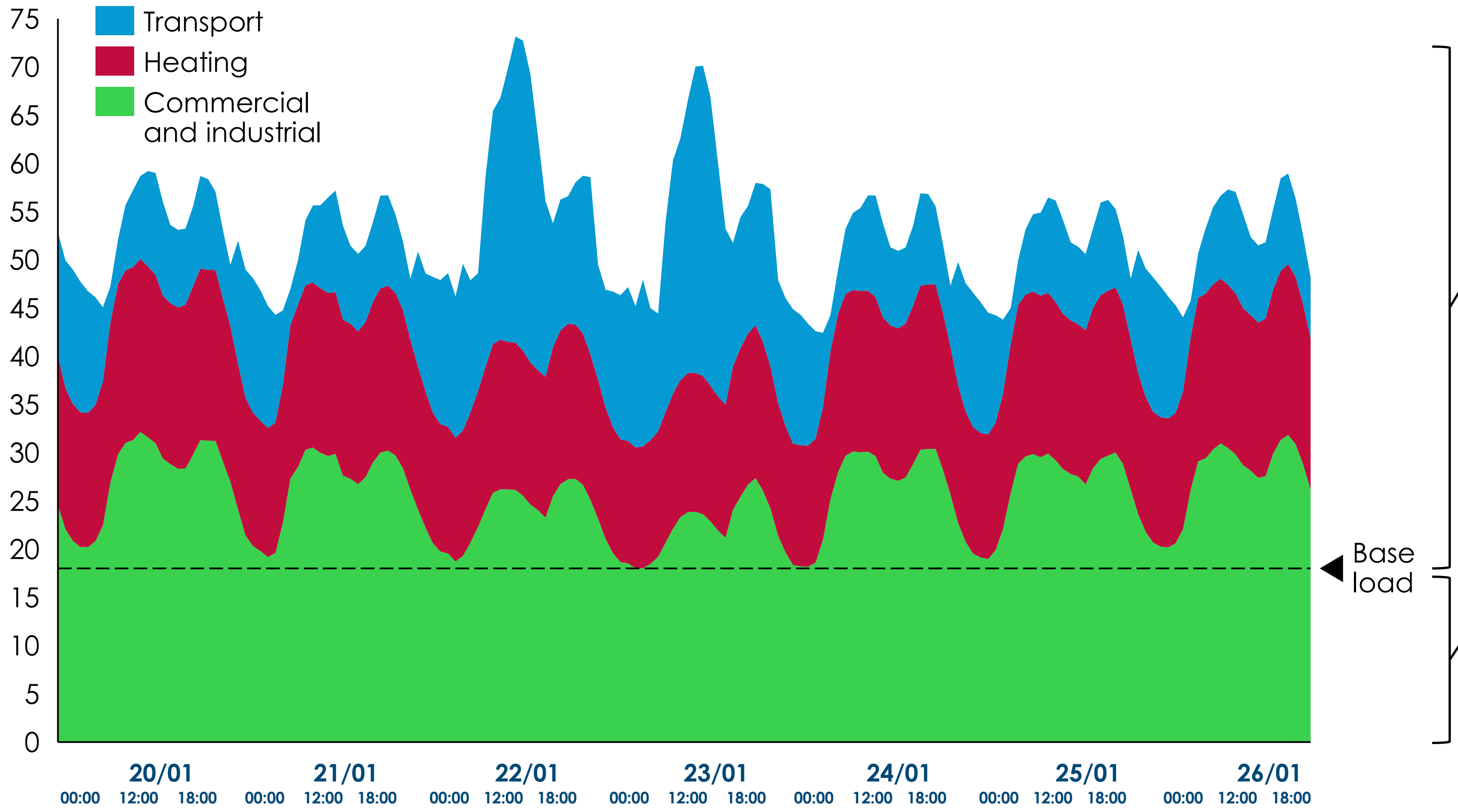
Estimated levelised cost of energy for 2050
$/MWh (real 2024$)



Source: Systemiq analysis for the ETC (2025); BNEF (2025), *LCOE: Data Viewer*

In highly electrified systems, commercial and industrial loads could be more aligned with Firm Low-Carbon generation

Spain hourly demand load January 20-26, 2050, highly electrified scenario
GW



Peaky, flexible or seasonal demand across:
- Transport
- Residential building (heating, cooling) demand

Low direct suitability for Firm Low Carbon

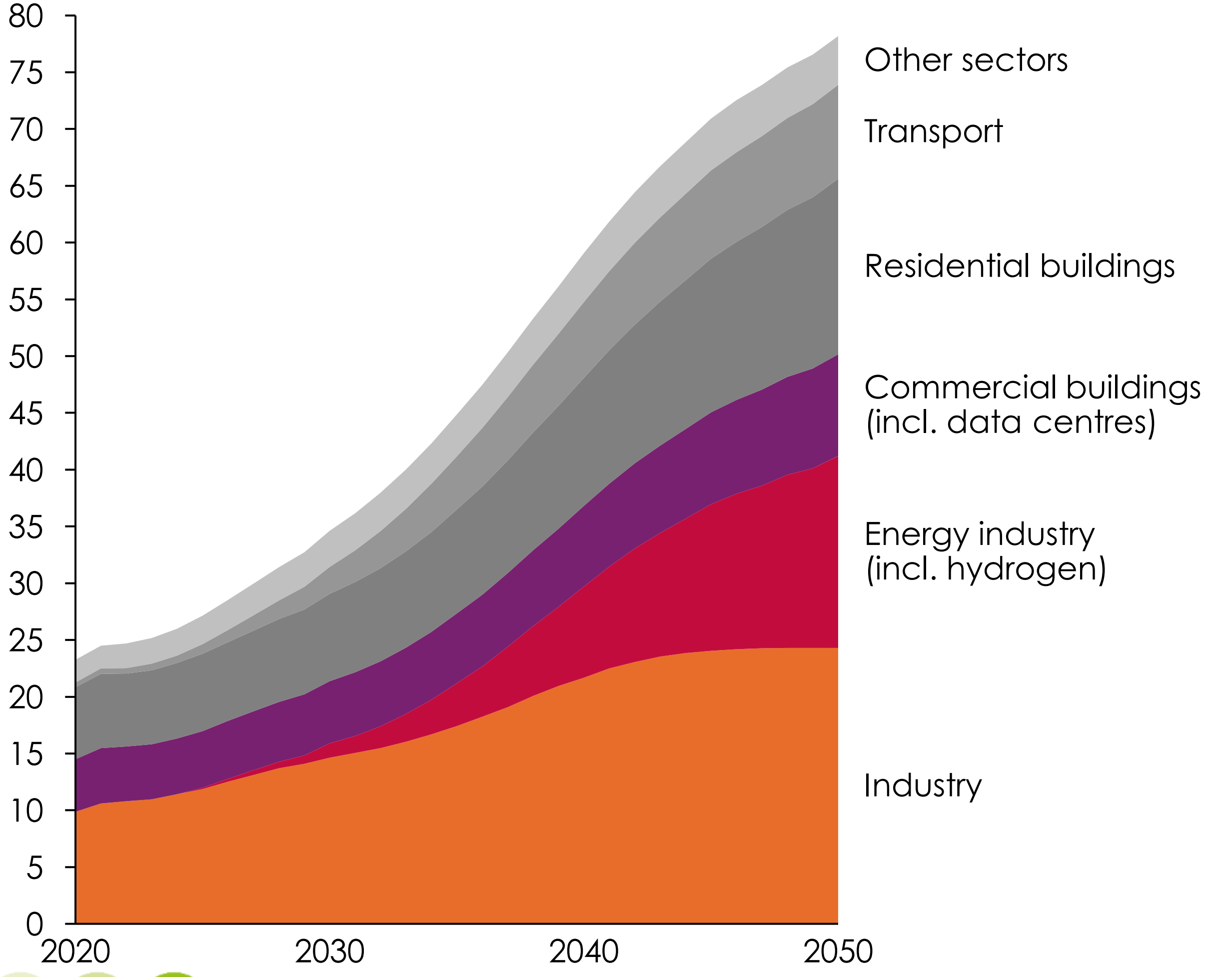
High-load factor sectors include:
- Commercial buildings (incl. data centres)
- Industry (incl. hydrogen

Higher suitability for Firm Low Carbon technologies' constant operational profiles

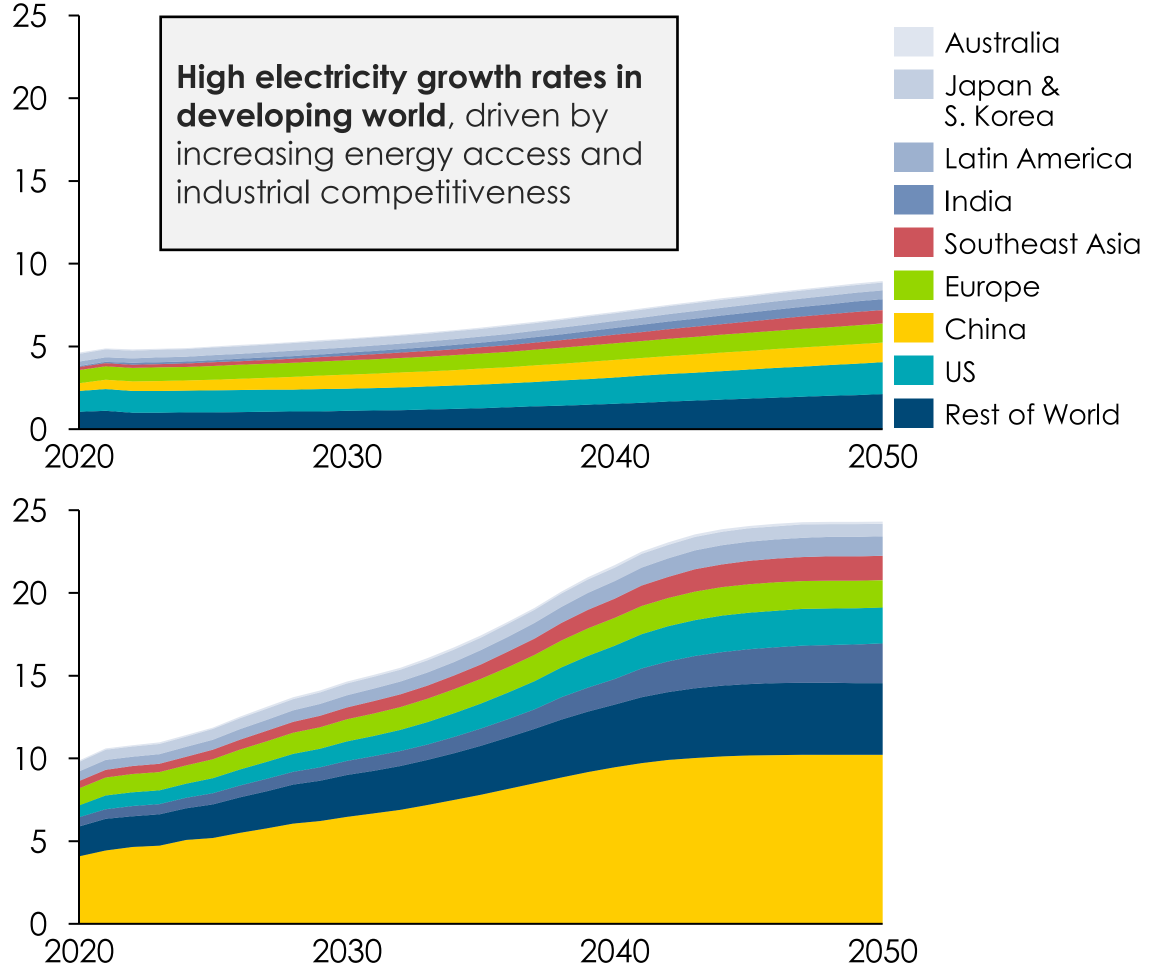
Notes: 20/01/2050 is the first day of the week.
Source: AFRY (2025), *Hourly Demand Projections*

Nuclear and geothermal could be a good fit where demand growth across data centres and industry is expected

Electricity consumption by sector, BNEF NZS
000 TWh



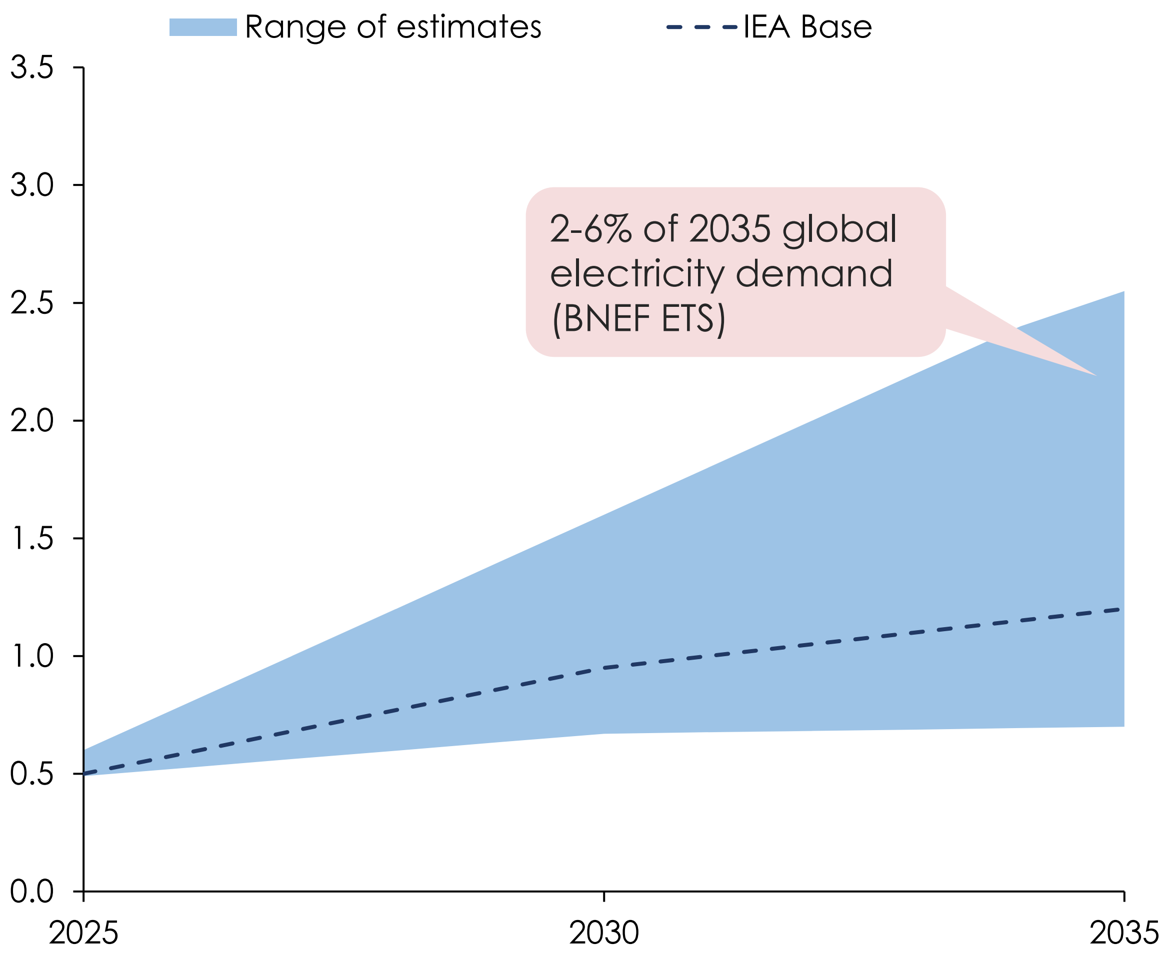
Electricity consumption by geography, BNEF NZS – commercial buildings (top) & industry (bottom), 000 TWh



Note: BNEF's NZS data centre demand projections are from 2024 so are expected to be revised upwards.

Data centre electricity growth is highly uncertain; SMR and next-gen. geothermal viability will depend on large cost reductions

Global data centre annual demand projections by scenario
000 TWh/year



Key uncertainty drivers

- Computing proliferation
- AI model scaling
- Jevons effect

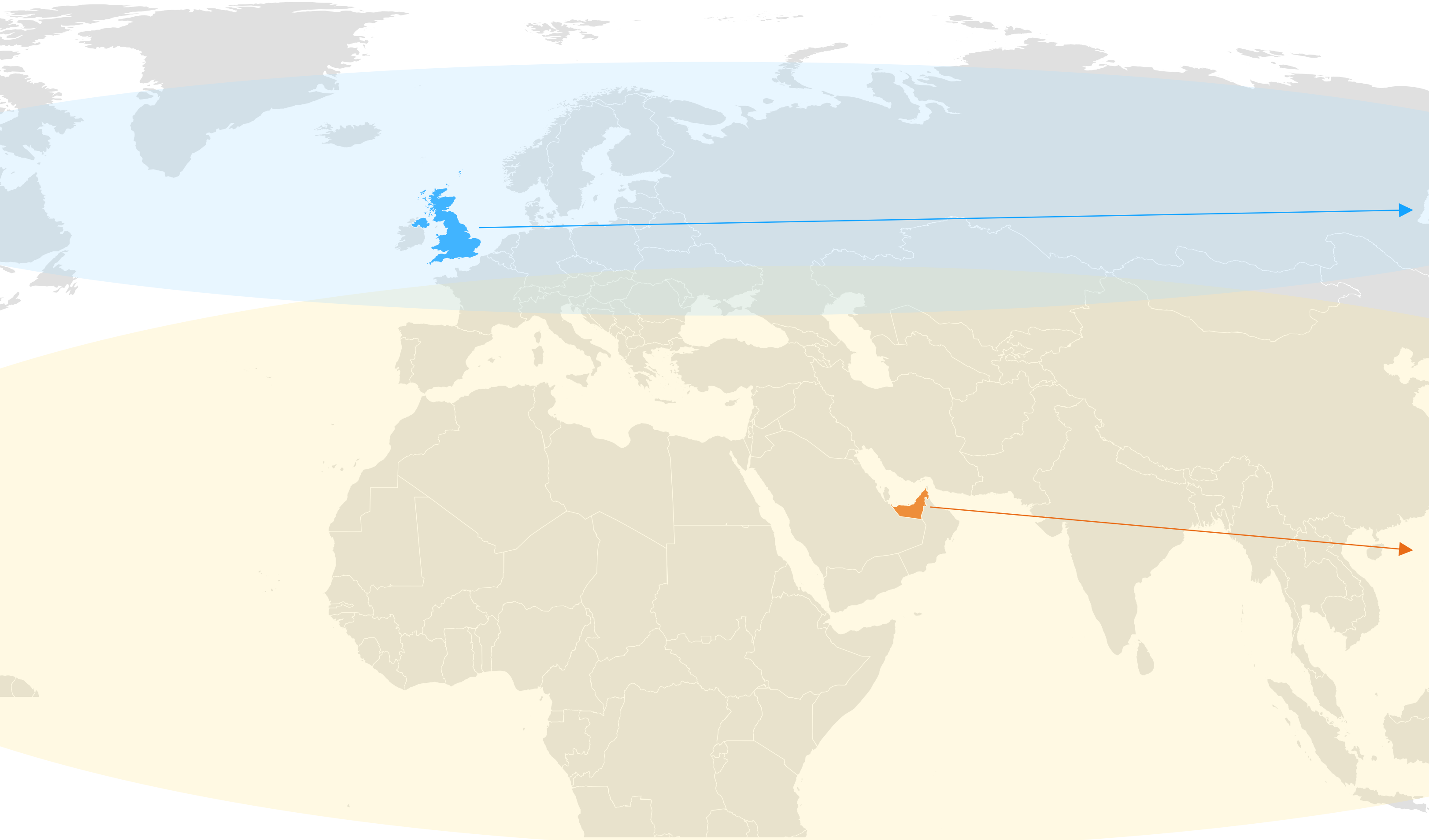
- Increasing compute efficiency
- Uptake uncertainty
- AI monetisation
- Supply chain grid connection constraints

- **80-300 GW** of dedicated data centre power needed **by 2035**
- **Energy costs are typically ~10% of total data centre costs** so there can be a high willingness to pay for firm power
- **SMR & next-gen. geothermal** contribution requires **undemonstrated cost reductions**

Notes: SMR = small modular reactor GPU = graphics processing unit; PUE = power usage effectiveness; FOAK = first of a kind; NOAK = nth of a kind. TSE conventional data centre cost breakdown used with "Servers & IT hardware" swapped with Bernstein GPU cost estimates. Sources: BNEF (2025), *New Energy Outlook*; IEA (2025), *Energy and AI*; Thunder Said Energy (2025), *AI energy: industrial demand and the Jevons effect?*; Thunder Said Energy (2025), *Data-centers: the economics?*; Investing.com (2025), *How much does a GW of data center capacity actually cost*

Renewables and storage are increasingly offering 24/7 clean power solutions across the "Windbelt" and the "Sunbelt"

Optimal renewables and storage system configuration to meet continuous baseload demand varies by region



UK – "Windbelt" solution

Centre for Net Zero modelling (2025)

- ~80% renewables (offshore wind + solar + BESS), ~20% gas
- 120 MW, 24/7 with COD 2028-30
- 43% cheaper than nuclear SMR
- 23% cheaper than gas-only

Implied LCOE: ~$90/MWh

Abu Dhabi – "Sunbelt" solution

Masdar / EWEC (under construction)

- 5.2 GW solar PV + 19 GWh battery
- Delivers 1 GW baseload, 24/7
- ~$6bn investment, online ~2027
- Zero gas backup required

Implied LCOE: ~$55/MWh

Note: Both scenarios assume 100% load-matching, however reliability statistics are not provided. Abu Dhabi LCOE is an illustrative estimate based on published capex of ~$6bn (AED 22bn), 30-year project life, 5% WACC, 1.5% annual O&M, and one battery replacement. Actual tariff not yet disclosed. UK figures derived from CNZ published annual costs (medium DESNZ cost assumptions). Source: PV Magazine (2025), *Masdar, EWEC announce 5 GW/19 GWh solar-plus-storage project in Abu Dhabi*; Centre for Net Zero (2025), *How to accelerate the UK's AI revolution – Powering data centres at speed and low cost*

Pre-read only

Understanding power "system value" requires accounting for full system costs

"System value" of power generation technology requires understanding full implications across total system costs

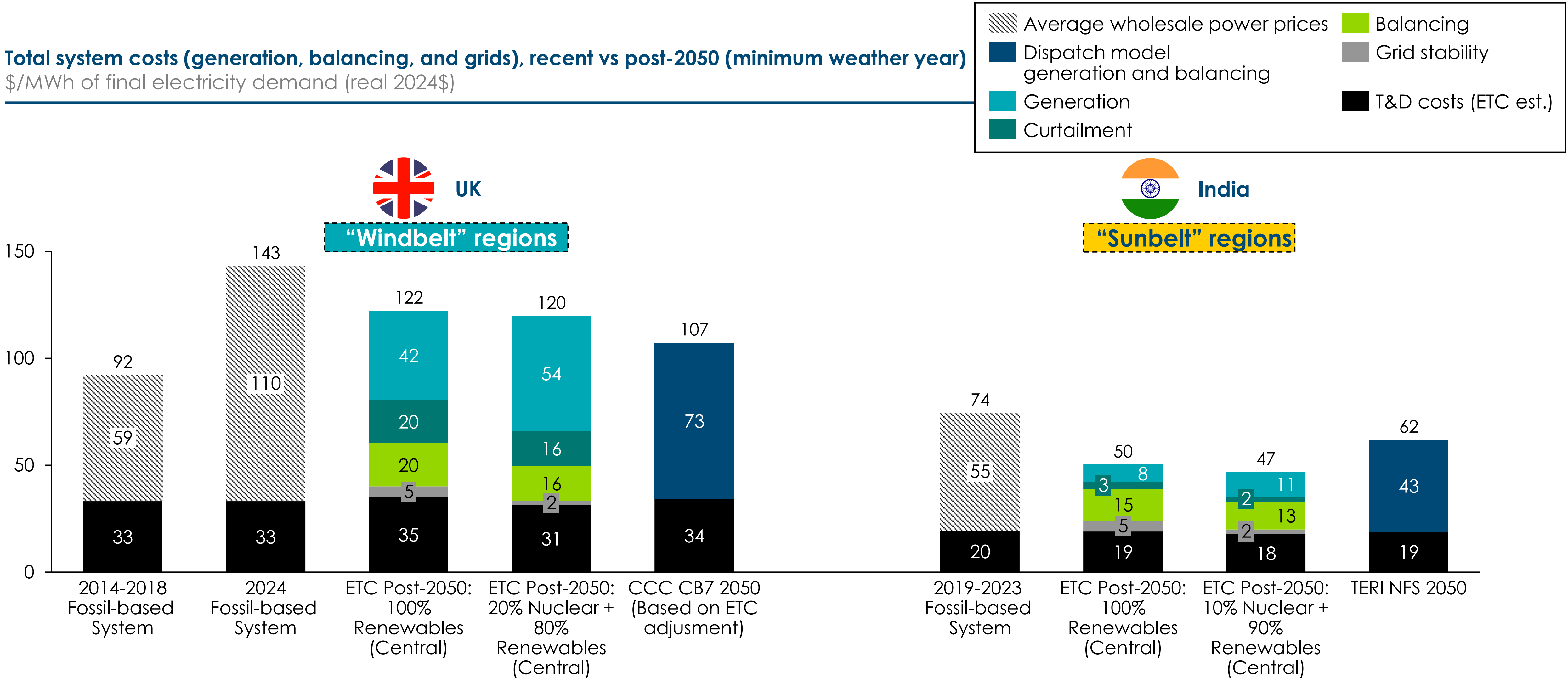
Definitions

System Cost Component	Definition
Generation costs (LCOE)	Generation asset costs (CAPEX & OPEX), including of wind, solar, nuclear, geothermal, hydro, gas
Curtailment costs	Costs associated with curtailing generation assets
Balancing costs	Costs of assets to provide balancing/flexibility/storage (CAPEX & OPEX), including batteries, pumped hydro, compressed air, gas peaking plants
Grid stability costs	Ancillary service costs to maintain grid stability across voltage (e.g., reactive power support, voltage control) and frequency (e.g., through reserves, inertia, fast frequency response)
Grid expansion costs	Additional grid build costs to connect generation assets to demand centres

Curtailment can be classified as either a generation or balancing cost

Clean power systems with nuclear could deliver similar total system costs to 100% wind & solar

Total system costs (generation, balancing, and grids), recent vs post-2050 (minimum weather year)
$/MWh of final electricity demand (real 2024$)

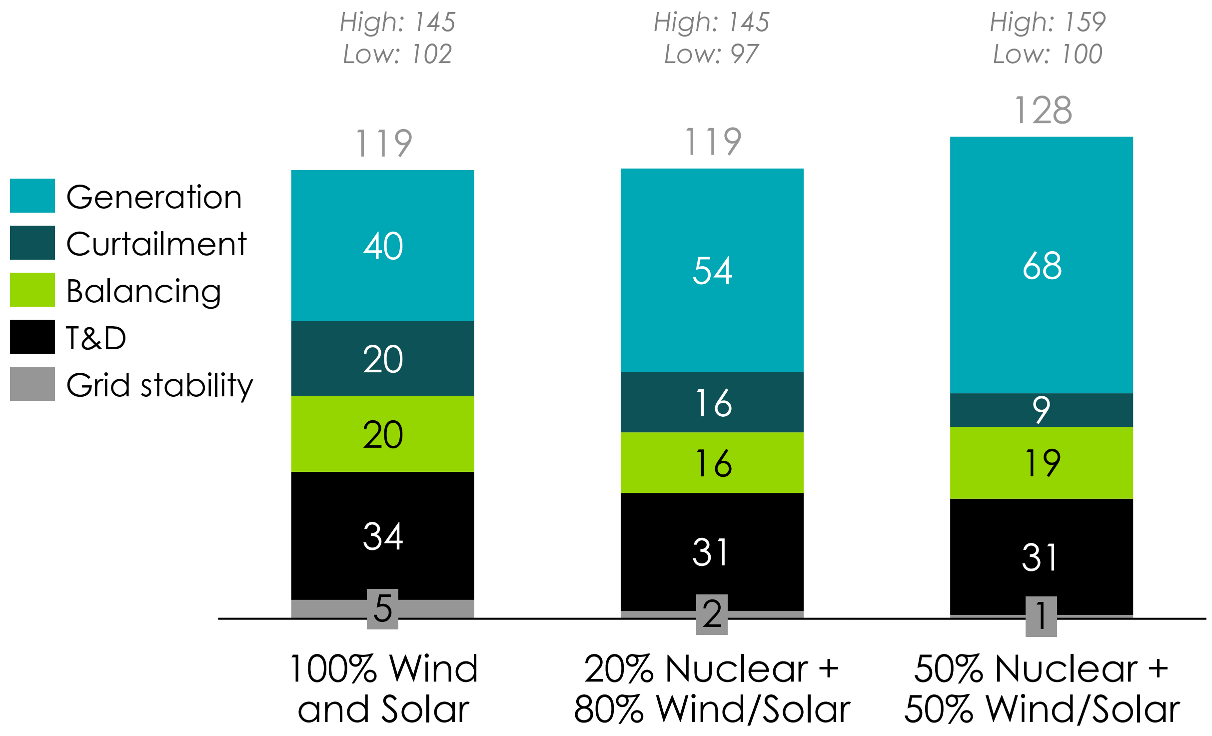


Note: T&D = Transmission and distribution. T&D costs per MWh have been assumed based on ETC modelling across all presented here for consistency.
Source: Systemiq analysis for the ETC (2025); BNEF (2025), *LCOE: Data Viewer*; Ofgem (2025), *Wholesale market indicators – Electricity Prices: Forward Delivery Contracts – Weekly Average (GB)*; IEA (2023), *Electricity Market Report – Update 2023*; Statista (2024), *Average electricity prices for enterprises in China from September 2019 to September 2024*; Ember (2025), *Wholesale electricity prices in Europe*; CCC (2025), *The Seventh Carbon Budget*; TERI (2024), *India's Electricity Transition Pathways to 2050: Scenarios and Insights*

Nuclear provides system value, but cost, delivery speed, and declining costs of alternatives likely limit role to ~10–20% of generation

Illustrative view of components of total system cost and variation by system, UK Case Study in 2050 (minimum weather year)

$/MWh (real 2024$)



System costs consistent at 0-20% nuclear share → ***System costs higher at >20% nuclear share***

Systems with Firm Low-Carbon…

- **Increase generation costs:** nuclear raises weighted average LCOE
- **Can lower curtailment costs**: need to overbuild generation decreases when nuclear is added
- **Can lower (but not eliminate) balancing costs at low nuclear penetrations**: as ultra-long duration balancing needs fall; as the share of nuclear rises, additional balancing costs occur to manage intra-day mismatches, as lower renewables overbuild reduces the number of hours of naturally concurrent supply and demand
- **Can lower grid stability and T&D costs:** nuclear can provide a wider set of grid stability services than variable renewables

Key LCOE assumptions (mid):

Offshore wind:
- 2024: $110/MWh
- 2050: $60/MWh

Firm Low-Carbon:
- 2024: $170/MWh
- 2050: $115/MWh

Notes: "20% nuclear" refers to the share of generation. T&D = Transmission & distribution. Sensitivities: Generation - BNEF's low, medium, and high 2050 CAPEX and OPEX estimates and assumptions for capacity factors, WACC, and lifetimes based on ETC modelling; Curtailment – surplus electricity at the weighted average wind & solar LCOE (assuming no nuclear is curtailed); Balancing – central CAPEX +/- 20% for high/low alongside high/low electricity input costs based on generation; Transmission & distribution - central CAPEX +/- $5/MWh for high/low. Source: Systemiq analysis for the ETC (2025); BNEF (2025), *LCOE Data Viewer*

Country criteria mapping suggests high nuclear alignment in land-constrained, import-exposed systems with large anchor loads

Criteria assessment by selected country

Low to high system value

Country	Wind, solar resource quality and land constraints	Cost and scalability of alternative firm capacity	High-load-factor demand share	Overall Rating
Sub-Saharan Africa (regional)				Low
Brazil				Low-moderate
Canada				Low-moderate
India				Moderate-high
United States				Moderate-high
China				High
France				High
United Kingdom				High
Japan				High
Singapore				High
South Korea				High

Notes: Criteria shaded from low to high nuclear alignment (1–3). Overall rating uses RAG based on average of criterion scores (equal weights), thresholds: 40/50/60/70%.
Source: The World Bank (2025), *Global Solar Atlas: Global horizontal irradiation*. World Bank (2023), *Global Wind Atlas*, World Bank (2025) Net energy imports, IAEA (2025) PRIS

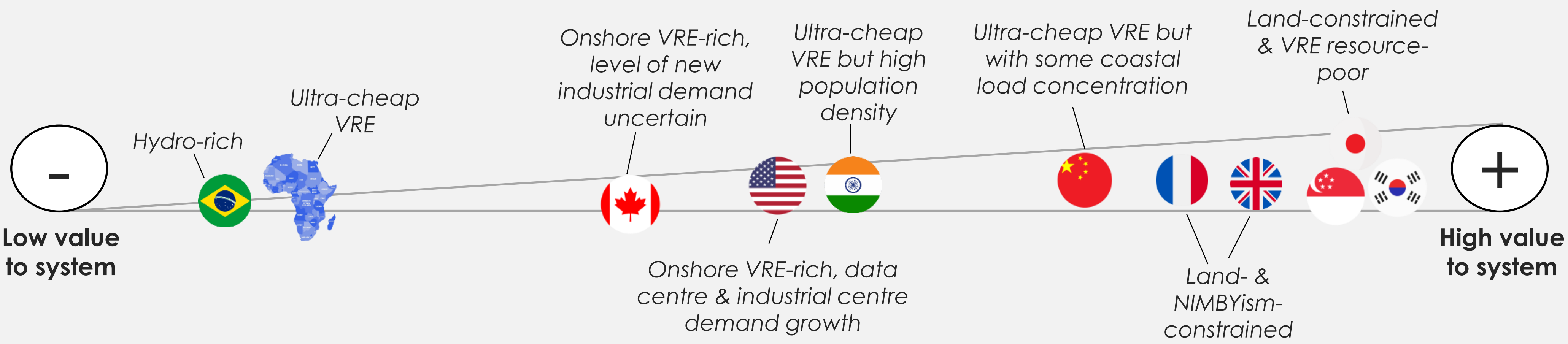
Highest power system foundation alignment is in places with high land constraints and low wind and solar resource

1. System benefits

a) Power system benefits

- Wind and solar resource quality and land constraints
- Cost and scalability of alternative firm capacity
- High-load-factor demand share

The relative system value of nuclear and geothermal increases under these conditions:



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1. System benefits	Nuclear	Geothermal
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c) Regulatory capacity	Credible, proportionate and predictable regulation and full lifecycle regulatory and siting capacity	
d) Financing availability	Access to low-cost capital and credible risk allocation and revenue frameworks	

Energy system benefits reflects scale of heating demand, hybrid application potential, and infrastructure integration

1. System benefits

a) Energy system benefits

Criteria	*Justification*
Scale and growth of low-carbon heat and energy demand	Large and growing industrial or district heating demand could favour reliable, baseload low-carbon supply from nuclear an geothermal where alternatives struggle to match at scale
Value from hybrid applications	Where direct electrification alone faces grid, cost, or temperature limits, nuclear and geothermal add value by serving multiple end-uses (process heat, hydrogen, desalination, and heat pump supply)
Integration with existing energy infrastructure	Existing district heating networks, industrial heat users, or hydrogen infrastructure make it easier to capture thermal output value

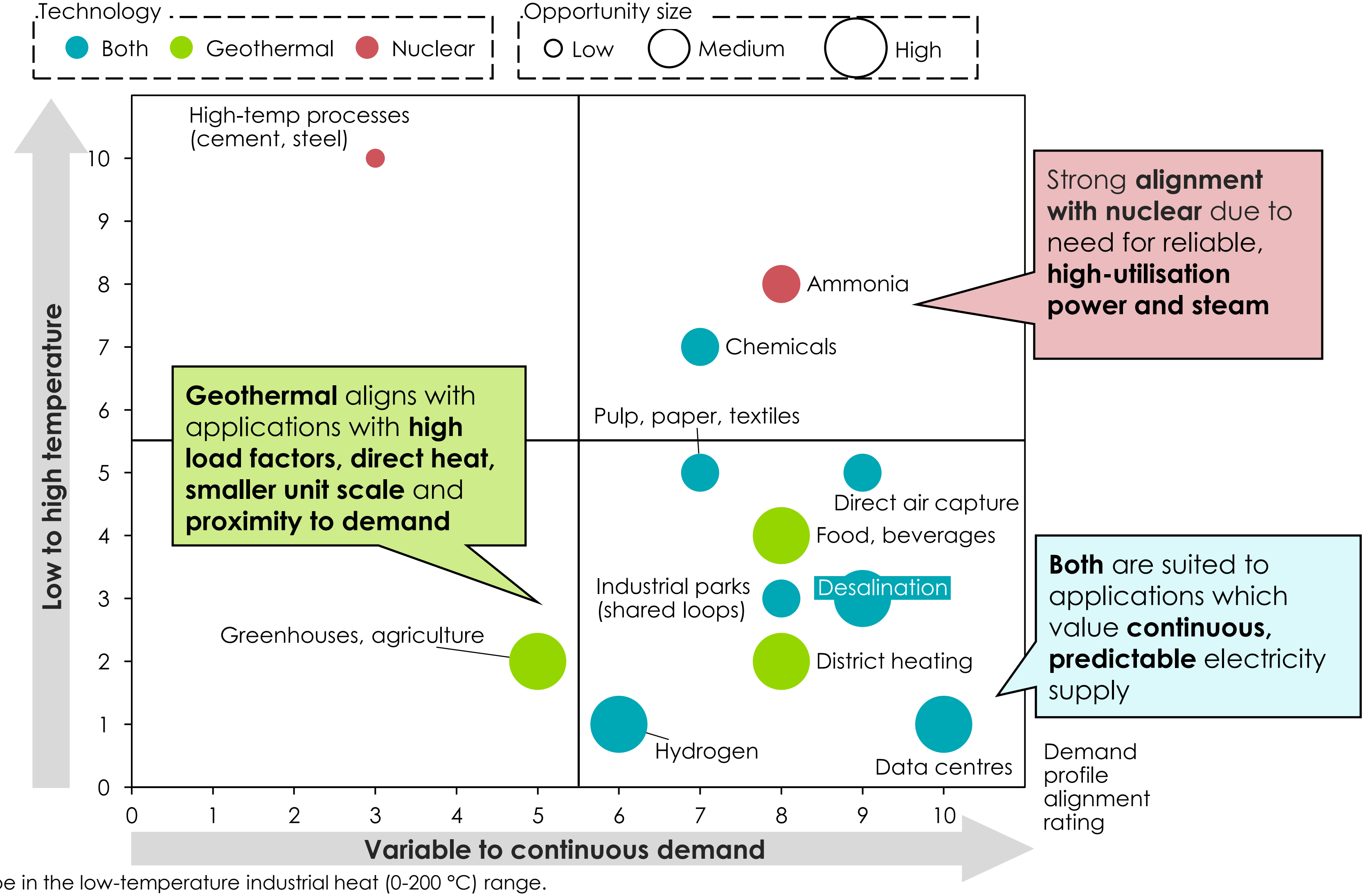
Next-generation nuclear and geothermal technology could enable specific niche use cases

3 key characteristics that determine high fit for specific nuclear and geothermal industrial applications:

- **New build site** because of site development impacts
- **Constant load** to align with economic high load factor supply
- **Heat demand co-location** to improve project economics

Best-fit nuclear and geothermal industrial co-location applications based on load and heat need

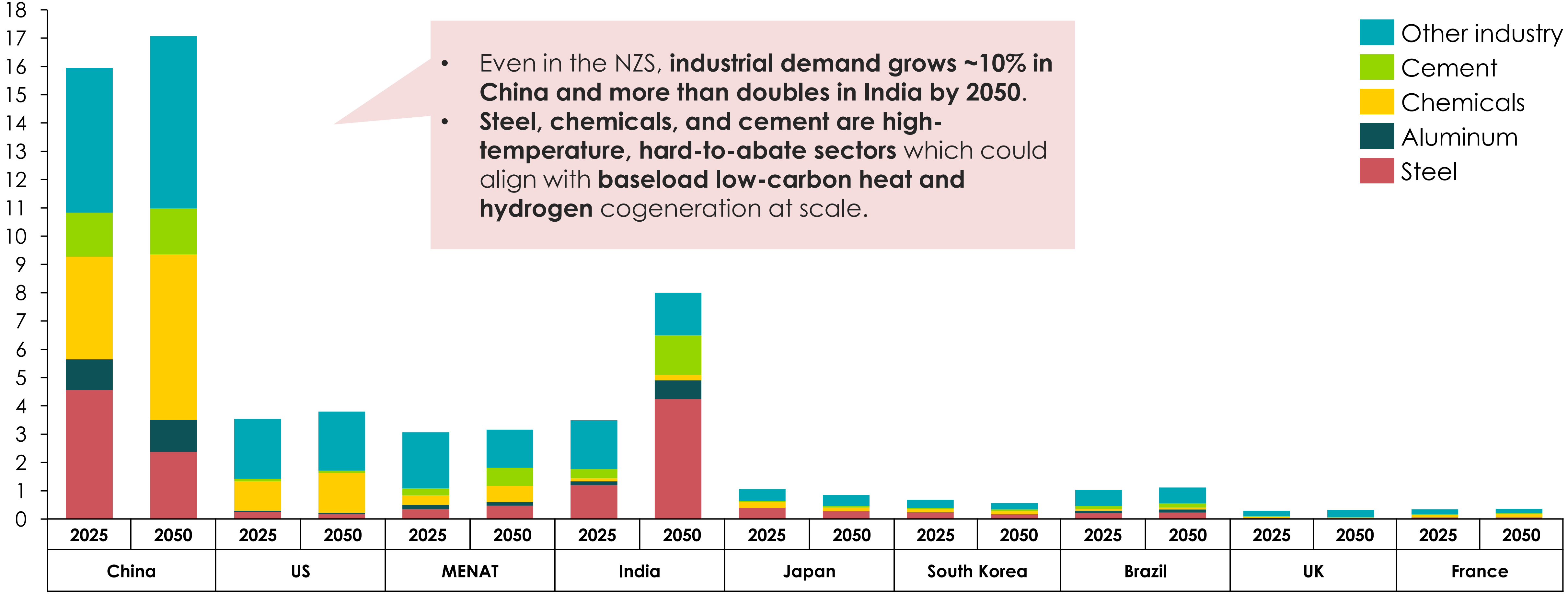
Temperature low to high scale (/10)



Note: High temperature alignment is defined to be in the low-temperature industrial heat (0-200 °C) range.
Source: Systemiq analysis for the ETC (2025); Systemiq (2024), *Global opportunities for Electrothermal Energy Storage*

Industrial energy demand increases in many countries under a net zero scenario, creating potential for nuclear and geothermal cogeneration

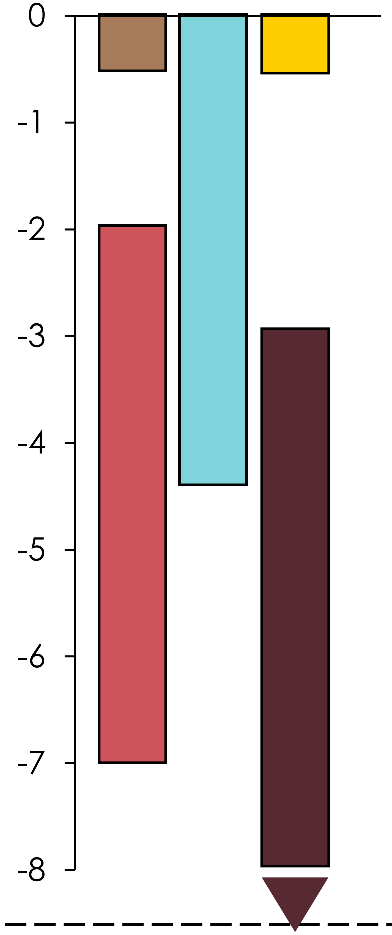
Industrial demand breakdown by source, 2025 vs 2050 (BNEF NZS)
000 TWh



- Even in the NZS, **industrial demand grows ~10% in China and more than doubles in India by 2050**.
- **Steel, chemicals, and cement are high-temperature, hard-to-abate sectors** which could align with **baseload low-carbon heat and hydrogen** cogeneration at scale.

Source: BNEF (2025), *New Energy Outlook*

Geothermal heat and depth vary by technology type; lowest risk options will be in low-temperature, shallow heat, cooling, and thermal storage



Geothermal Technology	Typical depth (km)	Temp (°C)	Use Case	Geo potential	Sector	TRL
Ground source heat pumps		4 - 25 °C	Heating, Cooling	Global	Resi., Industry	TRL 9
Geothermal energy storage		< 100 °C	Storage	Global	Resi., Industry	TRL 9
Conventional hydrothermal		10 - 120 °C (heat) 80 - 300 °C (power)	Heating, Power	Shallow resource	Grid, Industry	TRL 9
Next-gen. technologies						
Enhanced geothermal systems (EGS)		80 - 300 °C	Heating, Power	Global	Grid, Industry	TRL 7
Closed loop geothermal systems (CLGS)		80 - 300 °C	Heating, Power	Global	Grid, Industry	TRL 6
Superhot rock		375 - 500 °C	Heating, Power	Global	Grid, Industry	TRL 3-5

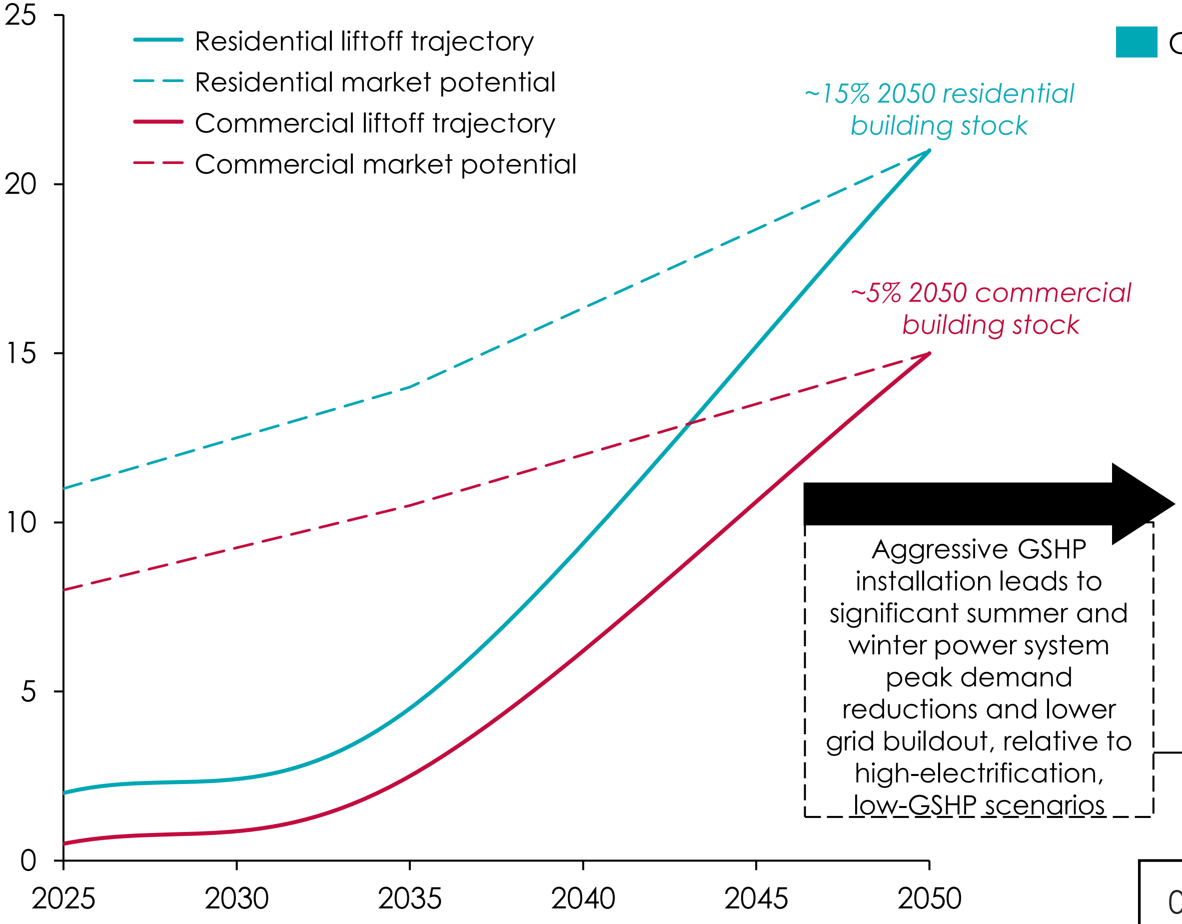
Heating | Cooling | Storage | Power | Global | Shallow resource | Resi. | Industry | Grid

Notes: Underground energy storage parameters refer to underground thermal energy storage (excluding more nascent options such as geothermal mechanical storage).
Assumed TRL scale: TRL 1-3 = Research to Proof of Concept; TRL 4-6 = Lab to Pilot Demonstration; TRL 7-9 = Prototype Demonstration to FOAK / Full Commercial Deployment

Geothermal in building heating reduces the strain on grids – high GSHP adoption in the US could reduce power capacity needs by 11%

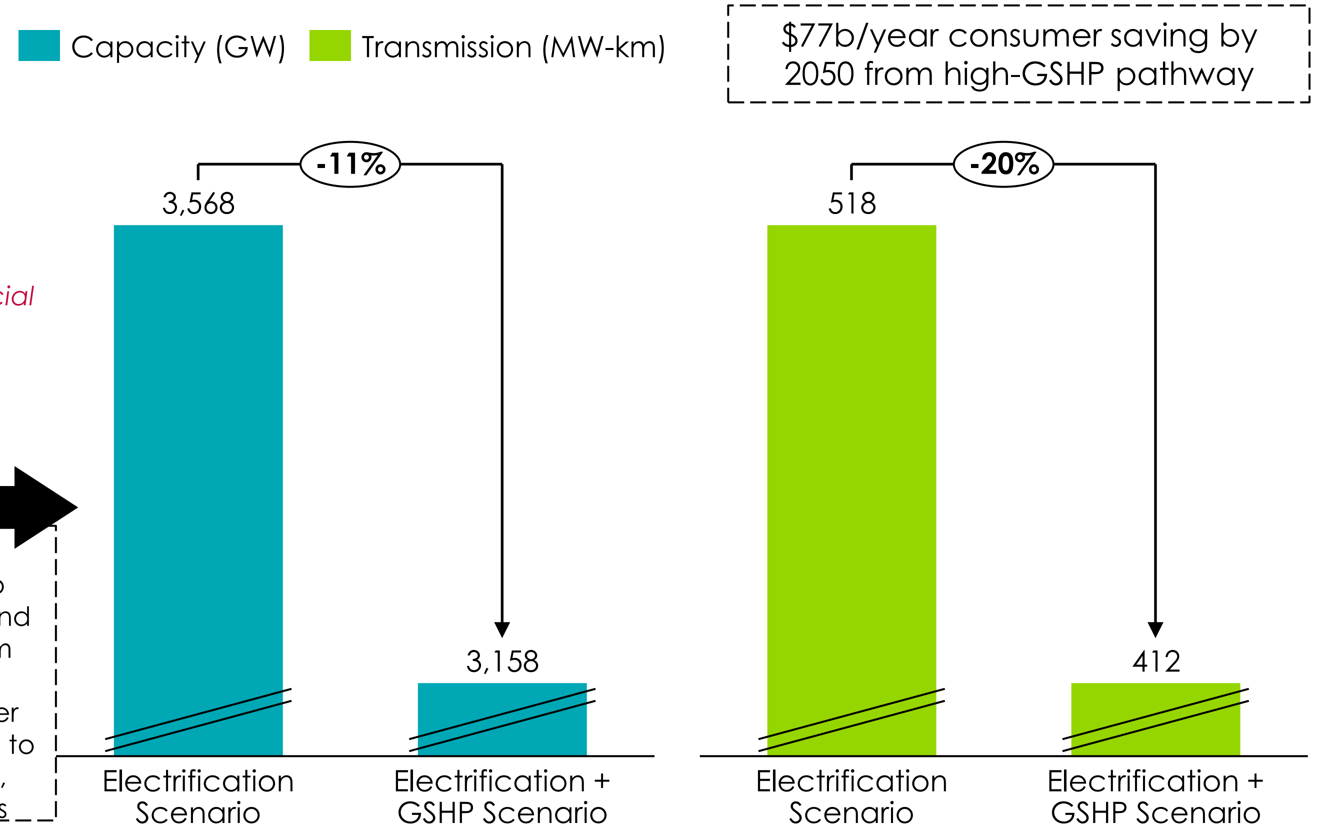
US DoE Liftoff trajectory for GSHP installations

Million homes equivalent (by building type)



Estimated 2050 US power system impacts by scenario

GW (LHS); MW-km (RHS)



0.04% of 2050 capacity avoided per GW_{th} of GSHP deployment

0.06% of 2050 transmission capacity avoided per GW_{th} of GSHP deployment

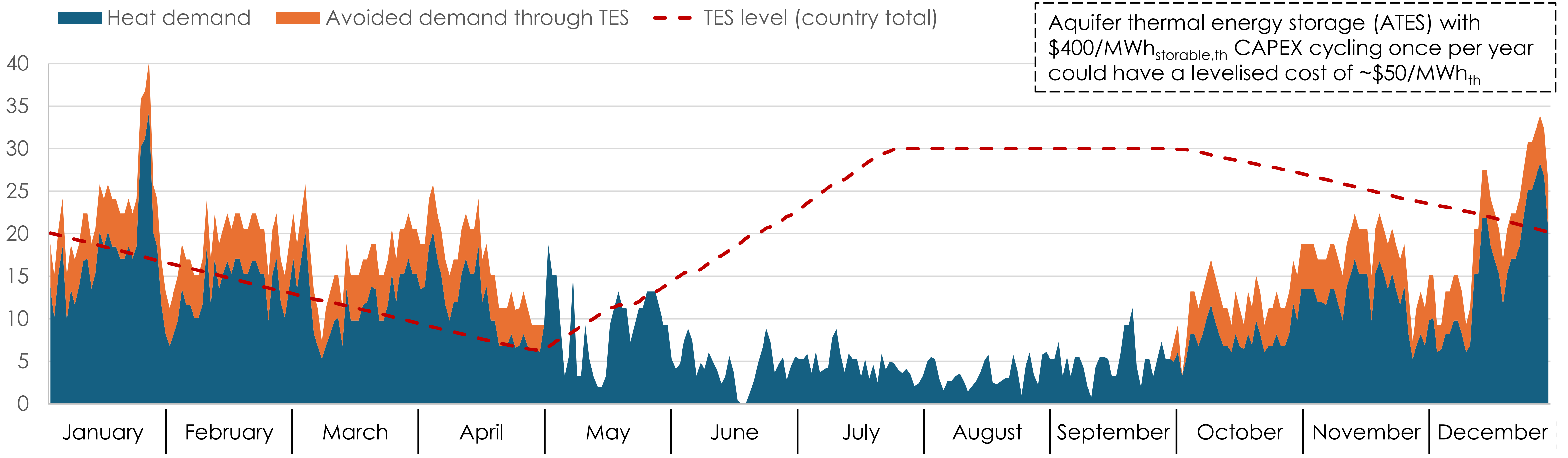
Notes: ERCOT = Electric Reliability Council of Texas

Source: US DoE (2025), *Pathways to Commercial Liftoff: Geothermal Heating and Cooling*; Oak Ridge National Laboratory (2023), *Grid Cost and Total Emissions Reductions Through Mass Deployment of Geothermal Heat Pumps for Building Heating and Cooling Electrification in the United States*

Geothermal seasonal underground thermal energy storage (UTES) could have material impacts on power system sizing and system costs

Hypothetical UTES impact on UK 2050 clean electrified heating demand

Daily average heat demand – GW_e; TES level – TWh_{th}



In a highly electrified UK energy system, building out 20 TWh_{th} of seasonal thermal energy storage could:

- **Demand:** Reduce maximum winter heating demand by up to 4 GW_e (5% of peak heat demand)
- **System sizing:** Reduce peak power capacity needs by up to 4 GW_e and ultra-long storage needs by ~15 TWh_e
- **System costs:** Save $5b/year in balancing costs and decrease average power system costs by ~$5/$MWh_e$

Notes: 20 TWh_{th} of thermal storage is 13% of the UK's 2050 annual heat demand and 0.03% of the UK's technical TES potential. 80% round trip efficiency and 4% real WACC assumed, alongside average heat pump coefficients of performance of 3 in winter and 4 in summer. TES assumed to be charged between May and September during periods of excess renewables (though this would likely occur through heat rejection from cooling systems, solar thermal collectors, industrial waste heat, and excess renewables through heat pumps). TES assumed to discharge when national heating demand is above 10 GW. Source: Systemiq analysis for the ETC (2025); ETC(2025), *Power Systems Transformation: Delivering Competitive, Resilient Electricity in High-Renewable Systems*; NESO (2022), *Future Energy Scenarios 2022 (FES 2022)*; C.S. Brown (2024), *Assessing the technical potential for*

Country criteria mapping suggests high firm power alignment in systems with fast-growing baseload demand

Criteria assessment by selected country

Low to high system value

Country	Scale and growth of low-carbon heat and energy demand	Value from hybrid applications	Integration with existing energy infrastructure	Overall Rating
Brazil				Low-moderate
Sub-Saharan Africa (regional)				Moderate
United Kingdom				Moderate
Canada				Moderate-high
France				Moderate-high
Singapore				Moderate-high
India				High
United States				High
South Korea				High
Japan				High
China				High

Notes: Criteria shaded from low to high nuclear alignment (1–3). Overall rating uses RAG based on average of criterion scores (equal weights), thresholds: 40/50/60/70%.
Source: IEA(2025), *Electricity Mid-Year Update 2025*

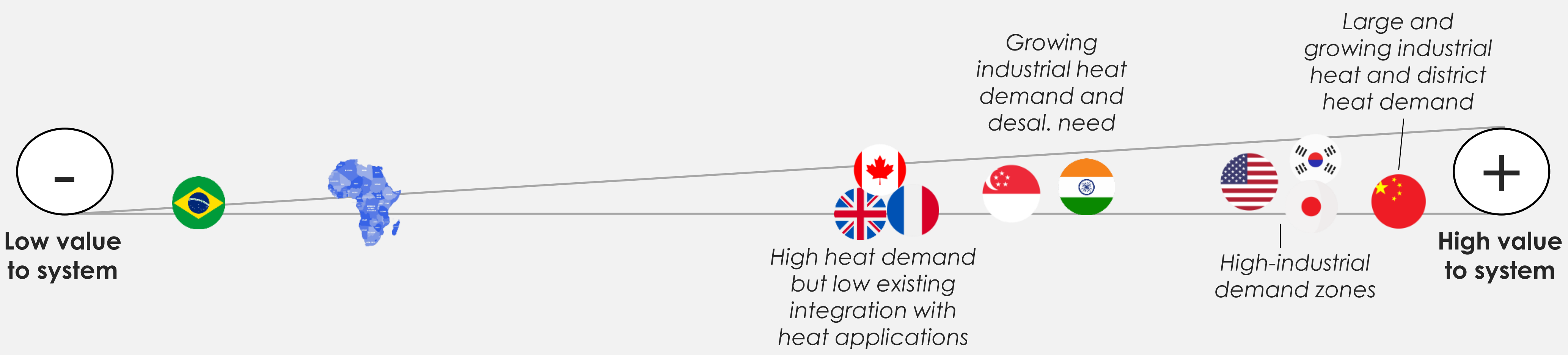
Highest alignment in regions with fast-growing heat demand, hybrid application potential, and infrastructure integration

1. System benefits

b) Energy system benefits

- Scale and growth of low-carbon heat and energy demand
- Value from hybrid applications
- Integration with existing energy infrastructure

The relative system value of nuclear and geothermal increases under these conditions:



Agenda

Nuclear and geothermal deliverability depends on delivery capability, resource availability, financing availability, and regulatory capacity

Six criteria determine the role of nuclear and geothermal by country

1. System benefits	Nuclear	Geothermal
a) Power system benefits	Wind and solar availability and cost; import and risk exposure to fossil; need for reliable firm supply	
b) Energy system benefits	Scale and growth of low-carbon heat and energy demand; value from hybrid applications; integration with existing energy infrastructure	
2. Deliverability		
a) Delivery capability	Experienced owner–operator and standardised repeat build capability or ability to upskill or import capability	Presence of an experienced geothermal or oil and gas workforce and supply chain, and the ability for standardised repeat build capability
b) Resource availability	End-to-end nuclear fuel cycle security	High cost-competitive resource availability for conventional or next-gen. technologies
c) Regulatory capacity	Credible, proportionate and predictable regulation and full lifecycle regulatory and siting capacity	
d) Financing availability	Access to low-cost capital and credible risk allocation and revenue frameworks	

Delivery capability depends on workforce experience, supply chain maturity, and repeat build track record

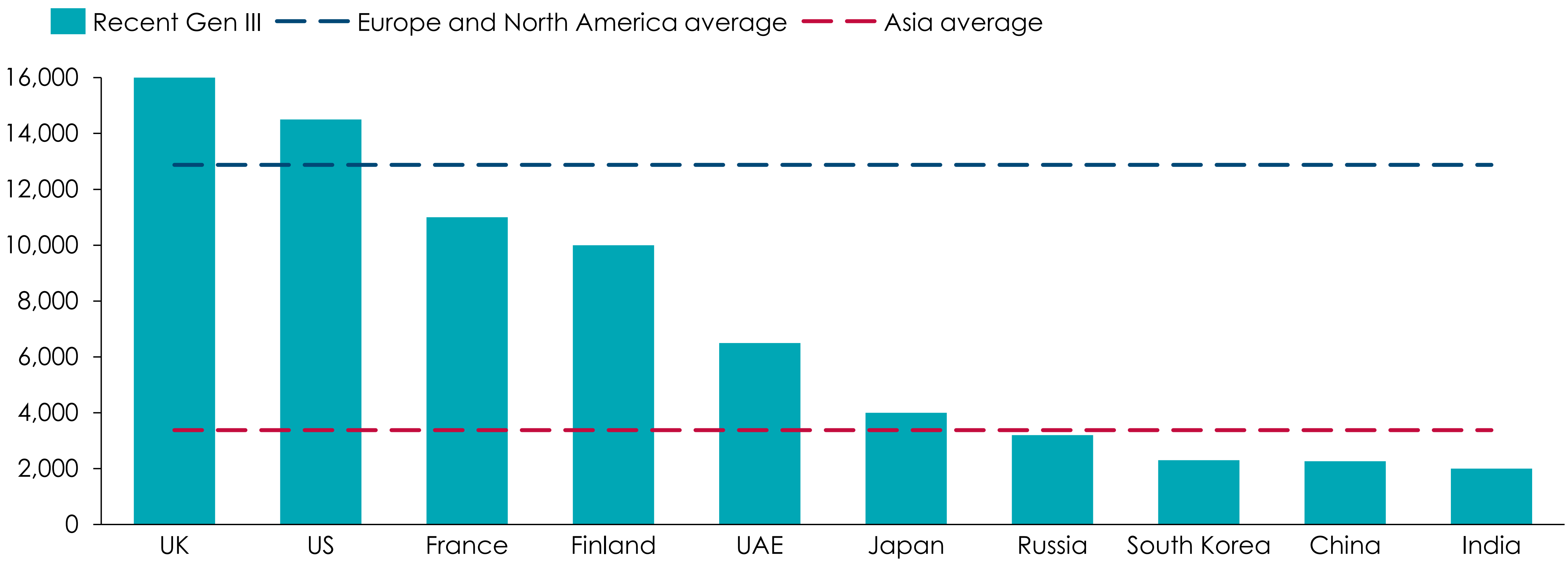
2. Deliverability

a) Delivery capability - nuclear

Criteria	*Justification*
Existing nuclear workforce and supply chain	Countries with experienced construction and engineering workforces from prior nuclear industries can more readily transfer skills to new build programmes
Standardised and repeat build track record	A history of delivering repeat, standardised projects reduces cost and schedule risk, as learning-by-doing effects lower costs over successive builds
Ability to develop or import missing capability	Where domestic capability gaps exist, countries with strong international procurement frameworks or bilateral partnerships can compensate through imports or joint ventures

CAPEX varies significantly by country, largely driven by supply chain readiness / costs

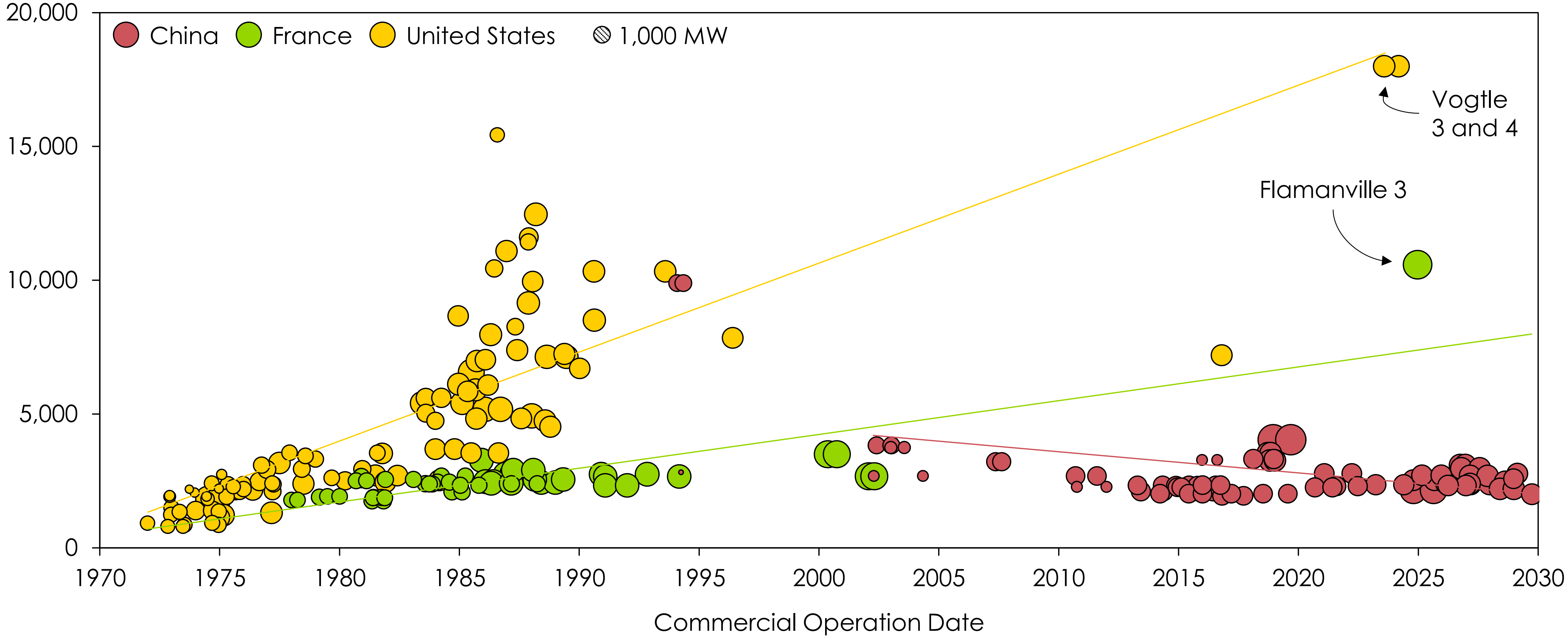
Recent Generation III overnight CAPEX estimates by country
$/kW, real 2024



Notes: FOAK = 1st of a kind; NOAK = nth of a kind. Source: BNEF (2025), *LCOE Data Viewer*; Energy Technologies Institute (2020), *The ETI Nuclear Cost Drivers Project*; INL (2024), *Nuclear Energy Cost Estimates for Net Zero World Initiative – 2024 Update*; Financial Times (2025), *Cost of Sizewell C nuclear project expected to reach close to £40bn*; Green Prizm (2024), *2023 Report on Chinese Nuclear Power Generation and Costs Analysis*

China has proven the effectiveness of standardised, programmatic deployment of large-scale, conventional reactors

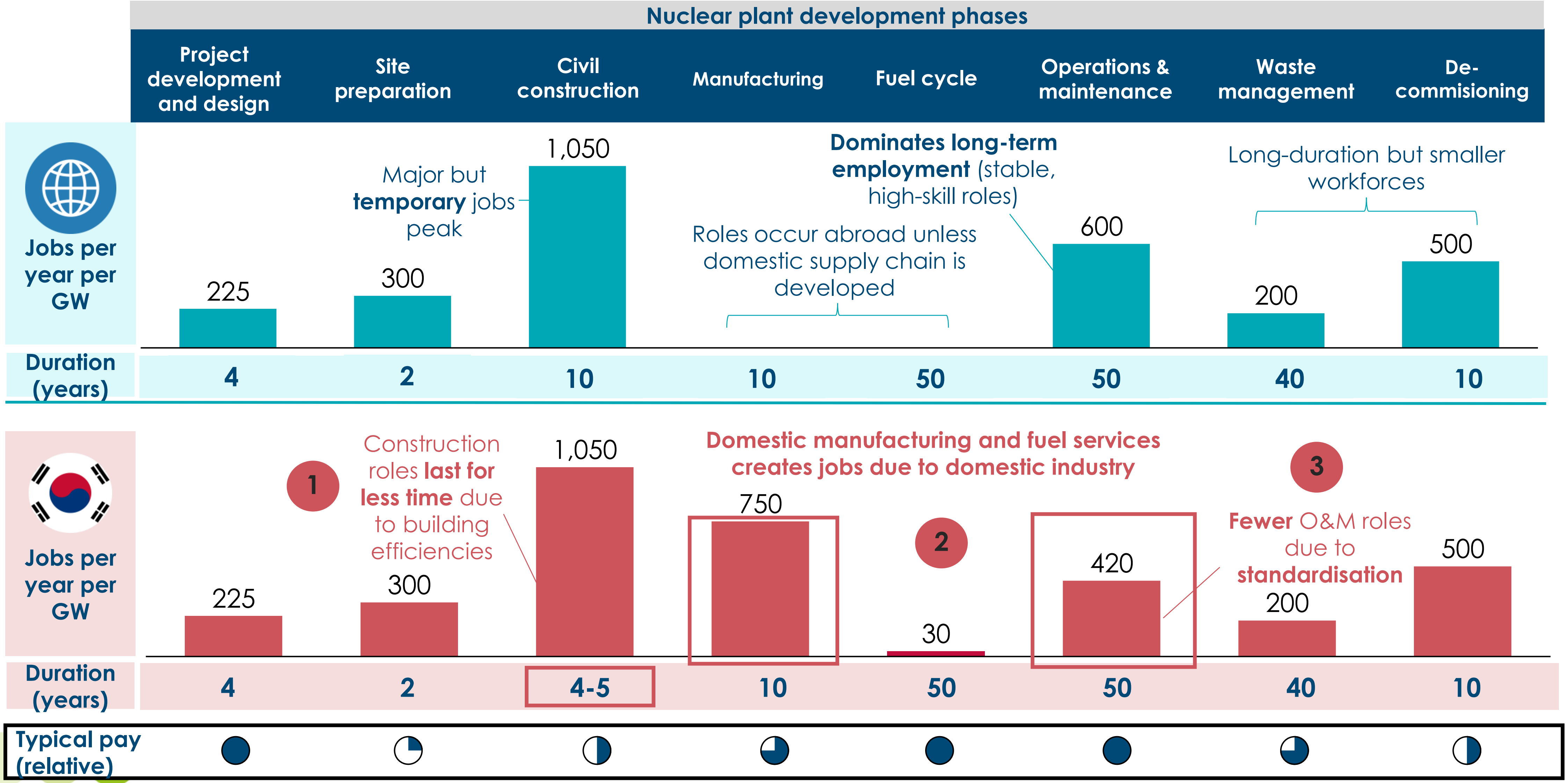
Overnight CAPEX vs commercial operation date
$/kW, real 2024



Nature (2025), Can China break the 'cost curse' of nuclear power?

Civil construction creates the most jobs but durations vary by country; highly-specialised and highest-pay manufacturing jobs only exist in a few countries

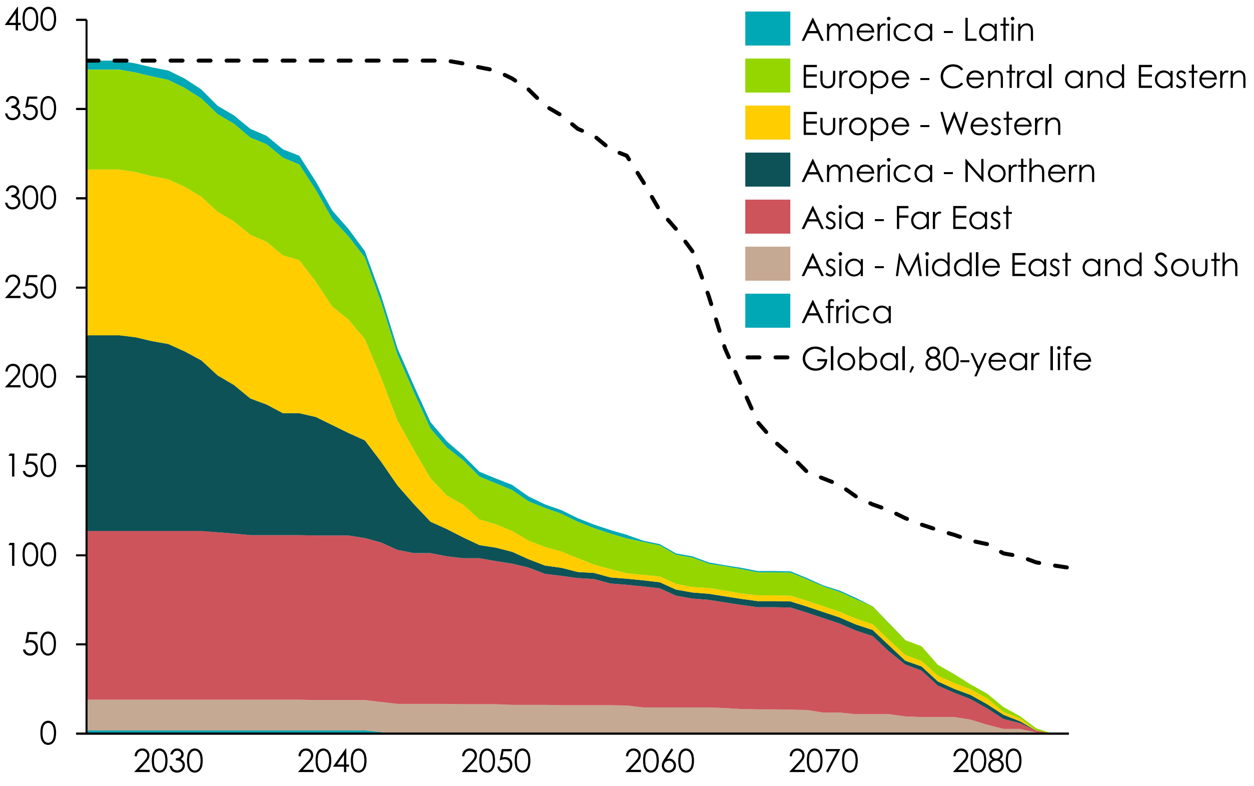
1 GW Light Water Reactor; 10-year build, 50-year operation (top – global average; bottom – South Korea)



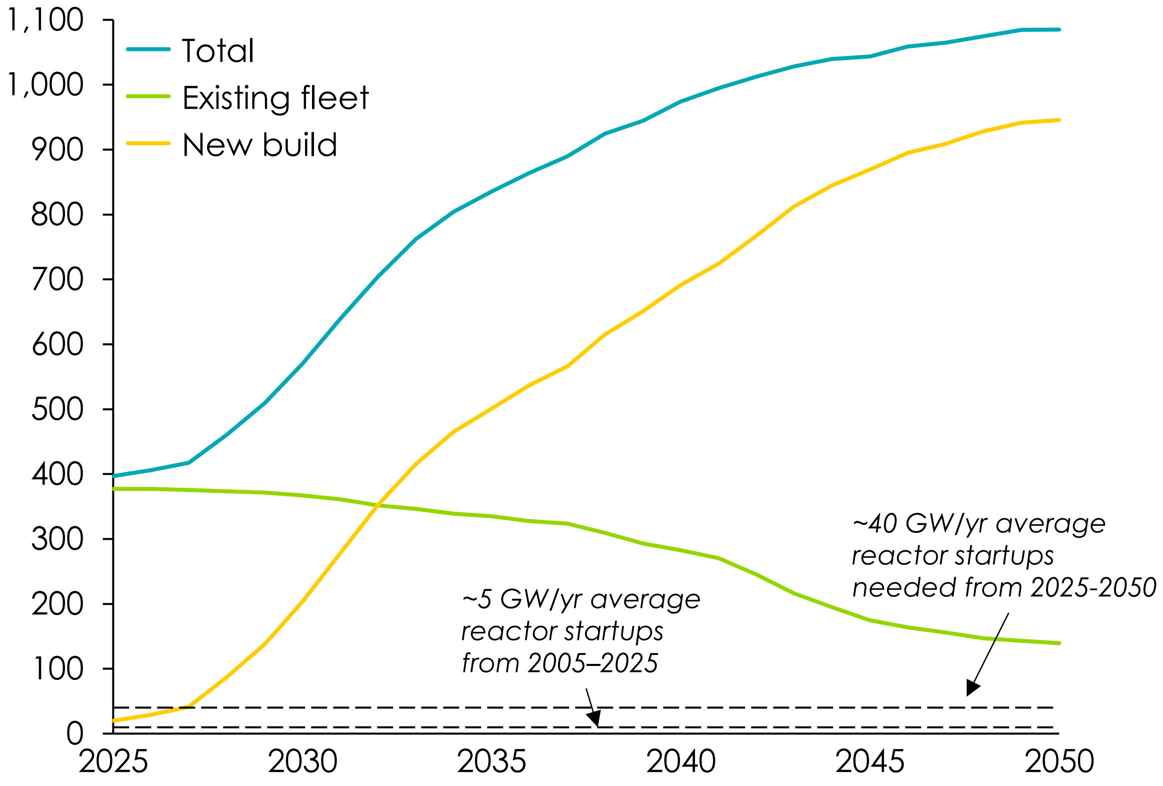
Source: Systemiq analysis for the ETC (2025); OECD-NEA & IAEA (2018), *Measuring Employment Generated by the Nuclear Power Sector*

Considering upcoming retirements of the existing fleet, around 40 GW per year of new reactors will be needed to meet a net-zero pathway

Capacity of existing nuclear fleet by year (assuming 60-year lifetimes) GW



Capacity needed to meet 10% of 2050 generation in a net-zero pathway (assuming 60-year lifetimes), GW



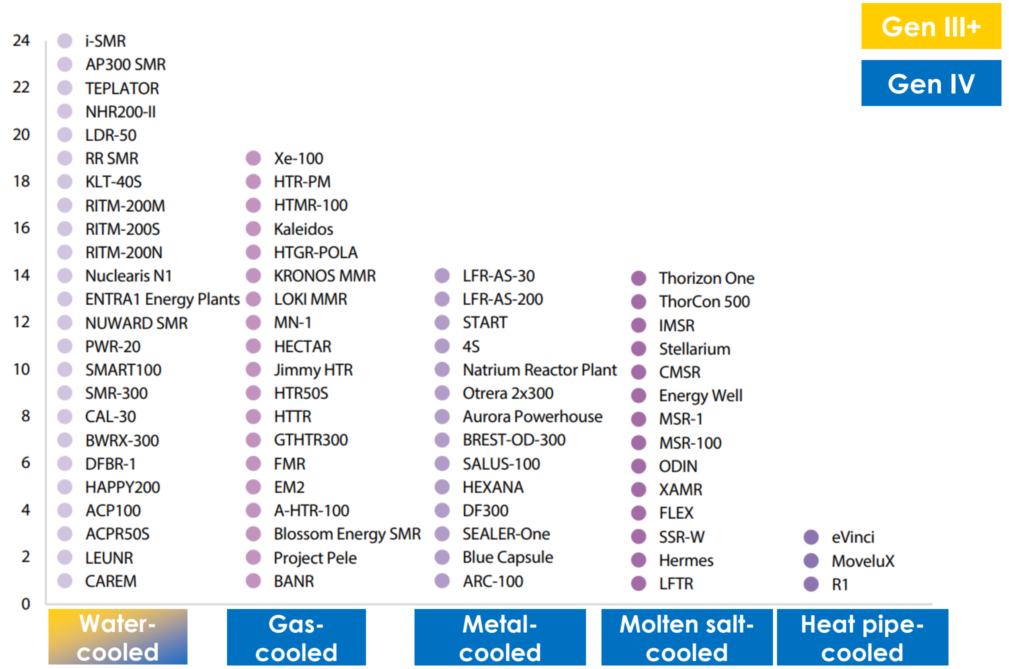
- Assuming 60-year lifetimes, the existing nuclear fleet capacity will half by 2050 and phase out by 2085
- If all reactors receive life extensions to 80 years, almost all capacity remains online in 2050 and 25% remains in 2080

- ~1,100 GW needed in total by 2050, up from 380 today
- ~950 GW new build needed between now and 2050

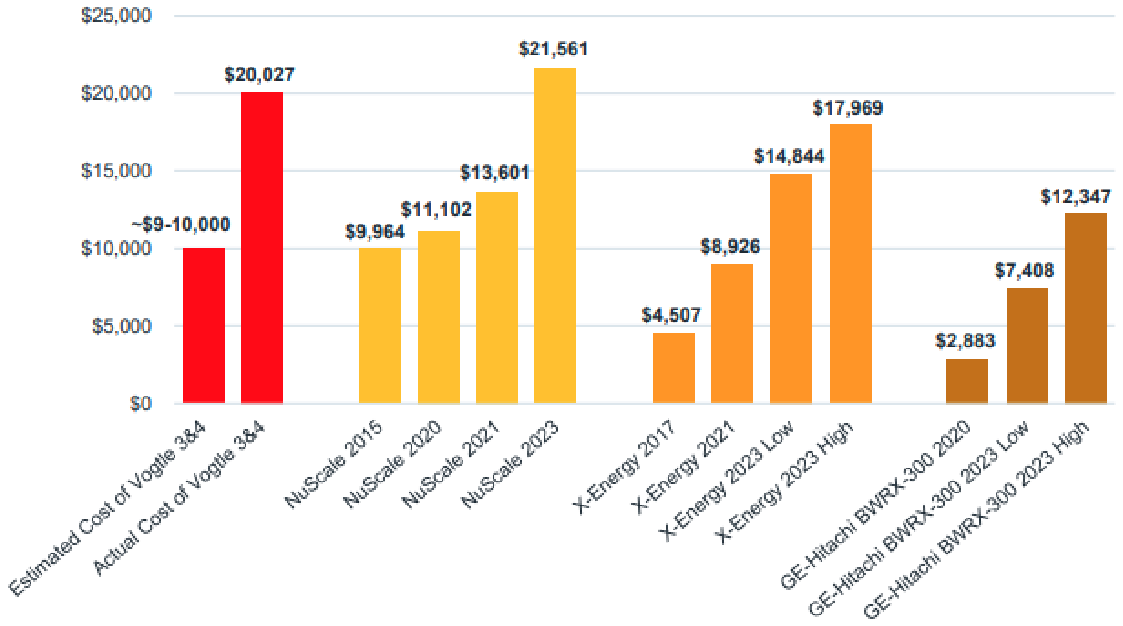
Source: IAEA (2026), *Power Reactor Information System*, BNEF (2025), *New Energy Outlook*; Mycle Schneider (2025), *World Nuclear Industry Status Report 2025*

SMRs will only deliver low costs if design consolidation and standardisation occurs; this has not been achieved in early SMR deployment

SMR concepts in development by reactor type
Number of concepts in development



Projected cost increases for proposed US SMR's
$/kW, real 2023



Key barrier:

- Consolidation is needed to unlock the standardisation and economies of scale that all SMR developers promise
- However, standardisation cannot happen with >100 designs competing for market share

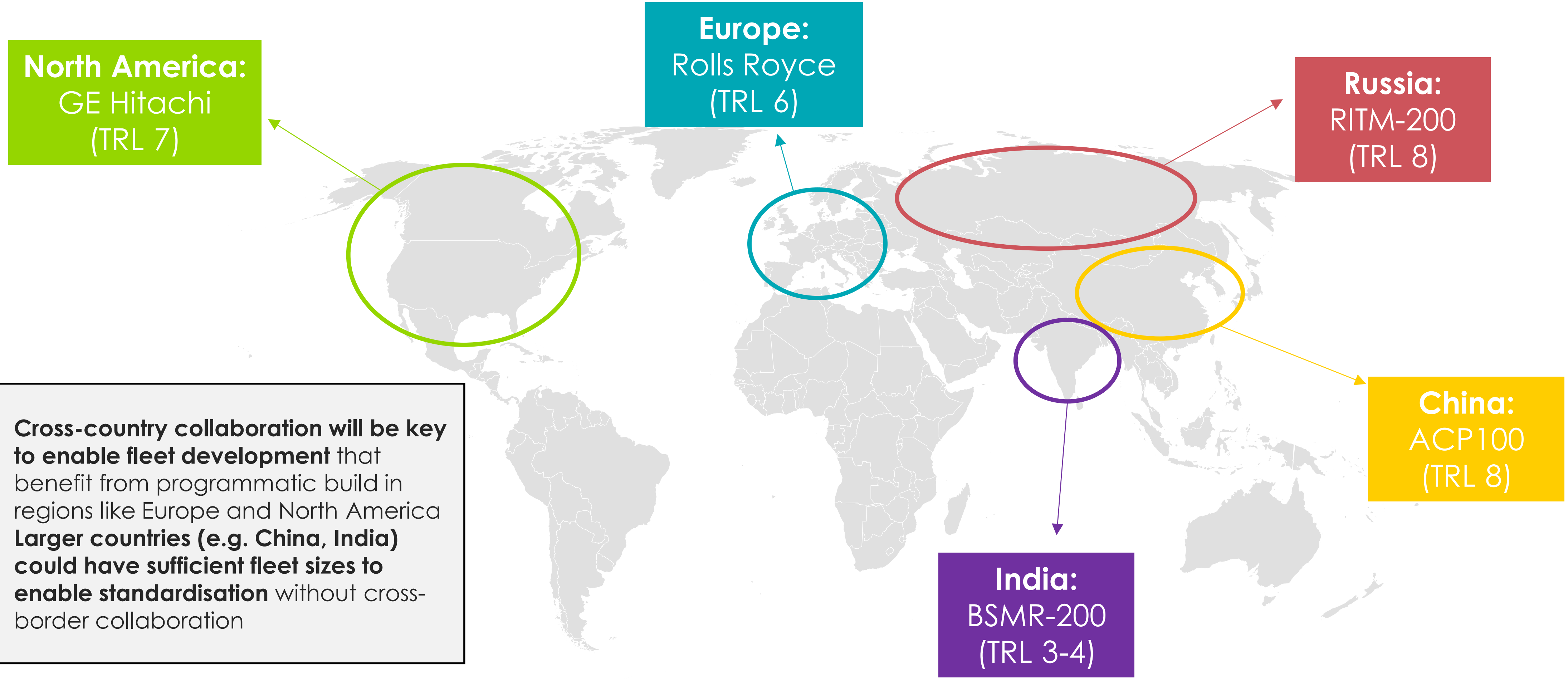
SMR vendors in the US have cited an increase in the following factors as cause behind rising costs;

- Inflationary pressures for construction materials
- Higher labour costs
- Increased interest rates
- Supply chain constraints for equipment

Source: IEEFA (2023) Small Modular Reactors; Still Too Expensive, Too Slow and Too Risky; Source: NEA (2025), *The NEA Small Modular Reactor Dashboard: Third Edition*.

SMR regional champions will need to be selected for consolidation and standardization to drive cost declines

Leading SMR designs by region and current technology readiness levels (TRL)

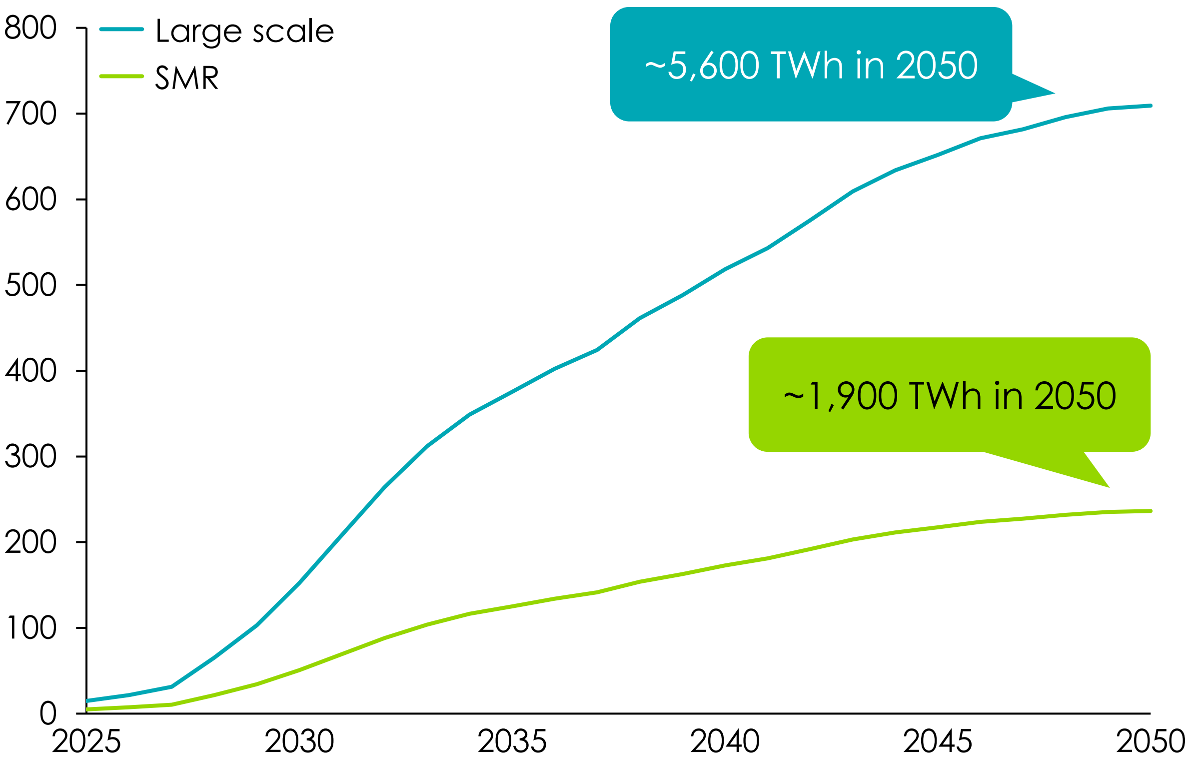


- **Cross-country collaboration will be key to enable fleet development** that benefit from programmatic build in regions like Europe and North America
- **Larger countries (e.g. China, India) could have sufficient fleet sizes to enable standardisation** without cross-border collaboration

Notes: TRL scale (TRL 1-3 = Research to Proof of Concept; TRL 4-6 = Lab to Pilot Demonstration; TRL 7-9 = Prototype Demonstration to FOAK / Full Commercial)

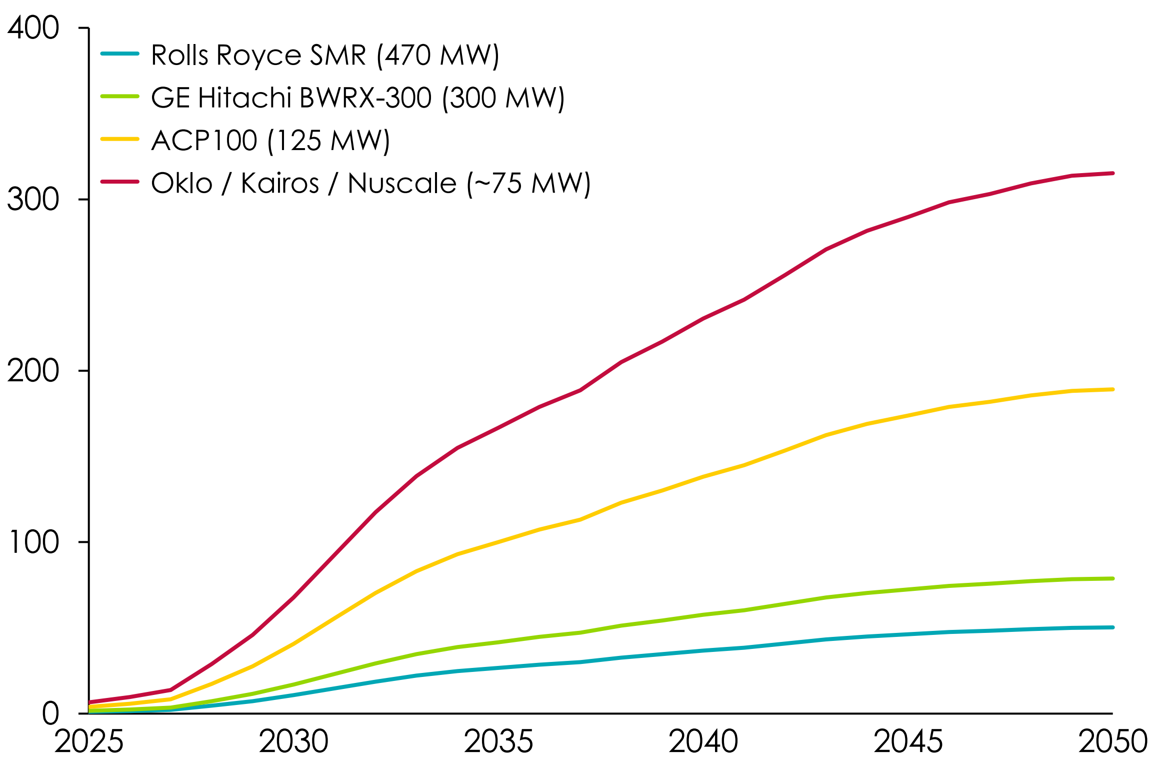
If SMRs scale to meet 25% of new builds, this could result in hundreds of units per leading SMR developer…

How many new SMRs are needed to meet 25% of new build needs?
GW



- Nuclear generation grows from 3,000 - 8,000 TWh from 2025 – 2050, meeting 9.4% of global generation in 2050
- 75% from growth is met by large-scale, 25% by SMR

How many units per SMR developer if each meets 10% of SMR growth?
units



If 10 SMR developers split 25% of nuclear growth equally, this could mean 300 x 75 MW units, 190 x 125 MW units, 80 x 300 MW units and 50 x 500 MW units by 2050

Source: BNEF (2025), New Energy Outlook

…However, SMR learning curve effects are inherently limited than more modular technologies like solar

Does this level of production allow sufficient scale to enable cost reduction from learning rates?

- **Modularisation** allows some repeated production
- **Standardisation** across whole supply chain needed for learning curve effects

Rolls Royce 470 MW SMR theoretical buildout

2025 → 2050

50 units cumulative
2 annual (average)
6 doublings

22% cost reduction from current level
(10% learning rate applied to 50% CAPEX)

Oklo / Kairos / Nuscale ~75 SMR theoretical buildout

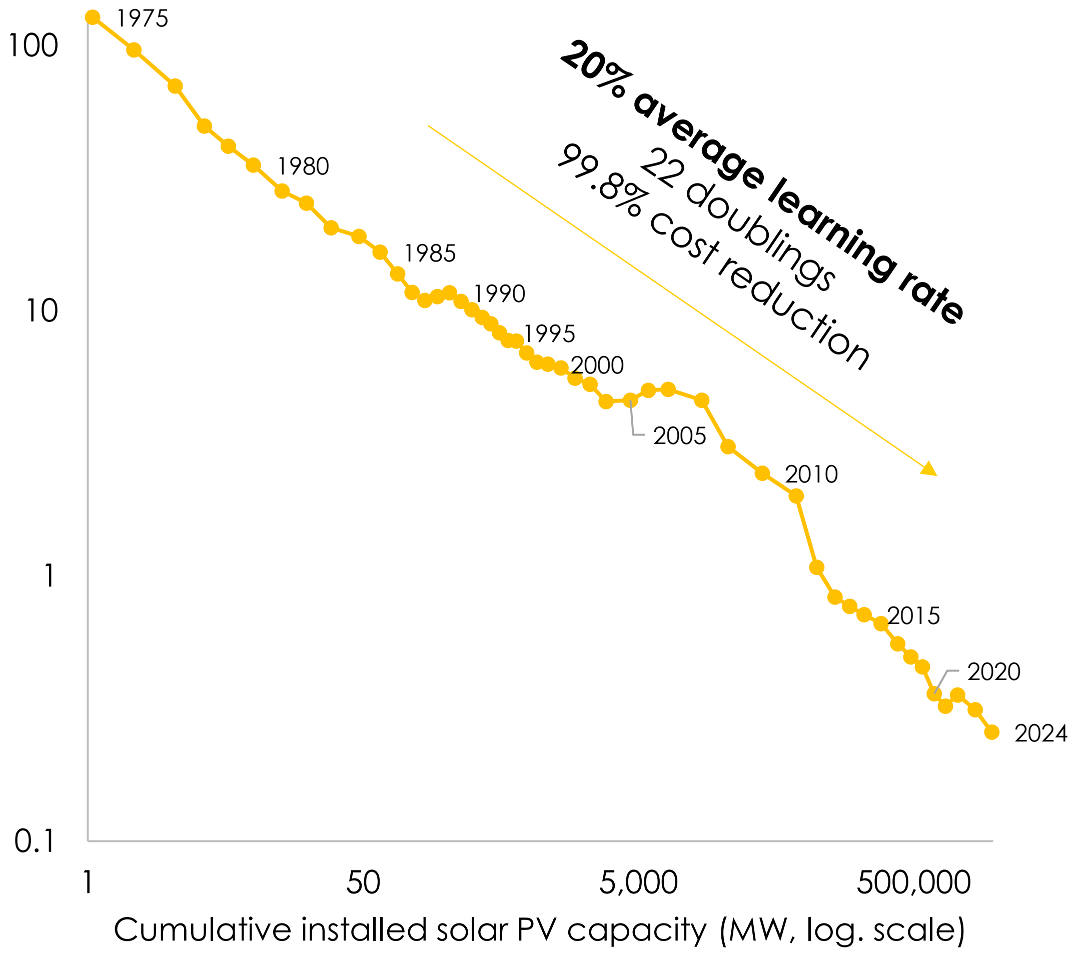
2025 → 2050

315 units cumulative
13 annual (average)
8 doublings

Max. 29% cost reduction from initial level
(10% learning rate applied to 50% CAPEX)

How does this compare to historic solar learning curve effects?

Solar module cost (2024$/W, log. scale)



Note: solar learning rate reflects decreasing module costs and increasing module efficiency; these trends are both expected to continue for solar, however efficiency increases will be limited for SMR technology.
Source: Our World in Data (2025), *Solar photovoltaic module prices vs. cumulative capacity*

Country criteria mapping suggests high nuclear alignment in systems with existing, standardised supply chains

Criteria assessment by selected country

Low to high deliverability

Country	Experienced owner–operator and standardised repeat build capability	Ability to import qualified EPC capability	Overall Rating
Sub-Saharan Africa (regional)			Low
Singapore			Low-moderate
United Kingdom			Moderate-high
United States			Moderate-high
France			Moderate-high
Canada			Moderate-high
India			Moderate-high
Russia			Moderate-high
Japan			Moderate-high
South Korea			High
China		N/A	High

Notes: Criteria shaded from low to high nuclear alignment (1–3). Overall rating uses RAG based on average of criterion scores (equal weights), thresholds: 40/50/60/70%.
Source: IAEA (2025) PRIS; World Nuclear Association (2025), World Nuclear Performance Report 2025

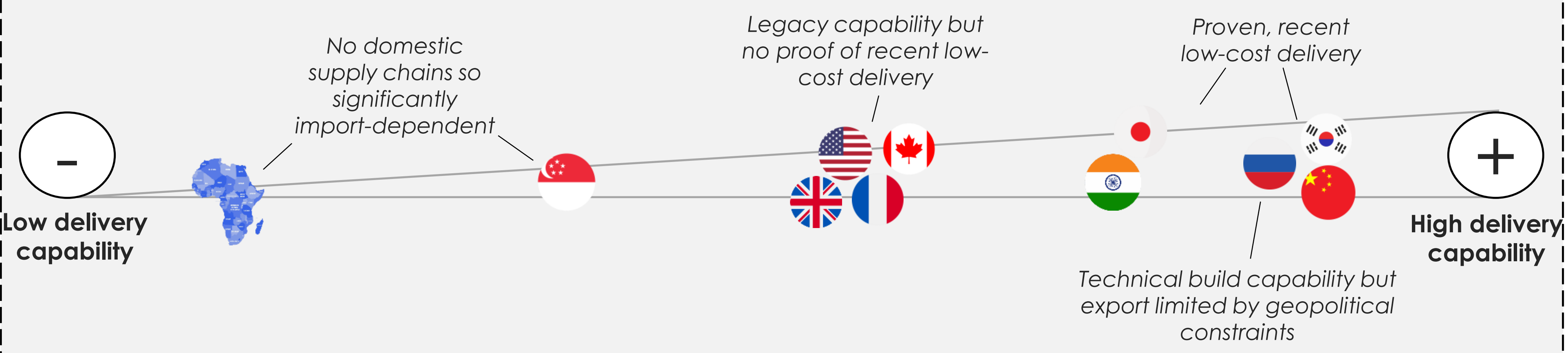
Proven, low-cost delivery capacity currently only exist in key Asian markets

2. Deliverability

a) Nuclear delivery capability

- Experienced owner–operator and standardised repeat build capability
- Ability to import qualified EPC capability

The relative deliverability of nuclear increases under these conditions:



Nuclear and geothermal deliverability depends on delivery capability, resource availability, financing availability, and regulatory capacity

Six criteria determine the role of nuclear and geothermal by country

	Nuclear	Geothermal
1. System benefits		
a) Power system benefits	Wind and solar availability and cost; import and risk exposure to fossil; need for reliable firm supply	
b) Energy system benefits	Scale and growth of low-carbon heat and energy demand; value from hybrid applications; integration with existing energy infrastructure	
2. Deliverability		
a) Delivery capability	Experienced owner–operator and standardised repeat build capability or ability to upskill or import capability	Presence of an experienced geothermal or oil and gas workforce and supply chain, and the ability for standardised repeat build capability
b) Resource availability	End-to-end nuclear fuel cycle security	High cost-competitive resource availability for conventional or next-gen. technologies
c) Regulatory capacity	Credible, proportionate and predictable regulation and full lifecycle regulatory and siting capacity	
d) Financing availability	Access to low-cost capital and credible risk allocation and revenue frameworks	

Resource availability covers nuclear fuel cycle security

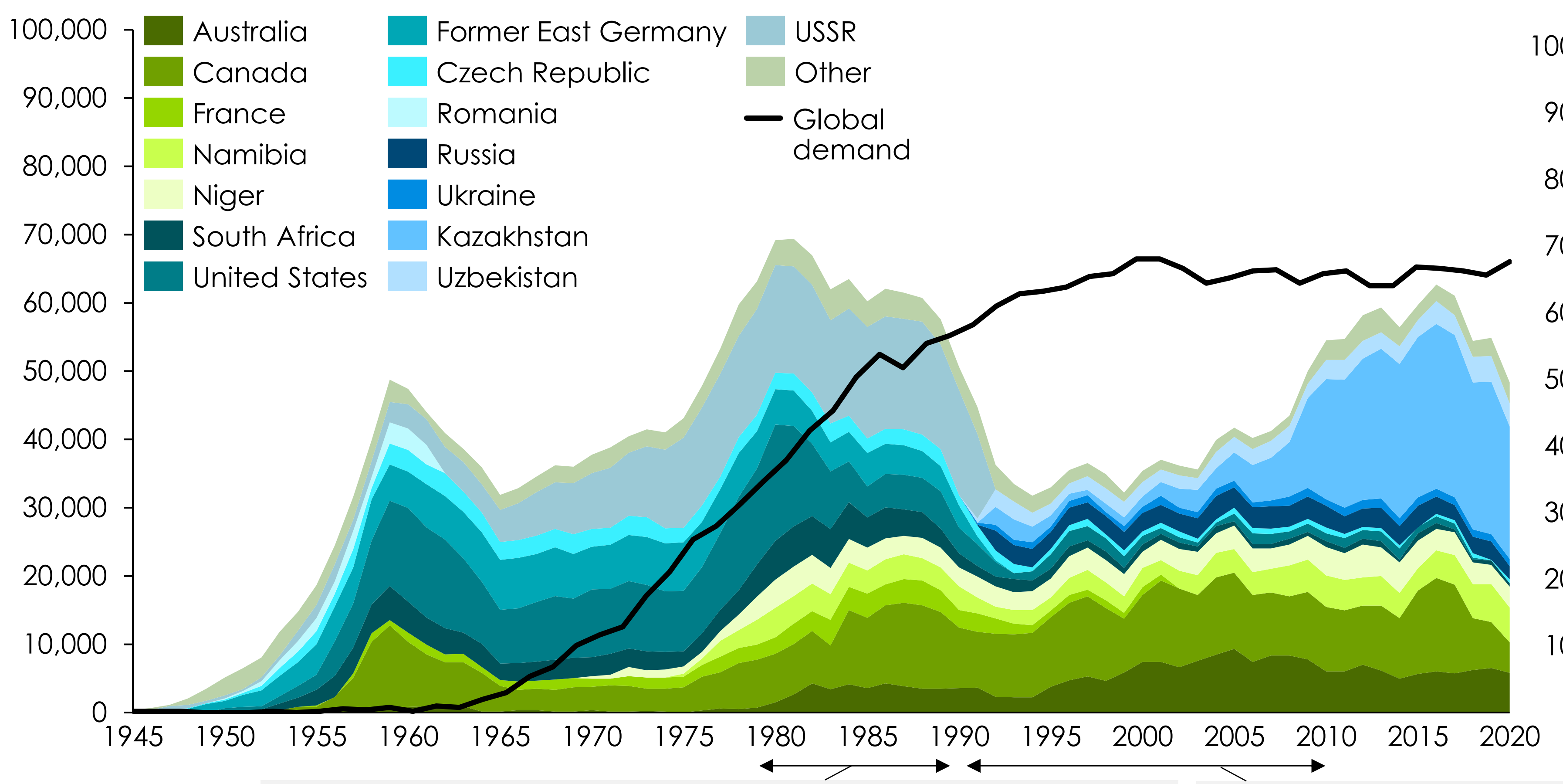
2. Deliverability

b) Resource availability - nuclear

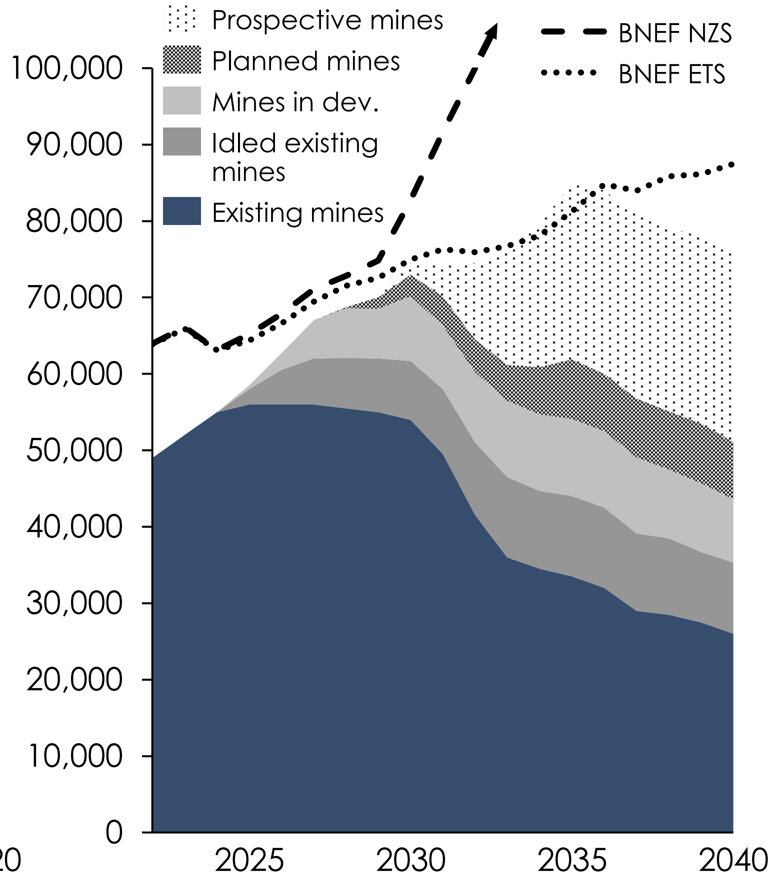
Criteria	*Justification*
Nuclear fuel cycle security	Access to diverse, stable uranium supply and enrichment/processing capacity reduces geopolitical exposure and ensures long-term fuel security

90% of uranium comes from seven countries today; meeting future demand under a net zero scenario requires a significant mining ramp up

World uranium production and reactor requirements, 1945-2020 (WNA)
Tonnes of uranium



Reference Scenario for future production (WNA)
Tonnes of uranium



In the 1980s, post-Three Mile Island (1979) and Chernobyl (1986) price collapses shuttered mines, but existing reactors kept consuming; utilities drew down large civilian stockpiles built up during the prior construction boom.

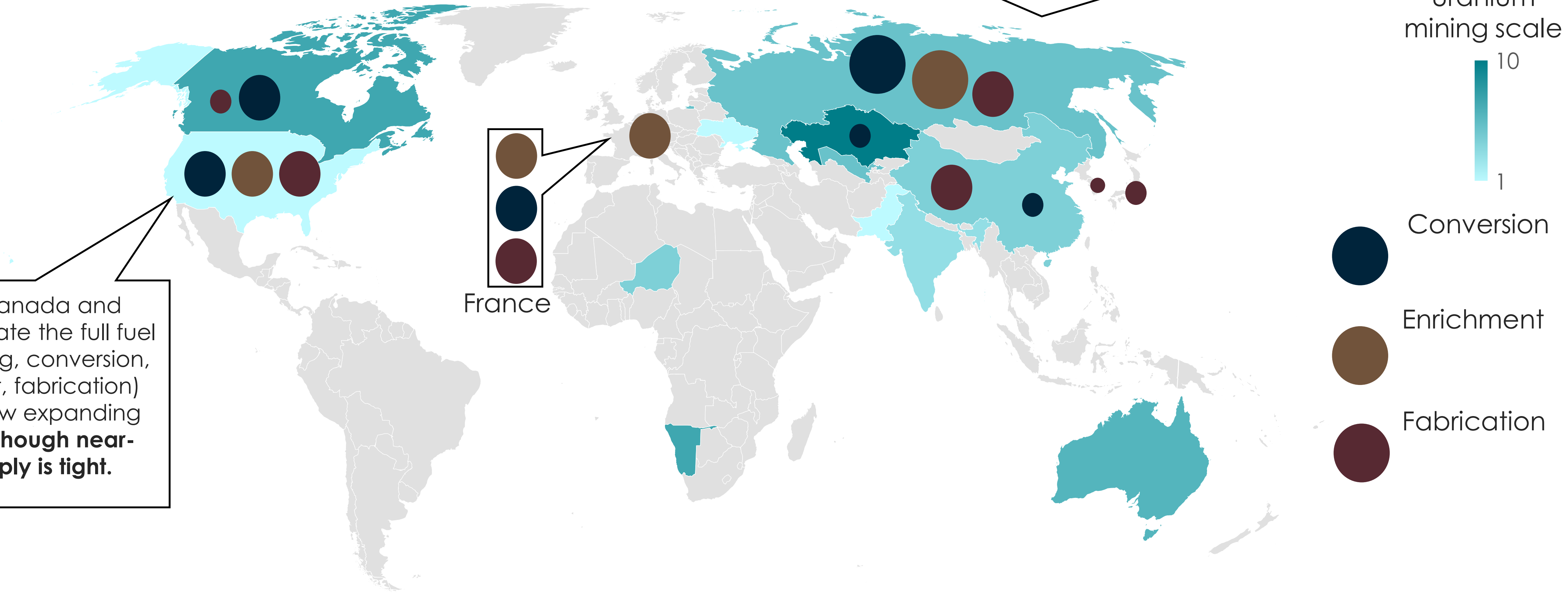
From 1990–2010, production ran below demand, bridged by Cold War stockpiles (Megatons to Megawatts, 1993–2013) and post-Chernobyl inventory overhangs. As these depleted, the market tightened and prices re-linked to mine output.

Notes: BNEF NZS natural uranium demand back-calculated using the WNA's conversion efficiency of 18.6 tU/TWh (new AP1000 or EPR, with 5% enriched fuel and 65 GWd/t burn-up). Source: World Nuclear Association (2024), *Nuclear Fuel Cycle – Uranium Markets;* World Nuclear Association (2025), *Nuclear Fuel Cycle Overview*

Nuclear fuel supply chain across conversion, enrichment and fabrication is concentrated in a small pool of countries

Global uranium mining ranked by annual production (score out of 10)

Russia still controls ~40% of global enrichment and **~25%** of conversion, making this the main pinch point for nuclear fuel security.



The US, Canada and France operate the full fuel cycle (mining, conversion, enrichment, fabrication) and are now expanding capacity, **though near-term supply is tight.**

Note: Countries are ranked by share of global uranium mine output (World Nuclear Association 2025). Each share is converted to a score out of 10 by setting Kazakhstan, the largest producer, as 10 and assigning lower scores in decreasing bands of production share. Size of the circles - Large ≈ major global player, Medium ≈ significant but secondary, Small ≈ minor share. Source: World Nuclear Association (2025) *World Uranium Mining Production; Supply of Uranium, Conversion, Enrichment and Fuel Fabrication*.

Pre-read only

Country mapping shows Russia, Canada, and France have the highest nuclear fuel security

Criteria assessment by selected country

Low to high deliverability

Country	Mining	Conversion	Enrichment	Fuel fabrication	Reprocessing / MOX	Overall Rating
Singapore						Low
Sub-Saharan Africa (regional)						Low
Brazil						Low-moderate
United States						Low-moderate
South Korea						Moderate
India						Moderate-high
Japan						Moderate-high
United Kingdom						Moderate-high
China						High
Canada						High
France						High
Russia						High

Notes: Criteria shaded from low to high nuclear alignment (1–3). Overall rating uses RAG based on average of criterion scores (equal weights), thresholds: 40/50/60/70%.
Source: World Nuclear Association (2025) Nuclear Fuel Cycle Overview; World Nuclear Association (2025) World Uranium Mining Production; World Nuclear Association (2025) Uranium Enrichment

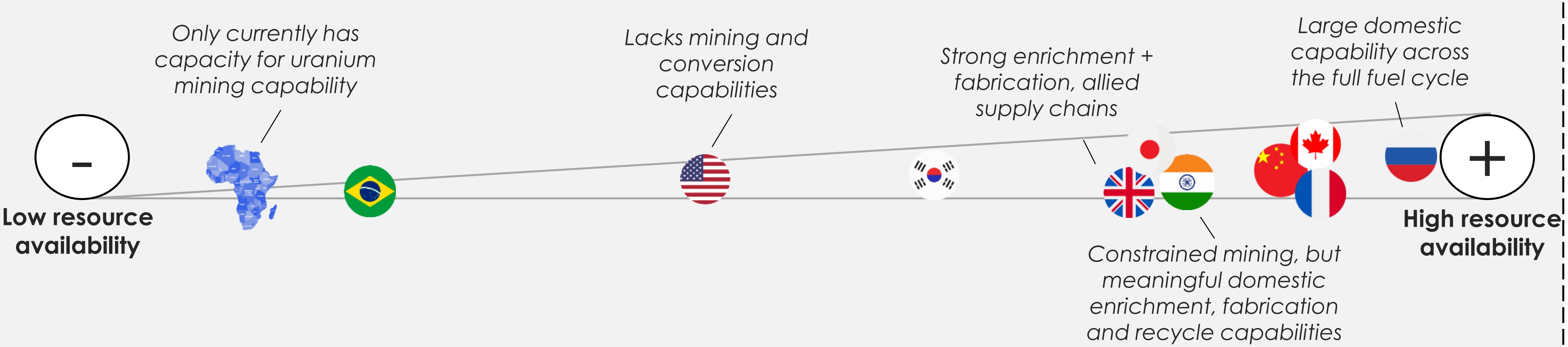
A small selection of countries control all key stages of the fuel supply cycle; those which don't rely on allies for secure supply

2. Deliverability

d) Nuclear resource availability

End-to-end nuclear fuel cycle security

The relative deliverability of nuclear increases under these conditions:



Agenda

Nuclear and geothermal deliverability depends on delivery capability, resource availability, financing availability, and regulatory capacity

Six criteria determine the role of nuclear and geothermal by country

	Nuclear	Geothermal
1. System benefits		
a) Power system benefits	Wind and solar availability and cost; import and risk exposure to fossil; need for reliable firm supply	
b) Energy system benefits	Scale and growth of low-carbon heat and energy demand; value from hybrid applications; integration with existing energy infrastructure	
2. Deliverability		
a) Delivery capability	Experienced owner–operator and standardised repeat build capability or ability to upskill or import capability	Presence of an experienced geothermal or oil and gas workforce and supply chain, and the ability for standardised repeat build capability
b) Resource availability	End-to-end nuclear fuel cycle security	High cost-competitive resource availability for conventional or next-gen. technologies
c) Regulatory capacity	Credible, proportionate and predictable regulation and full lifecycle regulatory and siting capacity	
d) Financing availability	Access to low-cost capital and credible risk allocation and revenue frameworks	

Delivery capability depends on workforce experience, supply chain maturity, and repeat build track record

2. Deliverability

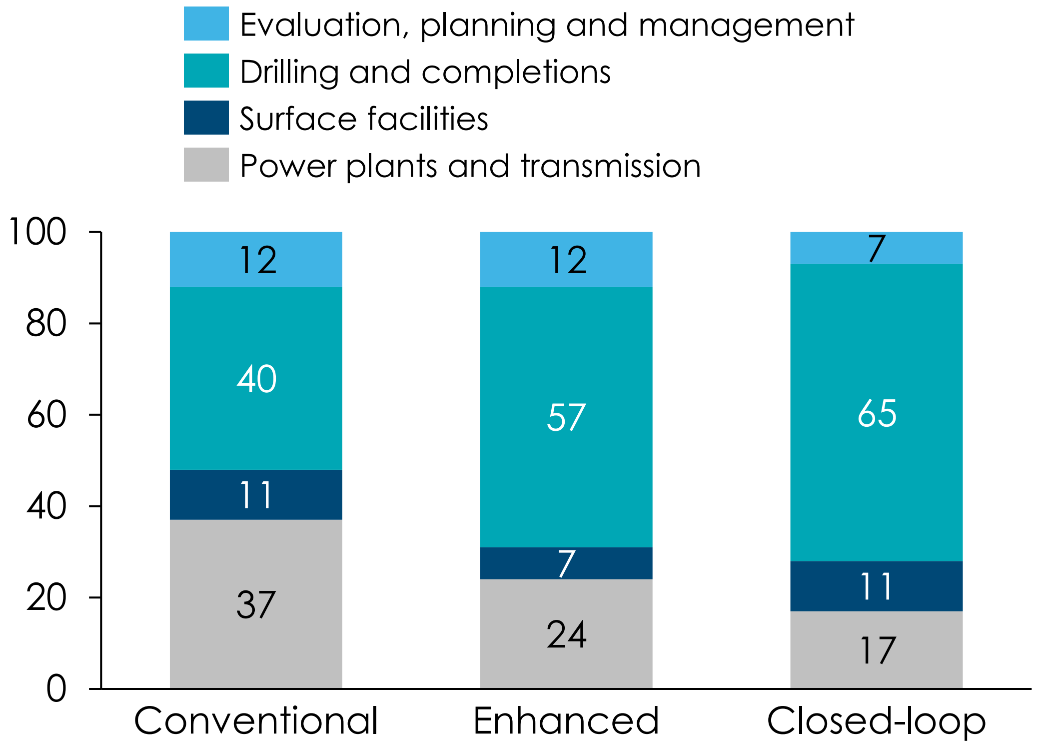
a) Delivery capability - geothermal

Criteria	*Justification*
Existing geothermal/O&G workforce and supply chain	Countries with experienced construction and engineering workforces from prior geothermal or oil and gas industries can more readily transfer skills to new build programmes
Standardised and repeat build track record	A history of delivering repeat, standardised projects reduces cost and schedule risk, as learning-by-doing effects lower costs over successive builds
Ability to develop or import missing capability	Where domestic capability gaps exist, countries with strong international procurement frameworks or bilateral partnerships can compensate through imports or joint ventures

Geothermal can leverage oil and gas expertise, but new job opportunities are minimal compared to the losses in oil and gas

Shares of conventional and next-generation geothermal technology investments that overlap with oil and gas industry skills and expertise

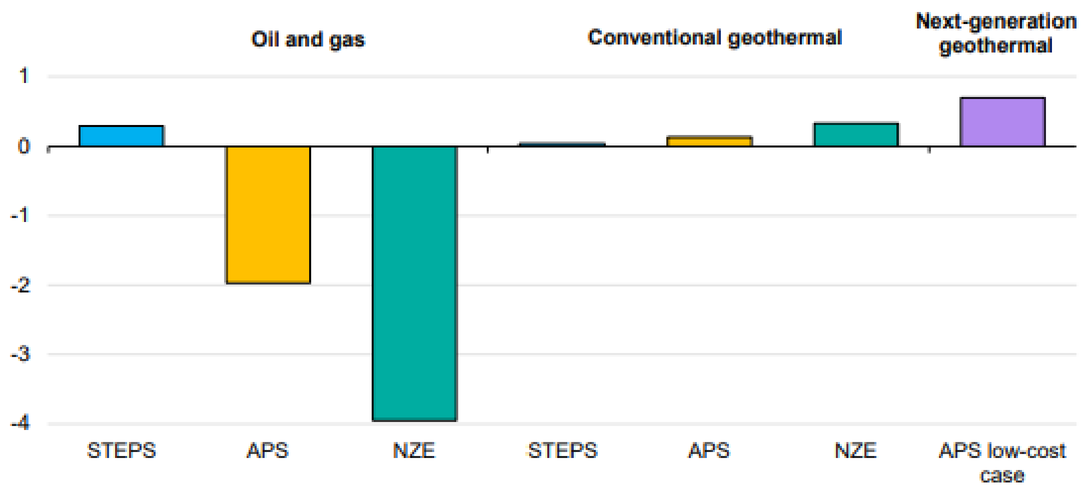
%



- **Around two-thirds of investment in conventional geothermal** overlaps with oil and gas industry capabilities - primarily in **drilling and completions.**

Total oil and gas and geothermal employment changes by scenario, 2023-2030

Million workers



However, overall job creation remains limited

- IEA etimates geothermal employment could rise from around 145,000 jobs today to **around 1 million by 2030**
- This is far smaller than the 4 million job losses projected in oil and gas under a net zero pathway.

Source: IEA (2024) The Future of Geothermal; IEA analysis based on NREL, IRENA and EGEC reports and publicly available research papers; Conversations with experts at Cascade Institute

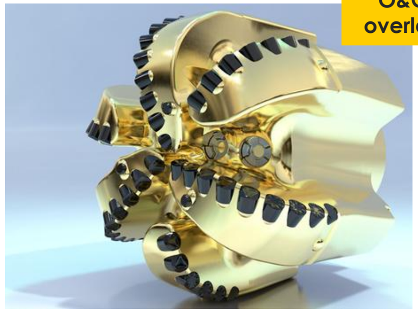
The oil and gas crossover can also cause supply chain risks, with particular issues around certain components including drilling rigs and tools

Geothermal components with potential for supply chain disruptions

O&G overlap

Heavy hook-load rigs

O&G overlap



Downhole tools

Organic Rankine Cycle Turbines

Key insights about overlap with O&G industry

Geothermal relies heavily on O&G supply chains

- Certain components compete directly with oil and gas demand
- This creates exposure to price spikes and capacity shortages.

Specialised components have thin global supply

- Certain products are produced by a very small number of manufacturers
- This raises lead times and project risk.

Skilled labour shortages can delay deployment

- Geothermal drilling requires specialist crews
- Timelines for obtaining qualifications for shallow and deep drilling are 2-3 years

Sources: Carnegie Endowment for International Peace (2025), Unlocking Global Geothermal Energy: Pathways to Scaling International Deployment of Next-Generation Geothermal; Turaga et al (2012), Supply Chain Challenges in Commercial Deployment of EGS

Country criteria mapping suggests high nuclear alignment in systems with existing, standardised supply chains

Criteria assessment by selected country

Low to high deliverability

Country	Experienced owner–operator and standardised repeat build capability	Ability to import qualified EPC capability	Overall Rating
Singapore			Low
Brazil			Low
India			Low
South Korea			Low
Sub-Saharan Africa (regional)			Low-moderate
United Kingdom			Low-moderate
Canada			Low-moderate
Italy			Low-moderate
Mexico			Low-moderate
France			Moderate-high
China			Moderate-high
Japan			Moderate-high
Indonesia			Moderate-high
Philippines			Moderate-high
Türkiye			Moderate-high
Kenya			Moderate-high
New Zealand			High
Iceland			High
United States			High

Notes: Criteria shaded from low to high nuclear alignment (1–3). Overall rating uses RAG based on average of criterion scores (equal weights), thresholds: 40/50/60/70%.
Source: IAEA (2025) PRIS; World Nuclear Association (2025), World Nuclear Performance Report 2025

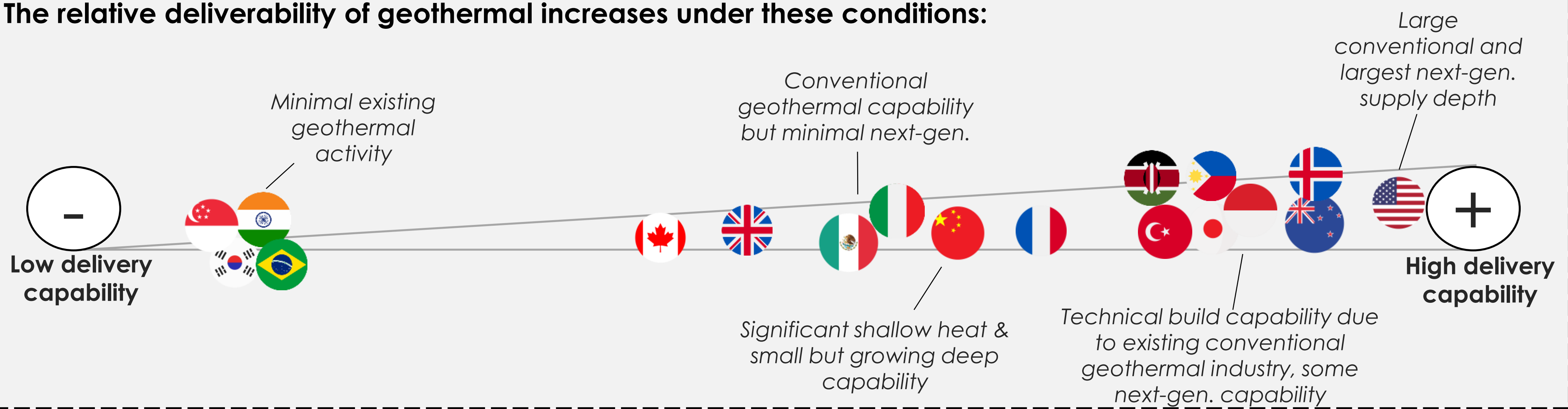
Proven, low-cost delivery machines for conventional geothermal span several countries and next-gen. capability is concentrated in the US

2. Deliverability

b) Geothermal delivery capability

- Presence of an experienced geothermal or oil and gas workforce and supply chain
- Ability for standardised repeat build capability

The relative deliverability of geothermal increases under these conditions:



Nuclear and geothermal deliverability depends on delivery capability, resource availability, financing availability, and regulatory capacity

Six criteria determine the role of nuclear and geothermal by country

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1. System benefits		
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b) Energy system benefits	Scale and growth of low-carbon heat and energy demand; value from hybrid applications; integration with existing energy infrastructure	
2. Deliverability		
a) Delivery capability	Experienced owner–operator and standardised repeat build capability or ability to upskill or import capability	Presence of an experienced geothermal or oil and gas workforce and supply chain, and the ability for standardised repeat build capability
b) Resource availability	End-to-end nuclear fuel cycle security	High cost-competitive resource availability for conventional or next-gen. technologies
c) Regulatory capacity	Credible, proportionate and predictable regulation and full lifecycle regulatory and siting capacity	
d) Financing availability	Access to low-cost capital and credible risk allocation and revenue frameworks	

Resource availability covers geothermal resource quality, and subsurface characterisation maturity

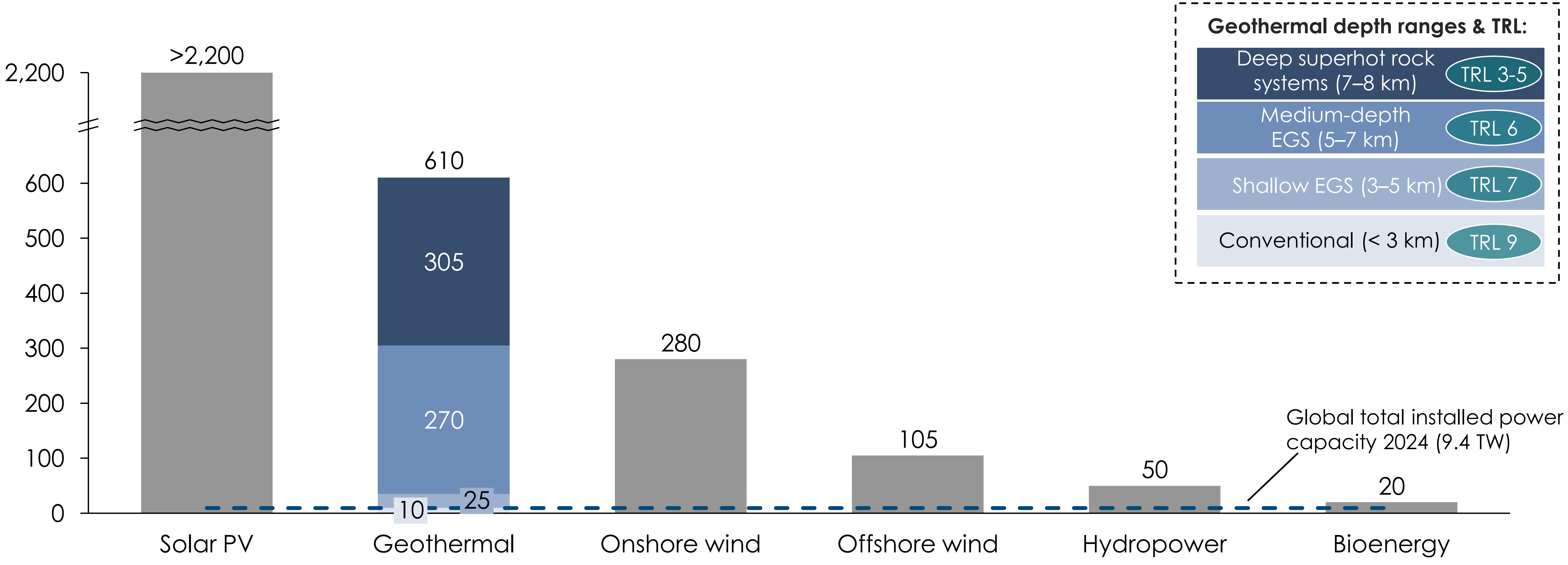
2. Deliverability

b) Resource availability - geothermal

Criteria	*Justification*
Geothermal resource quality and cost-competitiveness	High-quality geothermal resources with well-understood geology enable lower levelised costs; next-generation technologies may unlock resources in a wider range of geologies
Resource characterisation and exploration maturity	Countries with well-characterised subsurface data, whether from prior geothermal or oil and gas activity, face lower exploration risk and development costs

By expanding available resource across geographies, next-generation technologies could unlock significant power generation potential

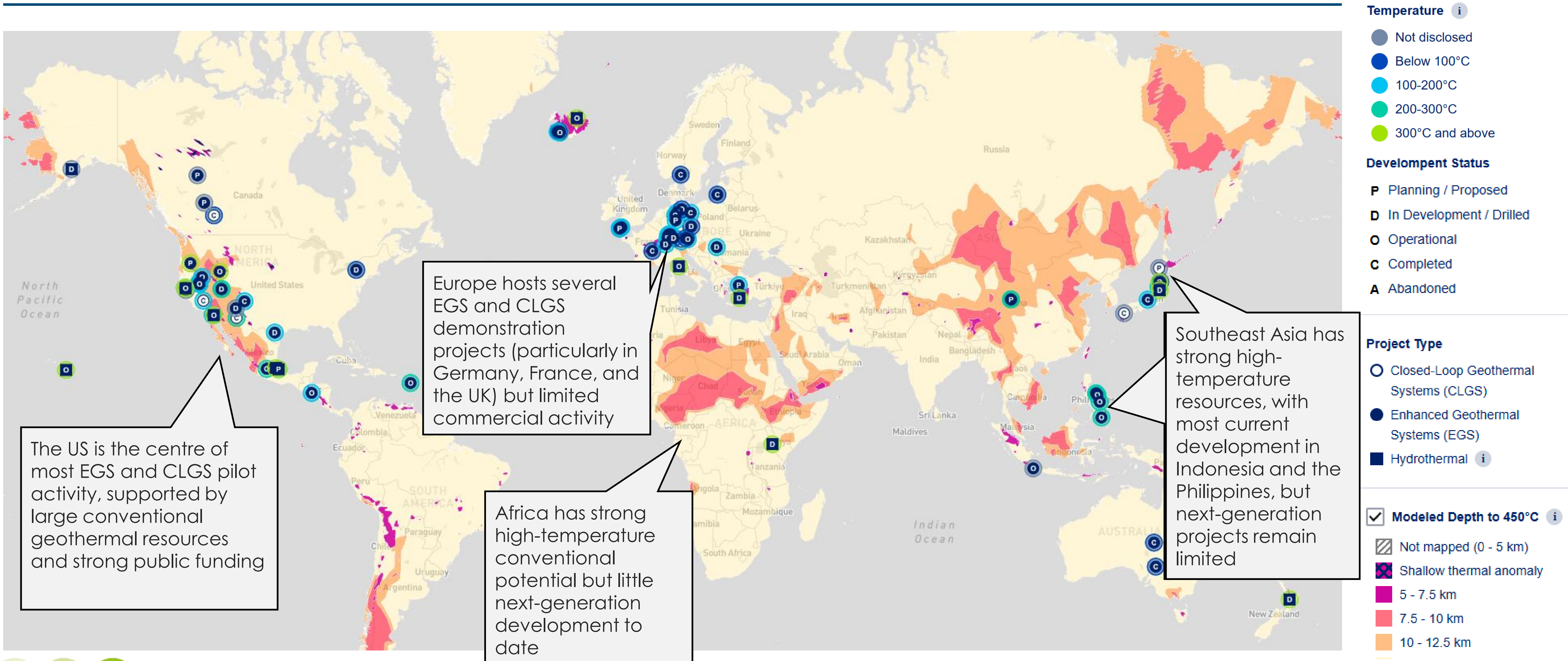
Technical potential of selected renewable energy technologies for electricity generation (IEA estimate)
TW



Source: IEA (2024) *The Future of Geothermal Energy*: Geothermal: *Project InnerSpace™ calculations for EGSs based on GeoMap™ data with a threshold of USD 300/MWh, in collaboration with IEA. Offshore wind: IEA (2019), Offshore Wind Outlook 2019. Hydropower: IEA TCP 2010.Bioenergy: IEA calculation based on the assumption that all sustainable bioenergy potential of 100 EJ is used for power generation. Onshore wind: Based on DTU-2027 study. Solar PV: Technical potential from various studies in de La Beaumelle N.A. et al. (2023), The Global Technical, Economic, and Feasible Potential of Renewable Electricity.*

Next generation geothermal power project development is expanding, with activity concentrated in North America, Europe, and APAC

Global geothermal project deployment map



Europe hosts several EGS and CLGS demonstration projects (particularly in Germany, France, and the UK) but limited commercial activity

The US is the centre of most EGS and CLGS pilot activity, supported by large conventional geothermal resources and strong public funding

Africa has strong high-temperature conventional potential but little next-generation development to date

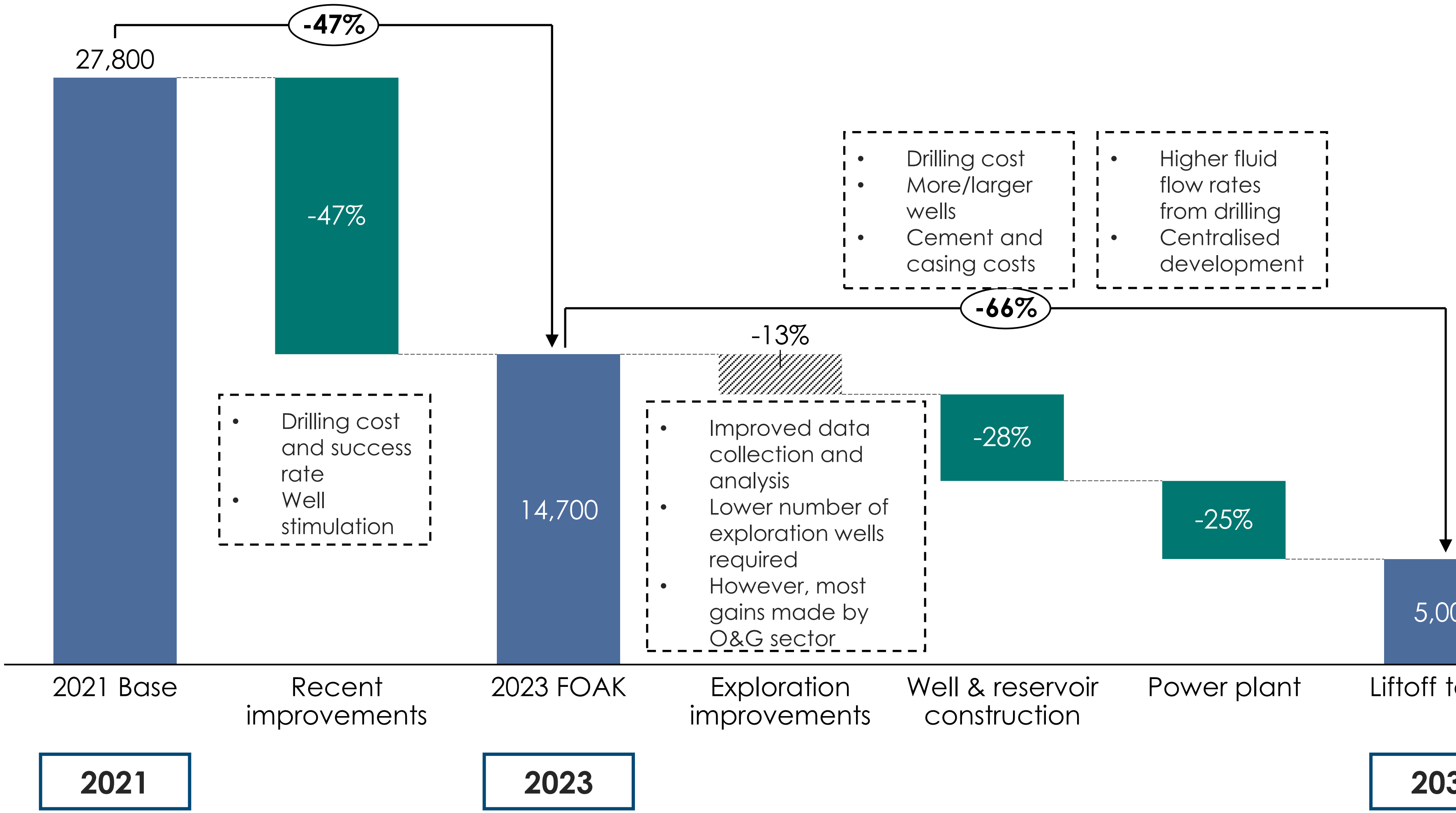
Southeast Asia has strong high-temperature resources, with most current development in Indonesia and the Philippines, but next-generation projects remain limited

Notes: APAC = Asia-Pacific. Shaded thermal regions indicate broad geothermal gradients, not specific next-generation resource requirements.
Sources: Clean Air Task Force (2025), The Next Generation of Geothermal Energy. Available at: https://www.catf.us/shr-map/

Significant improvements in drilling and power plant cost declines for next-generation geothermal to become widely competitive

EGS CAPEX decline drivers (based on US DoE data)

$/kW$_e$, real 2024



Next-generation geothermal:

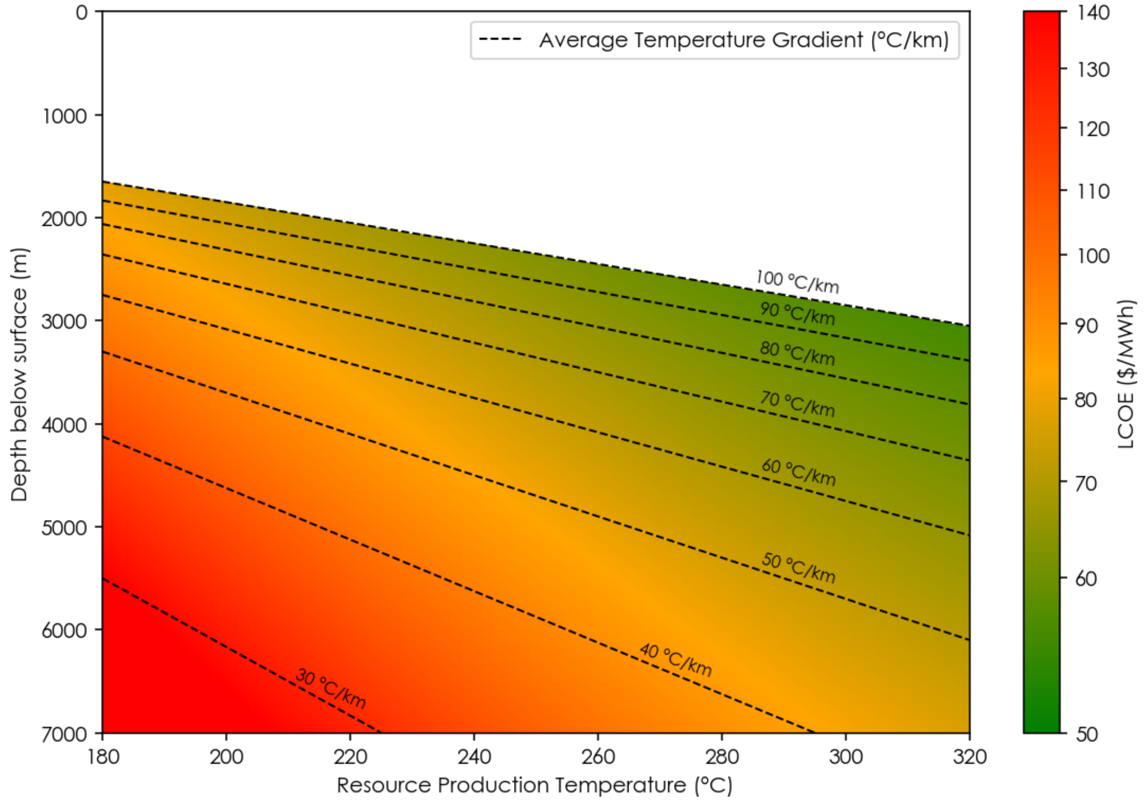
- Shifts main risk from subsurface uncertainty to **engineering performance**, leveraging oil & gas innovations.
- **Engineered reservoirs** can be adjusted to improve flow, lowering project failure risk.
- Need only basic subsurface data (temperature, rock properties, stress), **avoiding costly test wells needed for conventional projects**.
- EGS (TRL ~7) and CLGS (TRL ~6) **still maturing for deep-drilling and casing performance**.
- **Some learning-curve potential** as technologies scale

Notes: EGS = enhanced geothermal systems
Source: US DoE (2024) *Pathways to Commercial Liftoff: Next-Generation Geothermal Power Updated*

Next-generation geothermal costs vary widely depending on geology; they are driven by depth, temperature gradient, and financing risk

Illustrative EGS cost variation by depth and temperature (2035 costs, constant WACC)

Depth below surface – m; heatmap LCOE – $/MWh, real 2024



- **Shallower, hotter sites deliver the lowest cost**: LCOE drops sharply where high temperature gradients allow production at <3 km depth
- **Most of the world sits in the 15-45 °C/km range**, requiring deeper drilling and pushing LCOE estimates above $80/MWh at 2035 costs
- **Reducing development and operational risk is critical** to lowering WACC, which would shift LCOEs downward

Typical temperature gradients by region:

Low gradients: 15-30 °C/km *E.g., UK, Eastern US, Central/Eastern Europe, Brazil*	**Moderate gradients: 30-45 °C/km** *E.g., Australia, Northern India, Northwest Africa, Northern Canada, Southwest UK*	**High gradients: 45-100+ °C/km** *E.g., East African Rift, Iceland, Western US, New Zealand, Indonesia, Philippines, Central Andes (Chile, Bolivia, Argentina)*

Notes: EGS = enhanced geothermal systems, WACC = weighted average cost of capital, LCOE = levelised cost of energy. Source: Systemiq analysis for the ETC (2025); NREL (2025), *2025 Geothermal Drilling Cost Curves Update;* Koenraad F. Beckers (2019), *GEOPHIRES v2.0: updated geothermal techno-economic simulation tool;* US DoE (2024) *Pathways to Commercial Liftoff: Next-Generation Geothermal Power Updated;* F. Kolawole (2023), *Global distribution of geothermal gradients in sedimentary basins;* J. Limberger (2017), *Geothermal energy in deep aquifers: A global assessment of the resource base for direct heat utilization*

Country criteria mapping suggests high nuclear alignment in systems with existing, standardised supply chains

Criteria assessment by selected country

Low to high deliverability

Country	Experienced owner–operator and standardised repeat build capability	Ability to import qualified EPC capability	Overall Rating
Singapore			Low
Brazil			Low
Sub-Saharan Africa (regional)			Low-moderate
United Kingdom			Low-moderate
India			Low-moderate
South Korea			Low-moderate
France			Moderate-high
Canada			Moderate-high
China			Moderate-high
Mexico			Moderate-high
Japan			High
Indonesia			High
Türkiye			High
Kenya			High
Italy			High
United States			High
Philippines			High
New Zealand			High
Iceland			High

Notes: Criteria shaded from low to high nuclear alignment (1–3). Overall rating uses RAG based on average of criterion scores (equal weights), thresholds: 40/50/60/70%.
Source: IAEA (2025) PRIS; World Nuclear Association (2025), World Nuclear Performance Report 2025

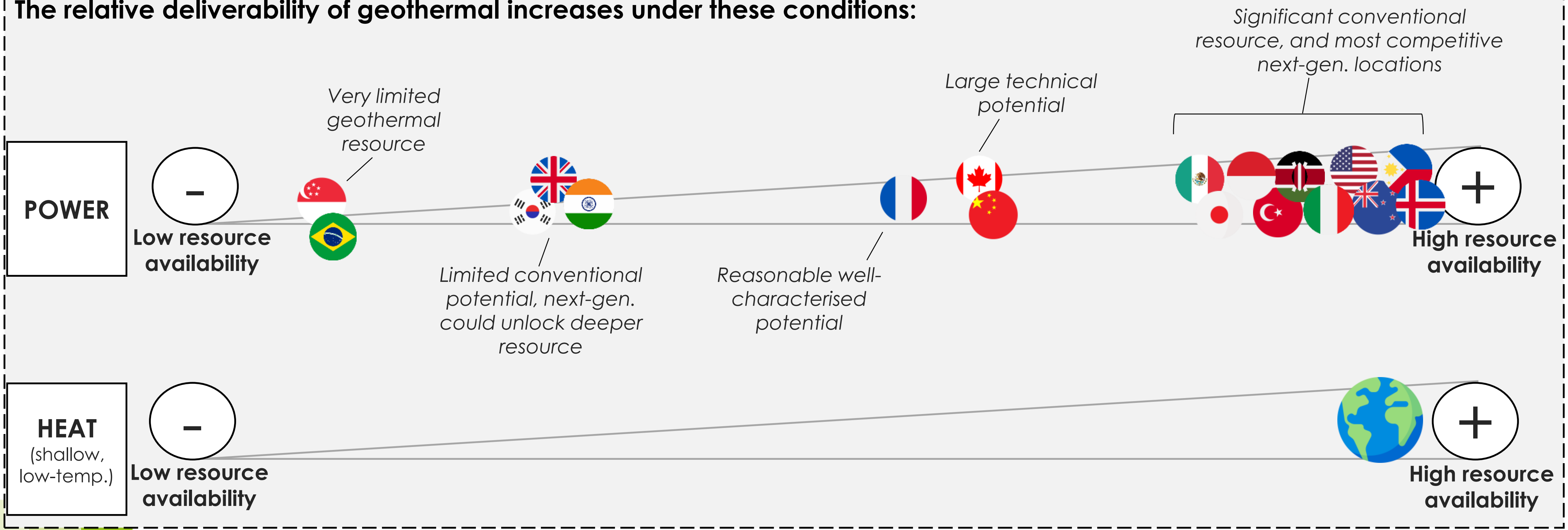
Cost-competitive power generation is likely to remain concentrated in existing geothermal countries; shallow heat/cooling is available everywhere

2. Deliverability

b) Geothermal resource availability

High cost-competitive resource availability for conventional or next-gen. technologies

The relative deliverability of geothermal increases under these conditions:



Agenda

Nuclear and geothermal deliverability depends on delivery capability, resource availability, financing availability, and regulatory capacity

Six criteria determine the role of nuclear and geothermal by country

	Nuclear	Geothermal
1. System benefits		
a) Power system benefits	Wind and solar availability and cost; import and risk exposure to fossil; need for reliable firm supply	
b) Energy system benefits	Scale and growth of low-carbon heat and energy demand; value from hybrid applications; integration with existing energy infrastructure	
2. Deliverability		
a) Delivery capability	Experienced owner–operator and standardised repeat build capability or ability to upskill or import capability	Presence of an experienced geothermal or oil and gas workforce and supply chain, and the ability for standardised repeat build capability
b) Resource availability	End-to-end nuclear fuel cycle security	High cost-competitive resource availability for conventional or next-gen. technologies
c) Regulatory capacity	Credible, proportionate and predictable regulation and full lifecycle regulatory and siting capacity	
d) Financing availability	Access to low-cost capital and credible risk allocation and revenue frameworks	

Regulatory capacity spans regulator independence, framework proportionality, and lifecycle siting and permitting capability

2. Deliverability

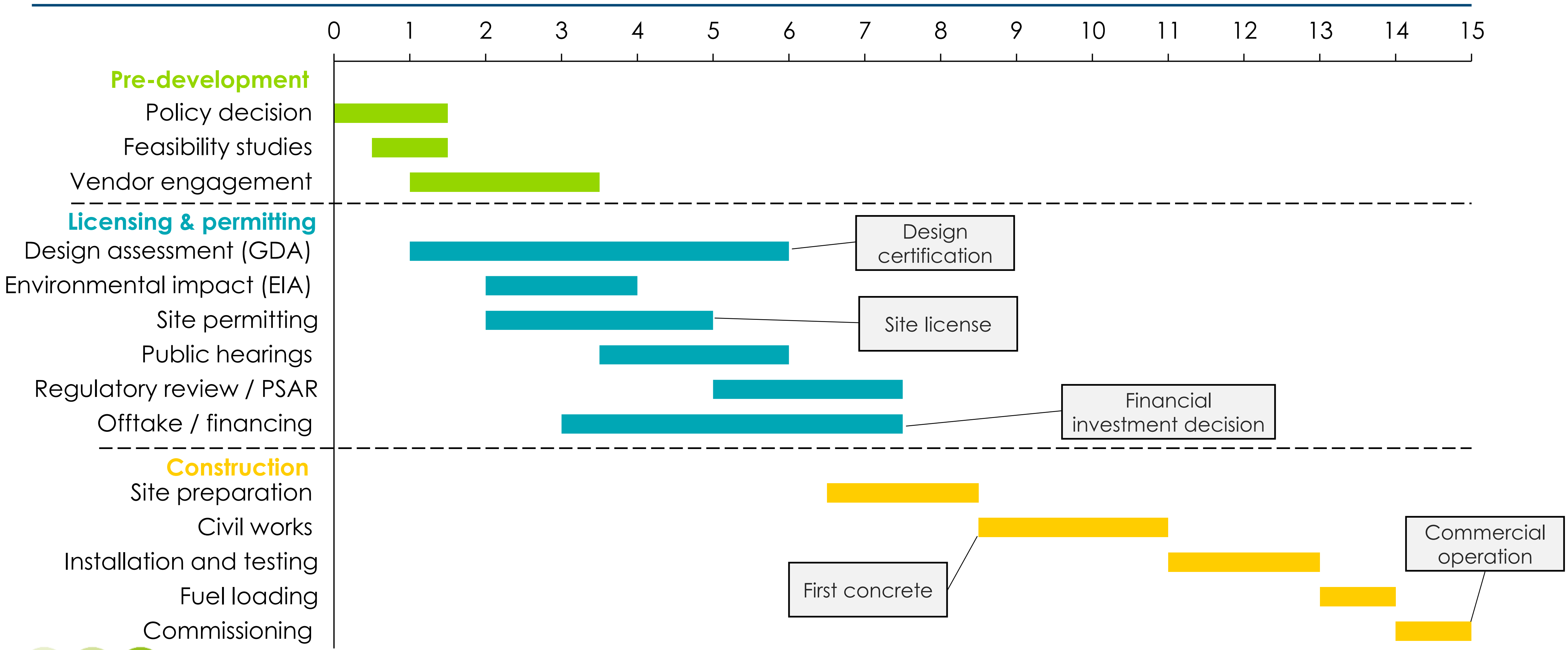
c) Regulatory Capacity

Criteria	*Justification*
Existence of a credible, independent regulatory body	A well-resourced and independent regulator builds investor and public confidence and reduces the risk of project delays from regulatory uncertainty
Proportionality and predictability of the regulatory framework	Overly burdensome or unpredictable regulation increases project cost and timeline risk; proportionate frameworks tailored to technology risk profiles support deployment
Siting and permitting capacity across the project lifecycle	Effective land-use planning, environmental permitting and community engagement processes are necessary to move projects from development through to construction and operation

Nuclear pre-development, licensing & permitting, and construction can take around 15 years

Indicative timeline for nuclear regulatory processes (UK example)

Years

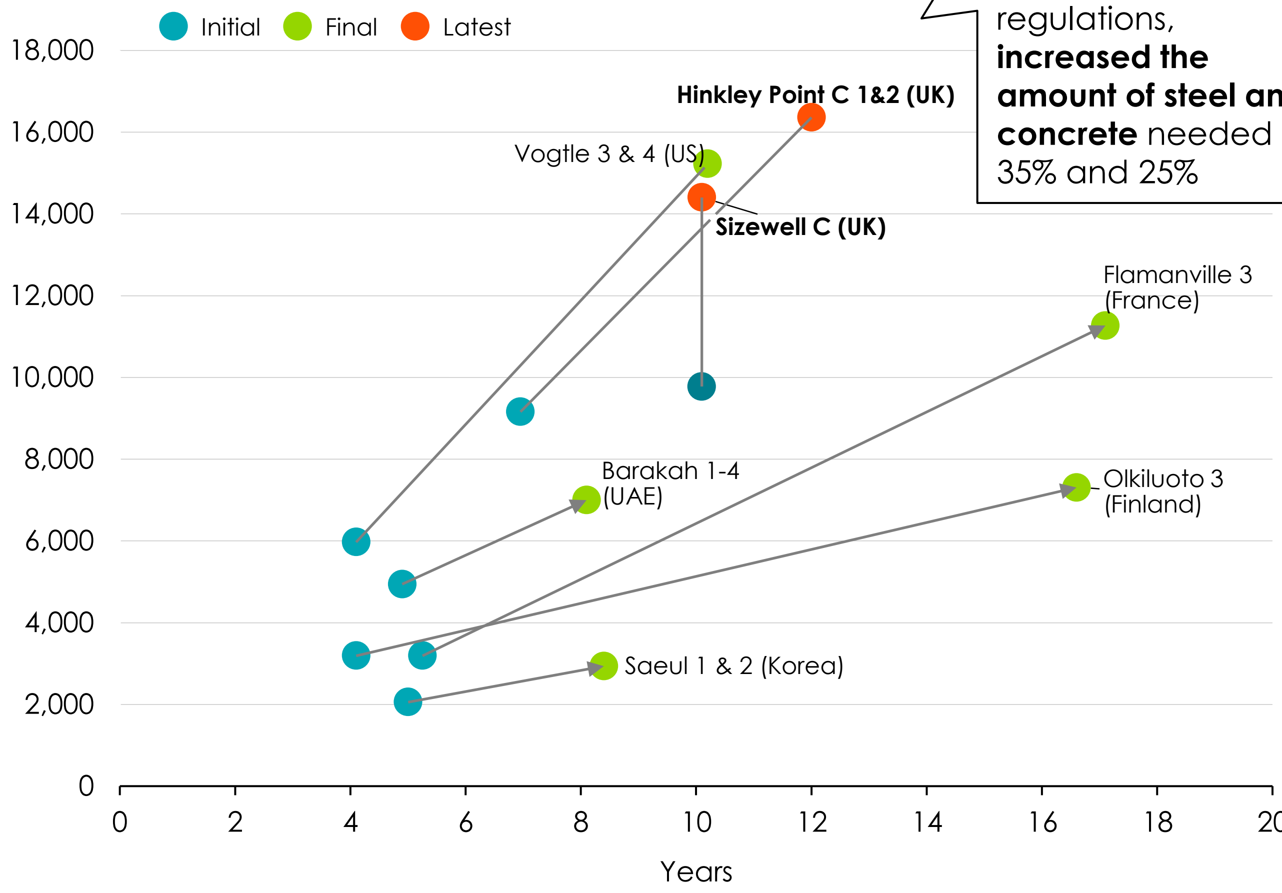


Notes: GDA = generic design assessment; EIA = environmental impact assessment; PSAR = Preliminary Safety Analysis Report. Source: IAEA (2024), *Navigating Nuclear Development*; IAEA (2012), *Project Management in Nuclear Power Plant Construction: Guidelines and Experience*; UK Government (2023), *New nuclear power plants: Generic Design Assessment guidance for Requesting Parties*; General Nuclear System (2022), *The GDA process*; N. Shykinov (2016), *Importance of Advanced Planning of Manufacturing for Nuclear Industry*

Regulations are a key driver of the speed and cost of project delivery – driving in increases in in both in recent Western projects

Initial and latest CAPEX estimates and construction times

$/kW, real 2024



7,000 design changes to HPC's reactor design, due to British regulations, **increased the amount of steel and concrete** needed by 35% and 25%

Effective regulation is the key to streamlining delivery

Key Problems:

- Too many regulators
- Disproportionate decisions
- Process-heavy rules
- Policy drift and slow decisions.
- Weak industry incentives due to near-monopoly

Key solutions:

- Fix fragmented oversight
- Make decisions proportionate
- Change culture, embrace innovation
- Remove systemic blockages
- Harmonise cross-border regulations

Source: Financial Times (2025), *Can the nuclear industry find a better way to build?*; Energy Technologies Institute (2020), *The ETI Nuclear Cost Drivers Project;* John Fingleton (2025), *Nuclear Regulatory Review 2025*

Accidents still shape public perceptions, however nuclear is statistically safer than many other electricity generation technologies

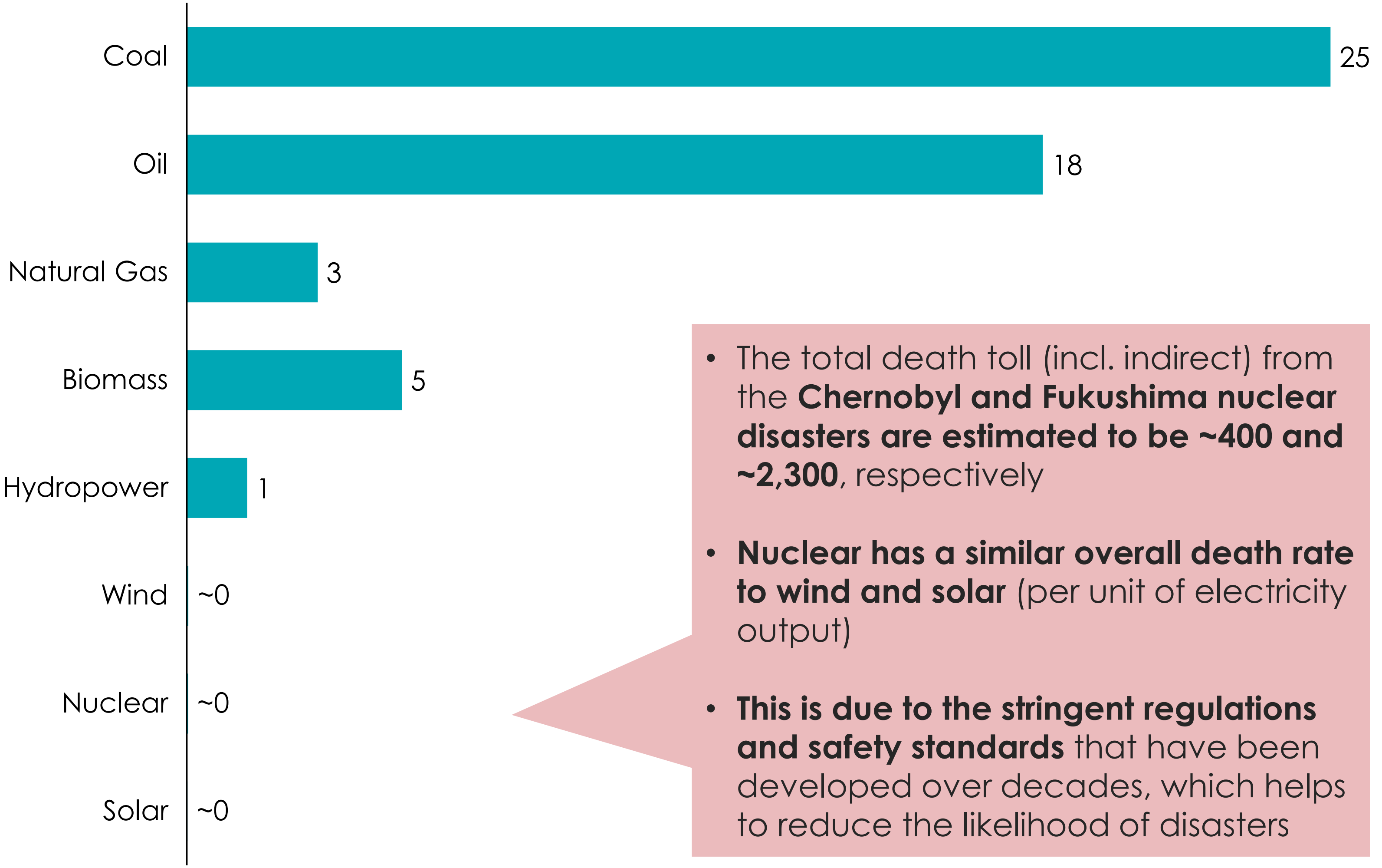
Key safety considerations: nuclear disasters

- **Historical accidents** (Chernobyl, Fukushima) continue to shape public safety perceptions despite high safety standards in recent decades

- **Higher concern in non-nuclear countries; lower in countries with long-standing nuclear programmes and trusted regulatory institutions (e.g. France, Sweden, US, UK, South Korea)**

Safety by electricity generation type (Our World in Data)

Deaths per TWh



- The total death toll (incl. indirect) from the **Chernobyl and Fukushima nuclear disasters are estimated to be ~400 and ~2,300**, respectively
- **Nuclear has a similar overall death rate to wind and solar** (per unit of electricity output)
- **This is due to the stringent regulations and safety standards** that have been developed over decades, which helps to reduce the likelihood of disasters

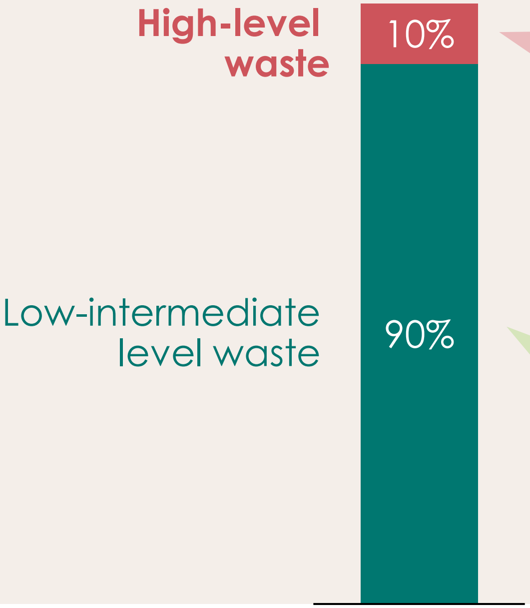
Notes: Death rates are measured based on deaths from accidents and air pollution per TWh of electricity. Our World in Data's estimates for Chernobyl and Fukushima include direct and cancer deaths from the accidents and indirect deaths from evacuation (stress, displacement from care settings, healthcare disruptions).
Source: Our World in Data (2020), *Death rates per unit of electricity production*, Our World in Data (2017), *What was the death toll from Chernobyl and Fukushima?*

Careful management is required for high-level nuclear waste; overall safety risks must be managed to maintain social license

Nuclear waste: low to high radioactivity levels

There are three different types of nuclear waste

- **Low-level waste (LLW)**, lightly contaminated materials (clothing, filters, and tools)
- **Intermediate-level waste (ILW)**, more radioactive materials (resins, sludges, reactor components).
- **High-level waste (HLW)**, spent nuclear fuel or vitrified reprocessing waste



- **Only a small fraction (<10%) is high-level waste**
- Long-term deep geological storage is needed - however many face challenges and delays

- **Over 90% of volumes are low- or intermediate-level waste** (protective clothing, tools, filters) which are routinely disposed of in engineered surface or near-surface facilities

France generates the following amounts of waste* per inhabitant per year:

13.8 t
of trade waste
(construction, industry, ag r iciculture, health care activities)

354 kg
of household waste

100 kg
of toxic industrial waste

2 kg
of radioactive waste
Of this waste:
60% is from the nuclelear industry, and 40% fron other setors

*Source ADEME (2016)

Public fear is often disproportionate: the scientific record shows nuclear waste is small in volume, highly regulated, and safely managed

Source: World Nuclear Association (2025) Radioactive Waste – Myths and Realities; IAEA (2023), Status and Trends in Spent Fuel and Radioactive Waste Management, which notes defence activities as a significant but uneven contributor; OECD-NEA (2021), Radioactive Waste Management and Decommissioning Review; Nuclear Decommissioning Authority (2014), Fact sheet: waste from defence activities; World Nuclear Association (2023) *Radioactive Waste Management*.

Geothermal safety and environmental risks are technology and site-specific, but all manageable with modern practices and regulation

Comparison with fracking is helpful to illustrate relative risk drivers across technologies, but indicative only because impacts vary by geology, design and regulation

Risk	Description	Risk Level – Shallow Heat	Risk Level – Deep geothermal incl. conventional and EGS	Risk Level – Oil and gas fracking
Groundwater pollution	*Leakage of artificial fluids, drilling chemicals or refrigerant leakage*	Low-Medium, none for closed loop systems	Low–Medium	Medium
Toxic gases or contaminants entering water sources	*Migration of arsenic, boron, or hydrogen sulfide into nearby waters*	None	Medium	Medium
Disruption of local water supply	*Alteration or depletion of aquifers from extraction*	Low, none for closed-loop systems	Low–Medium	Medium
Release of gases locally	*Emission of CO_2, H_2S, and trace gases during venting or maintenance*	None	Medium	Medium
Induced seismicity	*Small earthquakes triggered by injection or extraction*	None	Medium	Medium
Land subsidence	*Ground compaction due to pressure or fluid withdrawal*	None	Low	Medium
Other local impacts over time	*Noise, visual impact, or surface disturbance*	Low	Low	Low-medium

Impact (→) / Probability (↑)

Probability \ Impact			
	Low	Medium	High
	Low	Medium	Medium
	Low	Low	Low

Geothermal risks are low and can be well managed with modern monitoring and reinjection practices. Risks generally lower for shallow heat.

Fracking scores higher **due to greater surface activity and fluid handling,** but all risks are **manageable with modern practices**

Note: **Risk levels reflect published reviews and regulatory assessments. Actual impacts depend on geology, design, regulation and operator practice.** Source: U.S. Department of Energy (2024) *Environmental Analysis of Geothermal Energy* Clean Air Task Force (2025) *Introduction to the Next Clean Energy Frontier: Superhot Rock Opportunities and Responsible Development;* Union of Concerned Scientists (2024) *Environmental Impacts of Geothermal Energy;* BKV Energy (2024) *Environmental Impact of Geothermal Energy;* Fiveable (2024) *Environmental Impacts of Geothermal Energy;* University of Texas (2023) *Geothermal Energy Systems: Environmental Considerations;* U.S. Geological Survey (USGS) – Induced Seismicity Studies (2015–2023); International Energy Agency (IEA 2012, 2020): "Golden Rules for a Golden Age of Gas"; Groundwater watch studies – Jackson et al. (PNAS 2014, 2015; Science 2013)

Country criteria mapping suggests high nuclear alignment in systems with mature, predictable regulatory frameworks

Low to high deliverability

Criteria assessment by selected country

Country	Credible, proportionate and predictable regulation	Full lifecycle regulatory and siting capacity	Overall Rating
Sub-Saharan Africa (regional)			Low
India			Moderate-high
United Kingdom			Moderate-high
Japan			Moderate-high
Canada			High
United States			High
France			High
South Korea			High
China			High

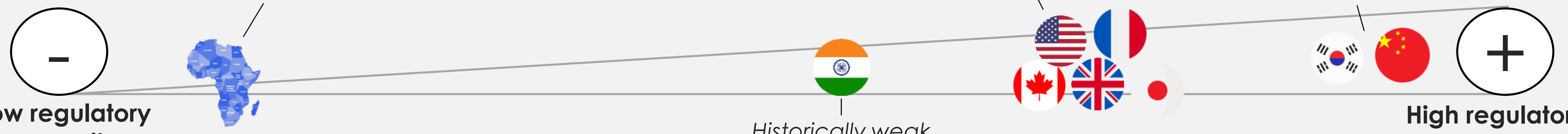
Notes: Criteria shaded from low to high nuclear alignment (1–3). Overall rating uses RAG based on average of criterion scores (equal weights), thresholds: 40/50/60/70%.
Source: IAEA (2025) PRIS; World Nuclear Association (2025), World Nuclear Performance Report 2025

Long-term regulatory capacity and support is most likely in China and South Korea, with long-term uncertainty in many other key markets

2. Deliverability

c) Regulatory capacity	Credible, proportionate and predictable regulation	Full lifecycle regulatory and siting capacity

The relative deliverability of Firm Low-Carbon increases under these conditions:



Nuclear and geothermal deliverability depends on delivery capability, resource availability, financing availability, and regulatory capacity

Six criteria determine the role of nuclear and geothermal by country

1. System benefits	Nuclear	Geothermal
a) Power system benefits	Wind and solar availability and cost; import and risk exposure to fossil; need for reliable firm supply	
b) Energy system benefits	Scale and growth of low-carbon heat and energy demand; value from hybrid applications; integration with existing energy infrastructure	
2. Deliverability		
a) Delivery capability	Experienced owner–operator and standardised repeat build capability or ability to upskill or import capability	Presence of an experienced geothermal or oil and gas workforce and supply chain, and the ability for standardised repeat build capability
b) Resource availability	End-to-end nuclear fuel cycle security	High cost-competitive resource availability for conventional or next-gen. technologies
c) Regulatory capacity	Credible, proportionate and predictable regulation and full lifecycle regulatory and siting capacity	
d) Financing availability	Access to low-cost capital and credible risk allocation and revenue frameworks	

Financing availability reflects access to low-cost capital, risk allocation frameworks, and long-term revenue certainty

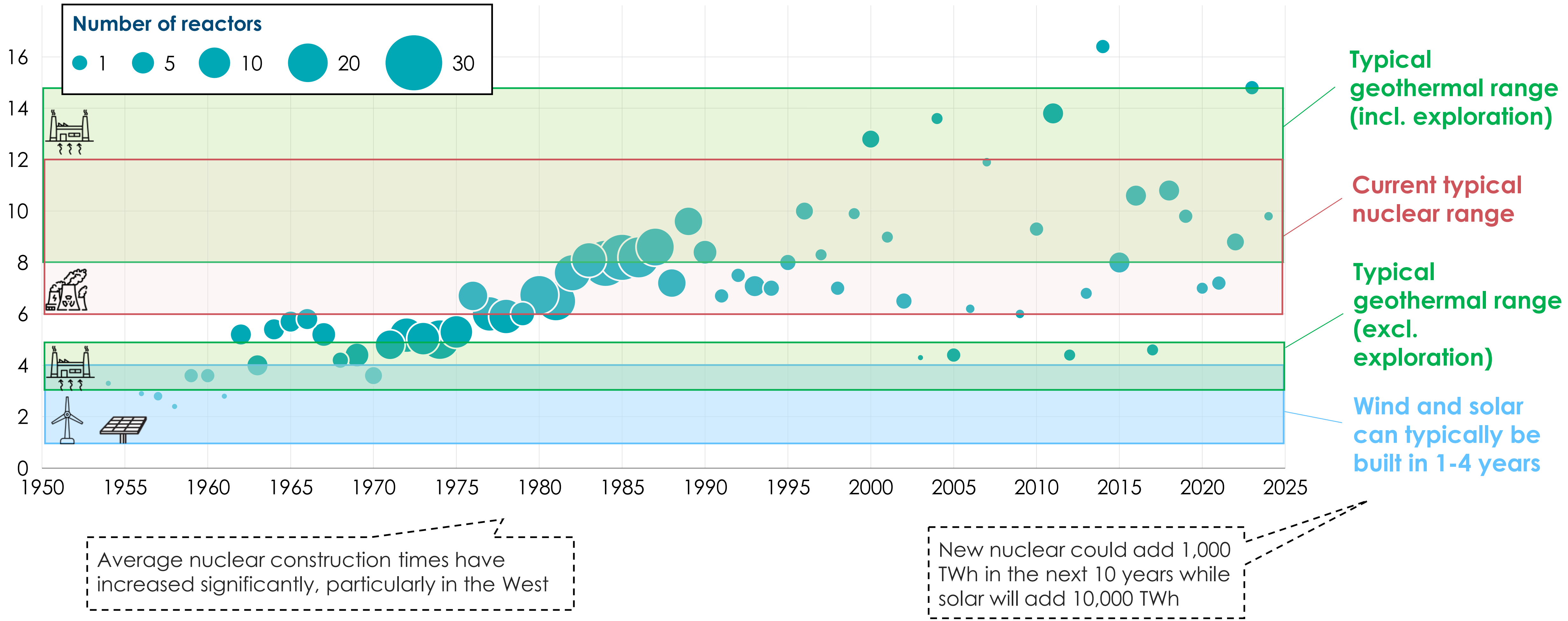
2. Deliverability

d) Financing Availability

Criteria	*Justification*
Access to low-cost capital	Nuclear and geothermal projects are capital-intensive with long payback periods; access to concessional, public or blended finance significantly reduces the cost of deployment
Credible risk allocation frameworks	Clear contractual and policy frameworks that allocate construction, revenue and operational risk appropriately between public and private actors are essential to attract investment
Revenue certainty and market frameworks	Long-term revenue visibility through contracts for difference, power purchase agreements or regulated asset base models reduces investment risk and enables project financing

Nuclear and geothermal have longer lead times than renewables that can be built in under three years – creating high WACC sensitivity

Average durations from final investment decision to commissioning over time
Years

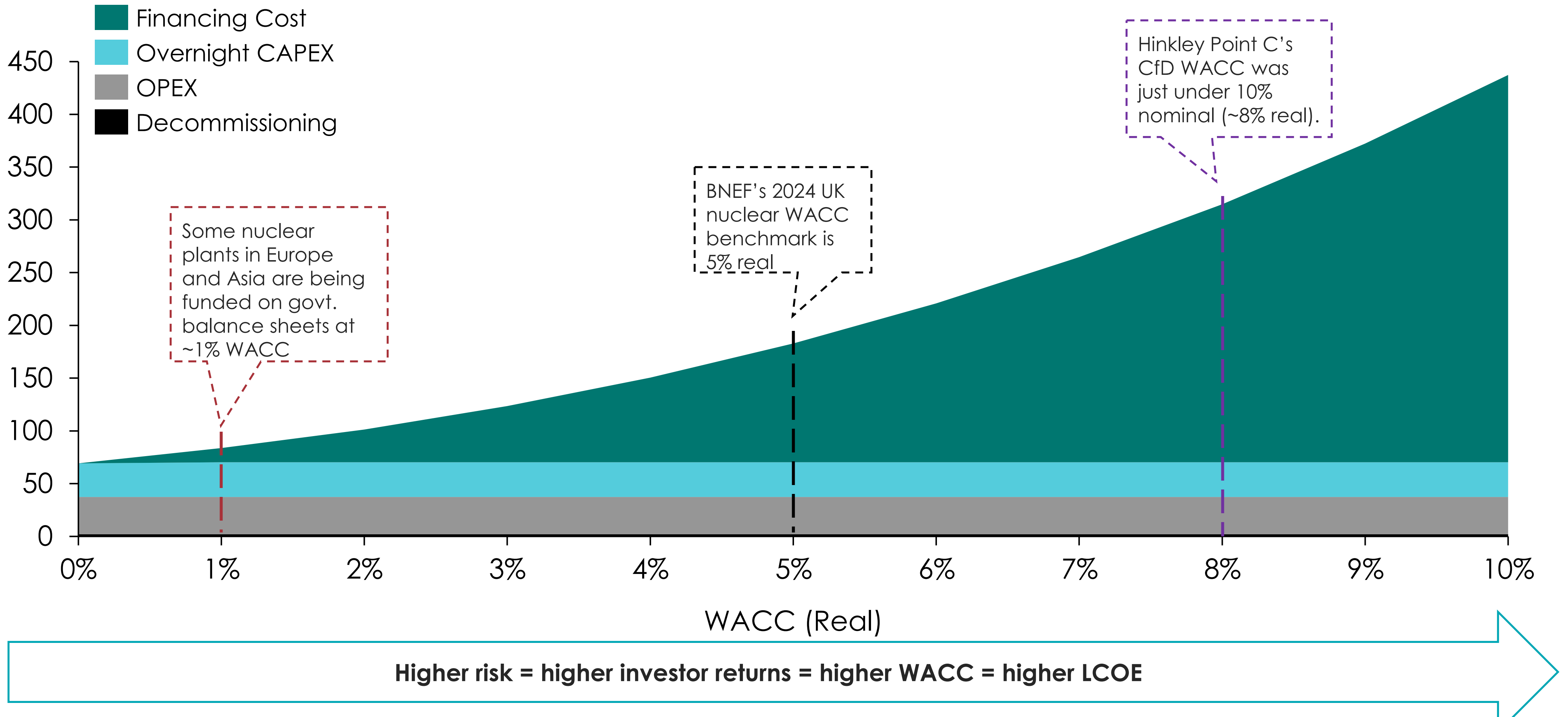


Sources: Adapted from Mycle Schneider Consulting (2024), *The World Nuclear Industry Status Report 2024*; Financial Times (2025), *Can the nuclear industry find a better way to build?*; A. Gumber (2024), *A global analysis of renewable energy project commissioning timelines;* British Geological Survey (2023), *Evidence report supporting the deep geothermal energy white paper: The case for deep geothermal energy - unlocking investment at scale in the UK*

The weighted average cost of capital (WACC) drives nuclear costs; govt. balance sheet use and revenue certainty mechanisms can reallocate risks

Nuclear Example - UK conventional nuclear 2024 sensitivity to WACC

$/MWh, real 2024



Notes: CfD = Contracts for Difference, CAPEX = Capital Expenditure, OPEX = Operating Expenditure (incl. fuelling), DECEX = Decommissioning Expenditure. Overnight CAPEX is the total CAPEX excluding financing costs. Only WACC varies as a sensitivity.

Source: BNEF (2025), *LCOE Data Viewer*, INL (2024), *Nuclear Energy Cost Estimates for Net Zero World Initiative*

Nuclear financing models range from fully state-backed to privately funded

Risk and funding shift from state balance sheet → consumers (regulation) → contracted counterparties → investors exposed to markets

	Administered tariff (state)	**Regulated revenue (RAB)**	**Government contracted revenue (CfD)**	**Corporate PPA + Market revenue (merchant)**
Who pays during construction	State / SOE	Investors, with regulated charge to customers (incl. during construction)	Private	Private
Revenue model	Administered tariffs or state PPA	Regulated allowed returns (incl. during construction)	CfD stabilises price once operating, typically for long project lifetimes	PPA stabilises price once operating then reliance on market prices
Who bears overrun risk	Mostly state / SOE	Shared (depends on contract structure)	Mostly private (unless wrapped by guarantees)	Private
Example countries *(for most new nuclear)*		*Sizewell C*	*Hinkley Point C*	?

State-backed loans / guarantees can apply to the range of revenue models

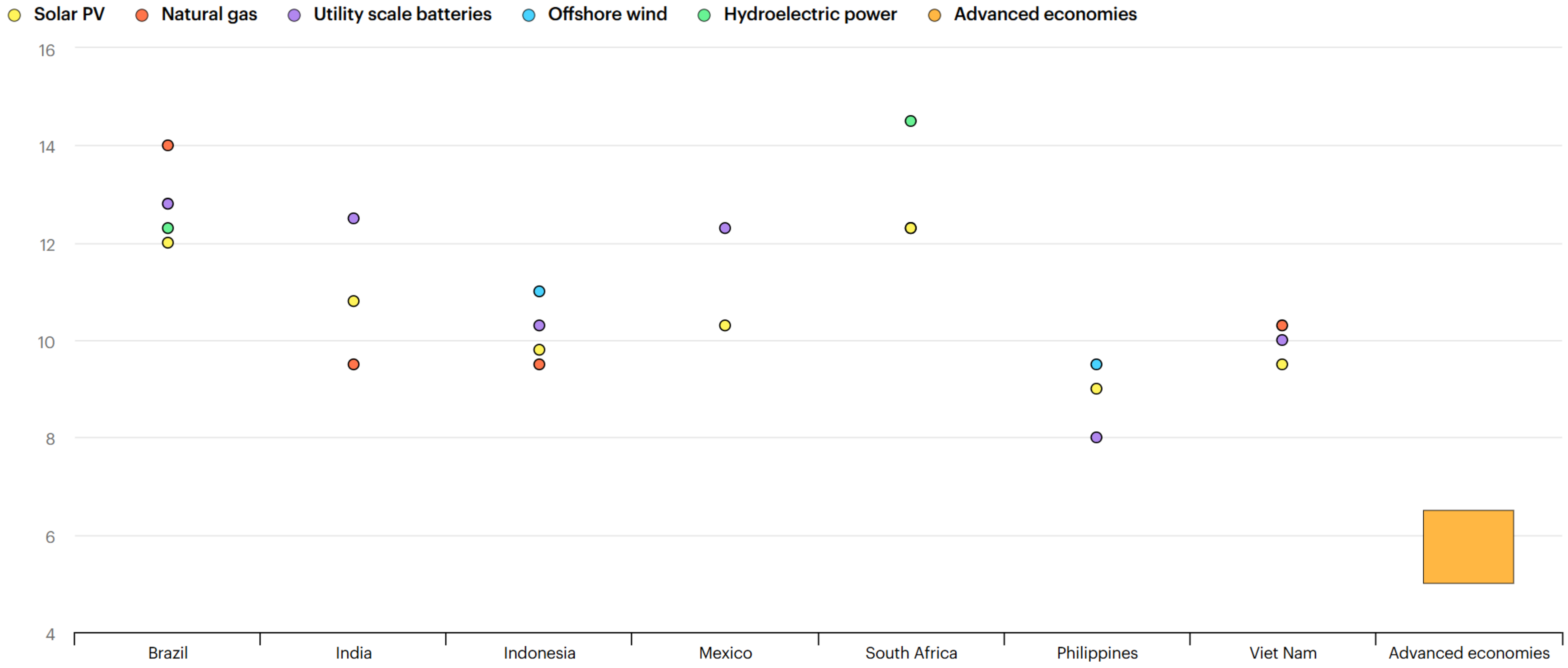
Fully privately funded projects could become viable if SMR costs decline significantly and corporates (e.g., data centres) sign PPAs

Note: SOE = state-owned enterprise; PPA = power purchase agreement; CfD = contracts for difference; RAB = regulated asset base

WACC will be a significant in many developing economies, particularly where this is the case for projects with lower capital intensity

WACC by project type in selected emerging markets and developing economies countries, 2024

%



Source: IEA (2025), *Cost of capital expectations for 2025 diverge amid rising uncertainty*

Country criteria mapping suggests high nuclear alignment in systems with high-confidence in long-term nuclear programmes

Criteria assessment by selected country

Low to high deliverability

Country	Access to low-cost capital	Credible risk allocation and revenue frameworks	Overall Rating
Sub-Saharan Africa (regional)			Low
Italy			Low-moderate
Mexico			Low-moderate
India			Moderate-high
Canada			Moderate-high
United States			Moderate-high
United Kingdom			Moderate-high
France			Moderate-high
Japan			Moderate-high
Indonesia			Moderate-high
Philippines			Moderate-high
Türkiye			Moderate-high
Kenya			Moderate-high
South Korea			High
China			High
New Zealand			High
Iceland			High
Singapore			High

Notes: Criteria shaded from low to high nuclear alignment (1–3). Overall rating uses RAG based on average of criterion scores (equal weights), thresholds: 40/50/60/70%.
Source: IAEA (2025) PRIS; World Nuclear Association (2025), World Nuclear Performance Report 2025

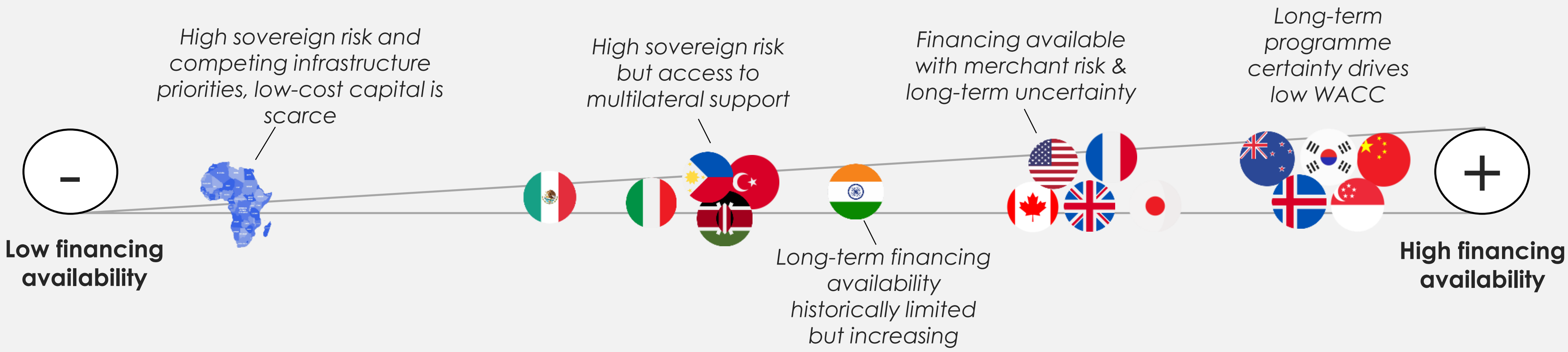
Low-cost, long-term financing for nuclear is most likely to be available in China and South Korea, with long-term uncertainty elsewhere

2. Deliverability

b) Financing availability

- Access to low-cost capital
- Credible risk allocation and revenue frameworks

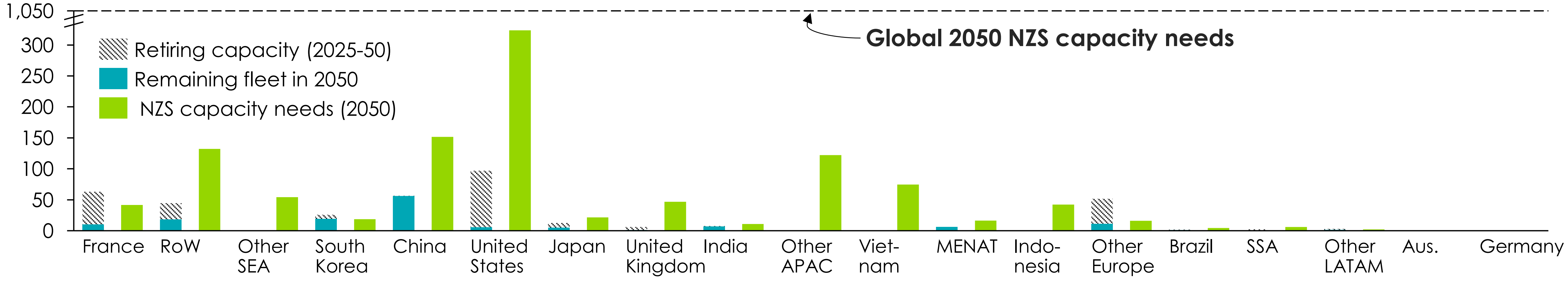
The relative deliverability of Firm Low-Carbon increases under these conditions:



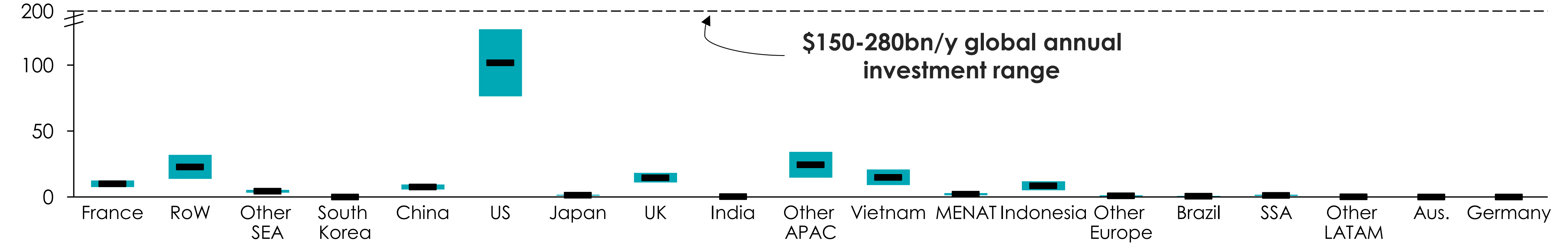
Agenda

The BNEF net-zero pathway requires around 40 GW of new build nuclear per year, equating to around $200bn of CAPEX per year…

2025 – 2050 existing nuclear fleet change and build need (BNEF Net Zero Scenario)
GW



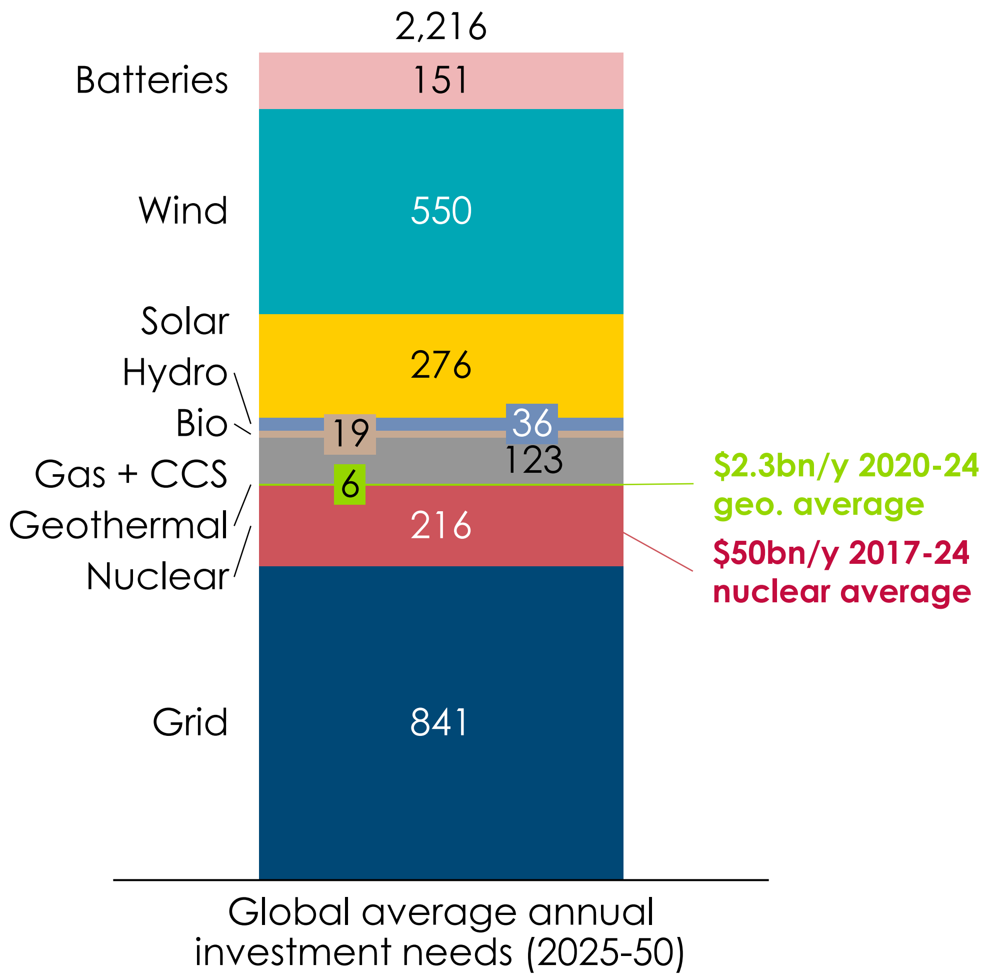
Nuclear annual investment need by archetype (2025 - 2050)
$bn/y



Notes: Nuclear CAPEX assumptions ($/kW, low–mid–high): $1,500–2,000–2,500: China, India, Japan, South Korea, Other SEA: $3,000–5,000–7,000: Brazil, Indonesia, MENAT, SSA, Vietnam, Other APAC, Other Europe, Other LATAM, RoW · $6,000–8,000–10,000: Australia, France, Germany, UK, US.
Source: IAEA (2026), *Power Reactor Information System*, BNEF (2025), *New Energy Outlook*

…which makes up around 10% of required average annual investment in clean energy and grids out to 2050

2025 – 2050 global average annual supply-side investment needs (BNEF NZS),
$bn/y

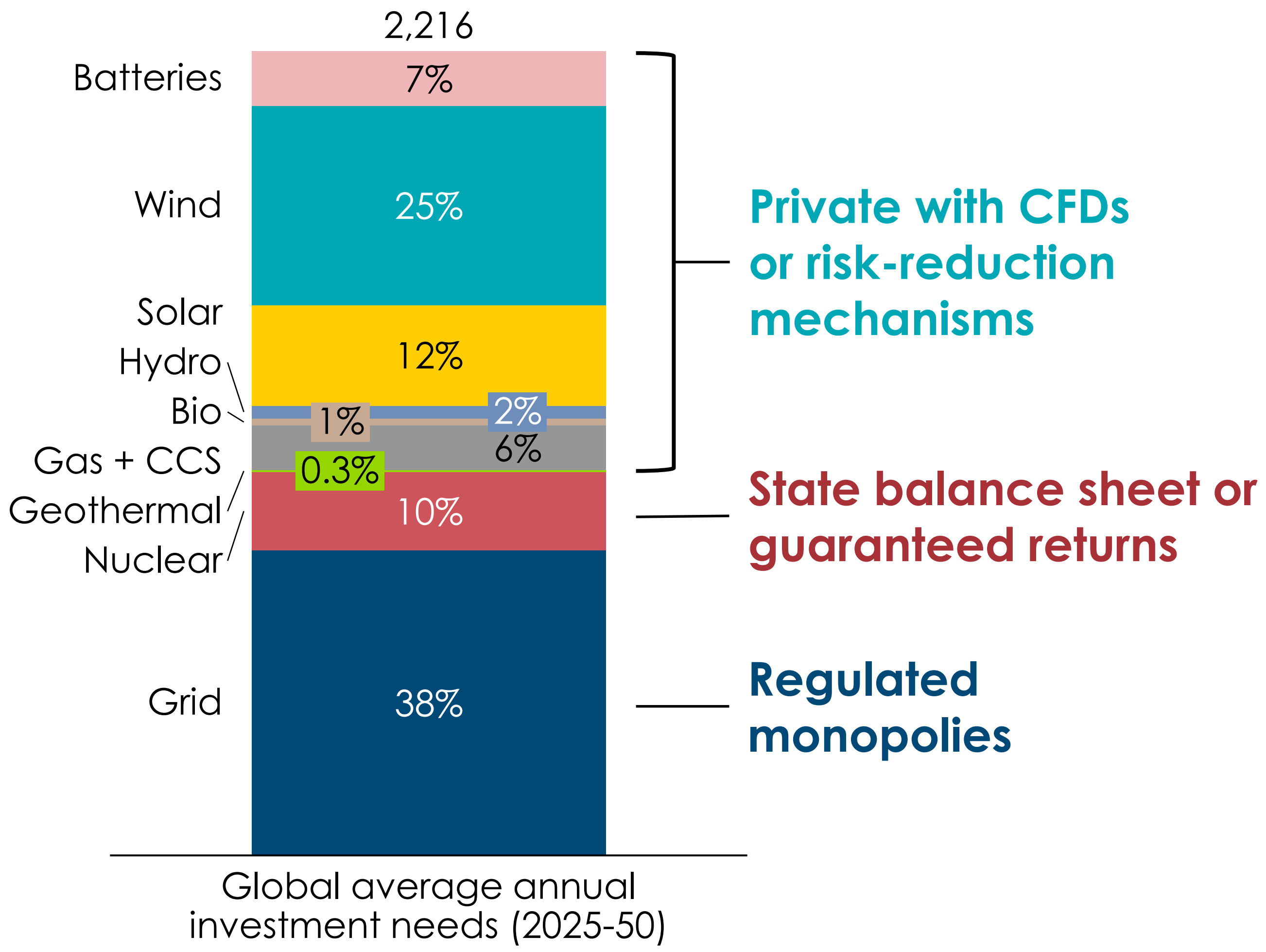


- $2.2 trillion per year represents roughly a **2x increase from 2021-25 average** global clean generation and grids investment levels
- Nuclear + Geothermal together **represent ~10.3%** (mostly nuclear based on current estimates)
- This will require a **significant scale up from the $50bn and $2bn** annual averages for nuclear and geothermal in recent years.
- However, investment in these technologies **should not detract from investments in the technologies that make up the remaining 90%**

Source: BNEF (2025), *New Energy Outlook*; IEA (2025), *Investment Data Explorer;* World Economic Forum (2025), *Nuclear energy: How finance, policy and innovation can triple capacity by 2050;* Canary Media (2025), *Chart: Geothermal energy is attracting more and more investment*

Investments by technology typically range from private capital to regulated monopolies and state balance sheets

2025 – 2050 global average annual supply-side investment needs (BNEF NZS)
$bn/y



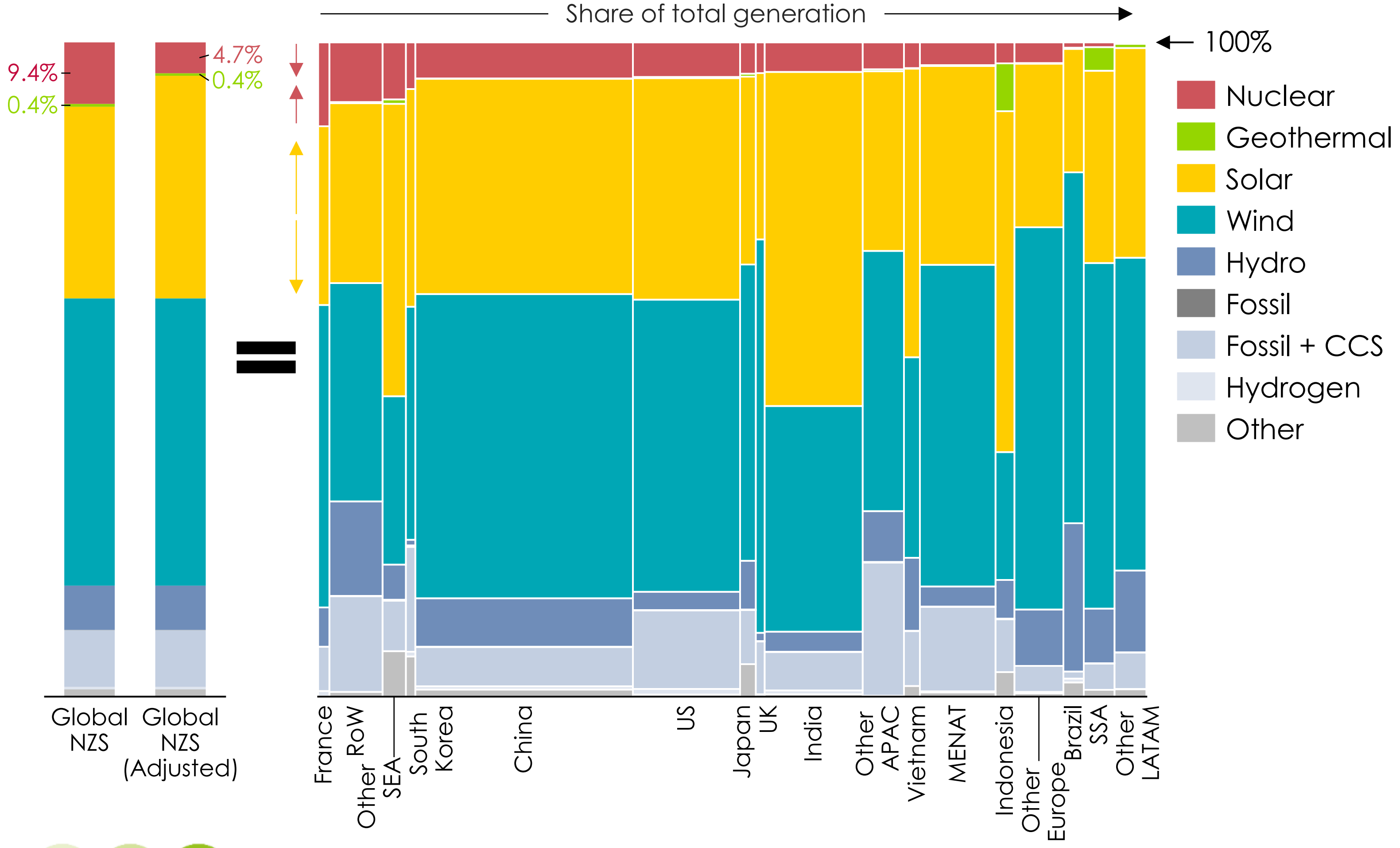
How should state balance sheets most efficiently be used to accelerate the energy transition?

1. Support the most capital-intensive / risky technologies (i.e. nuclear, floating offshore wind)
2. Support proven technologies to maximise scale of clean generation
3. Support demand-side electrification / hard-to-electrify measures

Source: BNEF (2025), *New Energy Outlook*; IEA (2025), *Investment Data Explorer;* World Economic Forum (2025), *Nuclear energy: How finance, policy and innovation can triple capacity by 2050;* Canary Media (2025), *Chart: Geothermal energy is attracting more and more investment*

Is a 5% nuclear/geothermal scenario more likely, considering constraints and increasing accessibility, affordability, and attractiveness of alternatives?

Share of nuclear and geothermal vs other technologies in BNEF's 2050 Net Zero Scenario (adjusted), %



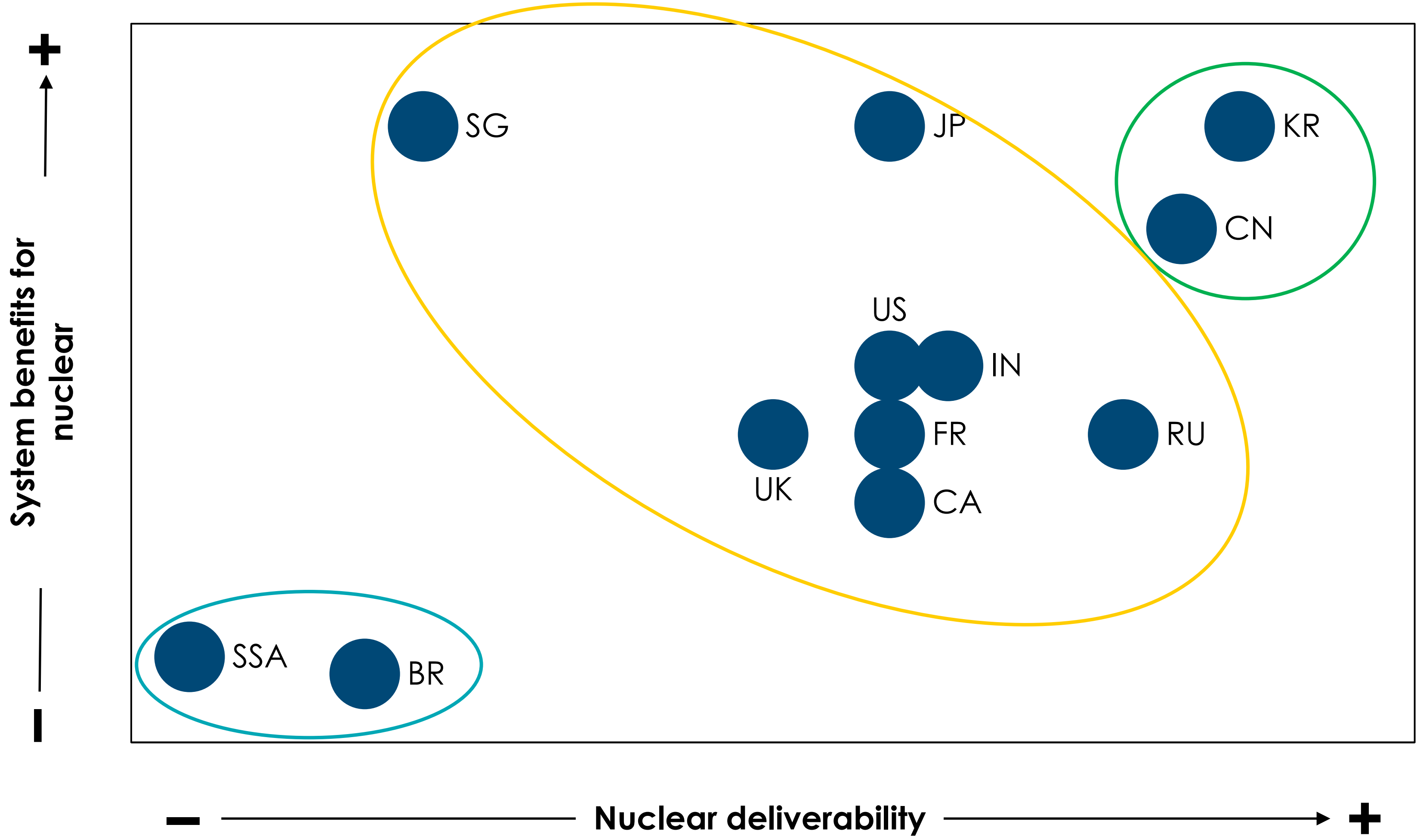
- **Supply-side constraints and falling alternative costs** suggest BNEF's 10% 2050 nuclear share may be optimistic; a ~5% scenario could be a more achievable goal
- **Solar and wind dominate across virtually all geographies** in either scenario, reinforcing that the energy transition is primarily a renewables story regardless of nuclear's outcome
- **A lower nuclear share strengthens the case for investment in flexibility, storage, and grid infrastructure** to manage the higher variable renewable penetration that fills the gap

Agenda

Nuclear deployment should be guided by energy system benefit and deliverability, not ideology

Indicative assessment of relative suitability of selected countries based on system benefits and deliverability

Low to high rating



Clear role for nuclear

South Korea, China

High system benefits; Recent low-cost delivery; Trained workforce; Institutional capacity; Higher system shares feasible

Nuclear is valuable but limited

Japan, Singapore, India, US, UK, Canada, Russia

Moderate system benefits or deliverability; alternatives likely to scale faster; nuclear limited to low shares

Limited near-term role for nuclear

Many VRE-unconstrained or hydro-rich systems

Low system benefits and deliverability; alternatives will scale faster; negligible shares of nuclear in short- to medium term

Notes: BR = Brazil, CA = Canada, CN = China, FR = France, IN = India, JP = Japan, KR = South Korea, RU = Russia, SG = Singapore, SSA = Sub-Saharan Africa (regional), UK = United Kingdom, US = United States

Clear role for nuclear: prioritise where firm capacity needs are high and programmatic build is feasible

Key countries: South Korea, China | System benefits: high | Deliverability: high | Indicative nuclear share of 2050 power mix: 10–30%

Government / Regulatory

Spatial Planning

- Strategic siting plan with pre-licensed locations (incl. existing nuclear sites)
- Grid connection planning aligned to nuclear sites
- Land use & environmental pre-assessments

Reactor Licensing & Standardisation

- Standardise 1–2 licensed reactor designs for fleet deployment
- Streamlined, predictable licensing timelines

SMR Optionality
Small-scale innovation & demo funding

Supply Chain & Workforce

- Continuous build pipelines to preserve workforce & supply chains
- Expand domestic supply chains & export capability
- Skills training & certification programmes

Business Co-investment

Decom. & Waste

- Long-term waste management & geological disposal strategy
- Decommissioning planning from project inception
- Funded liability provisions

Fleet Delivery & Co-investment

- Fleet-based construction for learning-by-doing
- Industrial heat, hydrogen & system balancing integration
- Next-gen reactors if commercial viability proven

Enabling / Cross-cutting

Regulations
Timely, predictable regulatory processes; harmonised international standards

Financing Support
Regulated financing models to sustain low-cost capital; risk-sharing instruments

System Planning
Plan nuclear within integrated energy system models, accounting for firm capacity needs and flexibility.

Guardrails
Prioritise nuclear where firm capacity needs are high and cheaper VRE alternatives cannot meet demand.

Notes: VRE = variable renewable energy

Nuclear is valuable but limited: retain as a targeted firm-power option where it adds system value

Key countries: Japan, Singapore, India, US, UK, Canada, Russia | System benefits: mid to high | Deliverability: mid to high | Nuclear share of 2050 mix: <10-20%

Government / Regulatory

Spatial Planning

- Identify locations where nuclear provides highest firm-capacity value (incl. considering existing nuclear sites)
- Align integrated strategic siting plan with pre-licensed locations

Reactor Licensing & Standardisation

- Pursue limited, standardised new build only where system value is clear
- Streamlined licensing for proven designs

SMR Optionality
Deploy only where they outperform alternatives on cost & delivery

Supply Chain & Workforce

- Retain minimum viable workforce and supply chain capacity
- Prioritise safe lifetime extensions of existing reactors
- Skills retention for targeted build programmes only
- Consider cross-country collaboration for SMR fleet

Business Co-investment

Decom. & Waste

- Long-term waste management for selective nuclear fleet
- Decommissioning planning from project inception
- Funded liability provisions; no deferred cost burdens

Fleet Delivery & Co-investment

- Accelerate VRE, storage, grids as the primary build-out
- Use regulated financing only where nuclear's system role is robust
- Integrate nuclear selectively with industrial heat, hydrogen, or constrained systems

Enabling / Cross-cutting

Regulations
Minimum viable regulatory framework; avoid over-investing in nuclear-specific regulation; harmonised international standards

Financing Support
Revenue support only where nuclear's system role is robust; avoid locking in high-cost commitments

System Planning
Plan nuclear based on residual firm capacity need after VRE, storage, and flexibility deployment.

Guardrails
Do not crowd out cheaper VRE, grids, storage; avoid one-off megaprojects without repeat-build potential.

Notes: VRE = variable renewable energy

Limited near-term role for nuclear: prioritise faster, lower-cost clean energy system pathways

Key countries/regions: Brazil, Sub-Saharan Africa | System benefits: low | Deliverability: low | Nuclear share of 2050 mix: Minimal, ~0%

Government / Regulatory

Spatial Planning

- Prioritise solar, wind, hydro, grids, and storage as core clean power pathways
- Expand transmission, flexibility, and regional power trade to improve reliability
- No new nuclear siting unless system benefits is proven after VRE deployment

Reactor Licensing & Standardisation

- Build technical and regulatory capability only if strategic optionality is later required
- Consider nuclear only where it competes on total system value and deliverability

SMR Optionality
Monitor SMRs and novel designs; avoid premature deployment commitments

Supply Chain & Workforce

- Strengthen core power-system institutions: planning, procurement, grid operations
- Focus public capital and institutional capacity on least-cost, rapidly deployable solutions
- Retain minimum viable workforce only for targeted nuclear optionality

Business Co-investment

Decom. & Waste

- If already operating nuclear, maintain safe operations with guardrails
- Reassess nuclear only if system conditions materially change
- No new waste liabilities without proven system benefits and funded provisions

Fleet Delivery & Co-investment

- Continue prioritising scalable low-cost clean power where it remains superior
- Integrate nuclear selectively only with industrial heat, hydrogen, or constrained systems
- Avoid locking into large capital commitments before system benefit is proven

Enabling / Cross-cutting

Regulations
Minimum viable regulatory framework; avoid over-investing in nuclear-specific regulation

Financing Support
Direct investment toward VRE, grids, storage; nuclear financing only where system role is proven

System Planning
Plan capacity around VRE, hydro, storage, and grids; nuclear only for residual firm-power need after alternatives are exhausted.

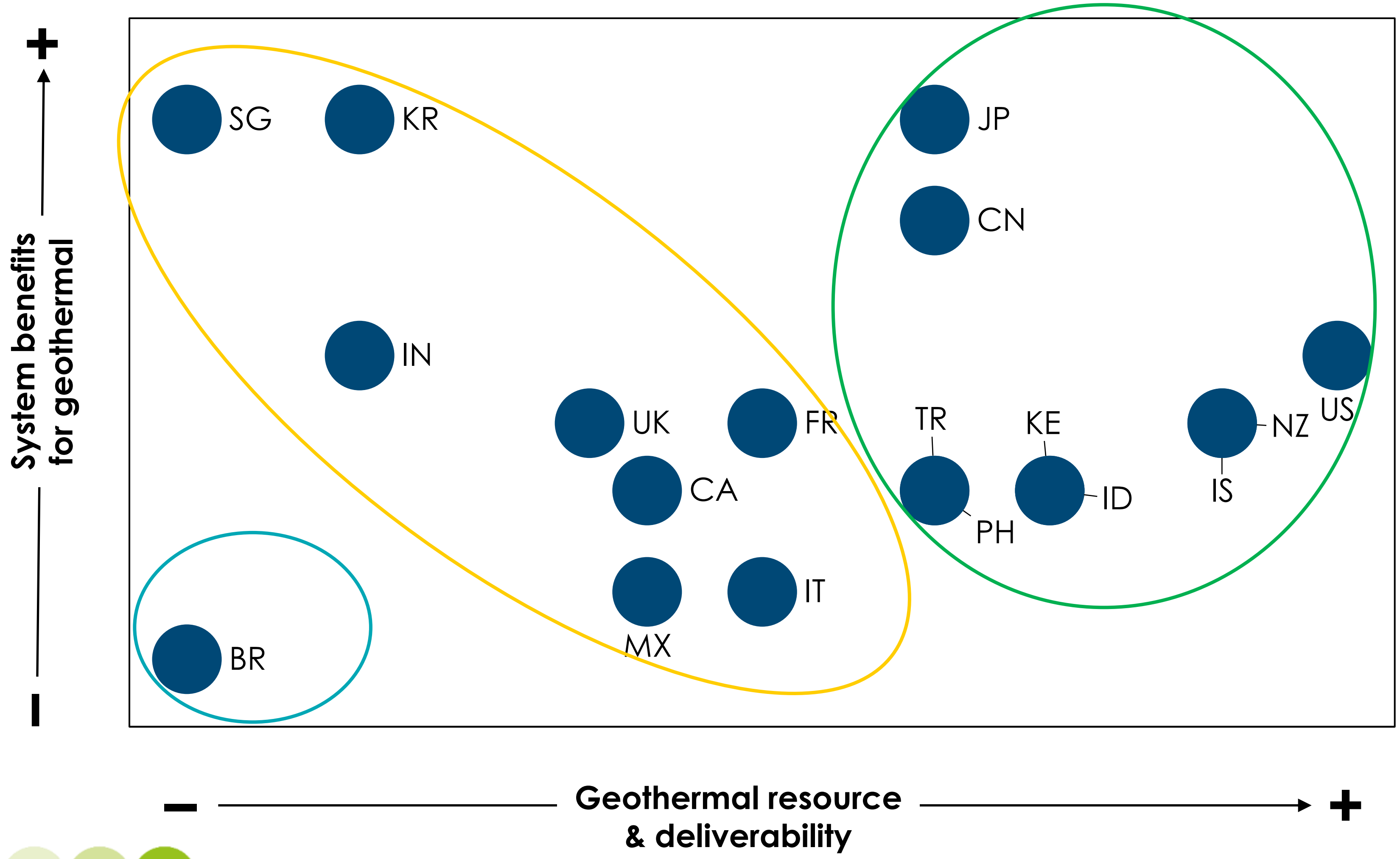
Guardrails
Do not prioritise nuclear ahead of cheaper, faster clean power options; avoid regulatory and financing burdens for projects unlikely to deliver at scale.

Notes: VRE = variable renewable energy

Geothermal deployment should be guided by system benefits and deliverability, across heat and power applications

Check IS vs US political

Indicative assessment of relative suitability of selected countries based on system benefits and deliverability
Low to high rating



Clear role for geothermal

US, Iceland, New Zealand, Indonesia, Philippines, Kenya, Japan, China

Recent low-cost delivery; Trained workforce; Aligned demand; Institutional capacity; Financing availability

Geothermal is valuable but limited

Singapore, India, Canada, UK, France

Moderate system benefits or deliverability; alternatives likely to scale faster; geo. limited to low shares

Limited near-term role for geothermal

Many VRE-unconstrained or hydro-rich systems

Low system benefits and deliverability; alternatives will scale faster; negligible shares of geo. in near-term

Notes: BR = Brazil, CA = Canada, CN = China, FR = France, ID = Indonesia, IN = India, IS = Iceland, IT = Italy, JP = Japan, KE = Kenya, KR = South Korea, MX = Mexico, NZ = New Zealand, PH = Philippines, RU = Russia, SG = Singapore, SSA = Sub-Saharan Africa (regional), TR = Türkiye, UK = United Kingdom, US = United States

Geothermal policy action framework: actions scale by resource archetype, technology type, and demand alignment

All three country classifications: Clear role | Optional | Low/no need | Technology spectrum: GSHP, UTES, Hydrothermal, EGS, CLGS, Superhot rock

Government / Regulatory			Business Co-investment	
Resource Assessment & Spatial Planning	**Permitting & Licensing**	**Supply Chain & Workforce**	**Technology Development**	**Project Delivery & Co-investment**
• Map and classify subsurface resources by heat, depth, and geological suitability • Integrate geothermal into long-term system planning, constrained by resource quality and alternatives • Ensure timely decisions on land access, grid connection, and PPAs	• Standardise permitting and licensing to reduce timelines and risk • Adapt frameworks across technology types (shallow GSHP to deep EGS) **Next-Gen. Optionality** EGS (TRL 7), CLGS (TRL 6), Superhot rock (TRL 3-5)	• Build domestic capability: subsurface, drilling, reservoir management, O&M (building on any existing O&G capabilities) • Develop shared infrastructure and skills across heat and power applications • Focus public capital on proven, deployable geothermal technologies	• Invest in conventional hydrothermal, GSHP, and UTES deployment at scale (TRL 9) where heat/cooling resource and demand align • Pilot and demonstrate EGS/CLGS for heat and power (80–300°C) • Fund early-stage superhot rock R&D (375–500°C) where geological conditions permit	• Publicly de-risk exploration via co-financing and drilling risk insurance • Enable low-cost capital access (MDBs, concessional finance) with credible risk-sharing • Prioritise bankable offtake and low-risk opportunities (brownfield, life extensions)

Enabling / Cross-cutting

Regulations
Standardise permitting across geothermal types; adapt frameworks for shallow heat vs. deep power applications

Financing Support
De-risk exploration via co-financing and drilling insurance; enable concessional finance where geothermal reduces system costs

System Planning
Integrate geothermal into long-term energy plans based on resource quality, system benefits (including heating and cooling demand), demand growth, and cost vs. alternatives (VRE, hydro, storage).

Guardrails
Do not prioritise geothermal where resource quality and system benefits are weak; avoid public assumption of exploration risk; restrict to pilots or niche direct-heat uses unless conditions change.

Notes: VRE = variable renewable energy; GSHP = ground source heat pump; UTES = underground thermal energy storage; EGS = enhanced geothermal systems; CLGS = closed loop geothermal systems; R&D = research and development; O&G = oil and gas; TRL = technology readiness level; PPA = power purchase agreement; MDB = multilateral development banks

Key messages

1. **There is growing focus on the potential role of nuclear and geothermal energy,** led by new technology development, rise in power demand from growing users (hyperscalers), and a favourable political environment.

2. **Risks related to supply chains, safety, waste, emissions and resource intensity are real** but, based on international experience, **are small in magnitude and manageable** with appropriate regulation, institutional capacity, and project design.

3. **Life extensions for nuclear should be carried out where they can be done safely**; 20-year extensions could double the remaining size of the existing fleet in 2050

4. **New nuclear and geothermal are likely to remain higher-cost than clean alternatives across most geographies,** with significant regional variation driven by financing, replicable project pipelines, regulation and resource quality; **next-generation technologies are unlikely to materially reduce costs or speed up scale-up in the near term, but may enable location-specific niche applications (e.g. new build heat and power offtake systems).**

5. **Nuclear and geothermal can deliver comparable power system costs to wind- and solar-dominated grids, if deployed at limited shares (e.g. 10–20% generation); certain geothermal applications could deliver system benefits by providing seasonal balancing to offset peak power demand.**

6. **Nuclear and geothermal do not consistently deliver greater economic or societal benefits than other clean technologies**; perceived "higher gross value-add" reflects higher capital intensity rather than superior productivity, and job creation varies significantly by country and supply-chain depth.

7. **Country deployment of nuclear and geothermal technologies should be based on a rigorous assessment of costs, system value constraints, and associated benefits and risks. While these technologies do not meet deployment thresholds in many countries, new nuclear can play a role in specific contexts** (e.g. new nuclear in UAE, next-generation geothermal in USA).