



Energy
Transitions
Commission

Emerging insights: The role of firm low-carbon power – nuclear and geothermal

10 February 2026

The ETC's "Firm-low carbon power: nuclear and geothermal" workstream is 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

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

NEXT STEPS

- Report drafting and production



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. **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).**
3. **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.**
4. **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. **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.**
5. **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).**



1. Nuclear and Geothermal have emerged as focus areas in recent years

- Nuclear and geothermal increasingly seen as “**clean firm**” power
- **Technology innovation and data-centre demand are driving renewed interest** across both technologies

Nuclear

- **Renewed political momentum:** >20 countries pledged at COP28 to triple capacity by 2050
- **Corporate buyers** (Microsoft, Google) exploring nuclear
- **Large influx of new entrants to the nuclear technology space**
- **Challenges to be addressed:** High upfront cost, long permitting, safety and waste concerns



Geothermal

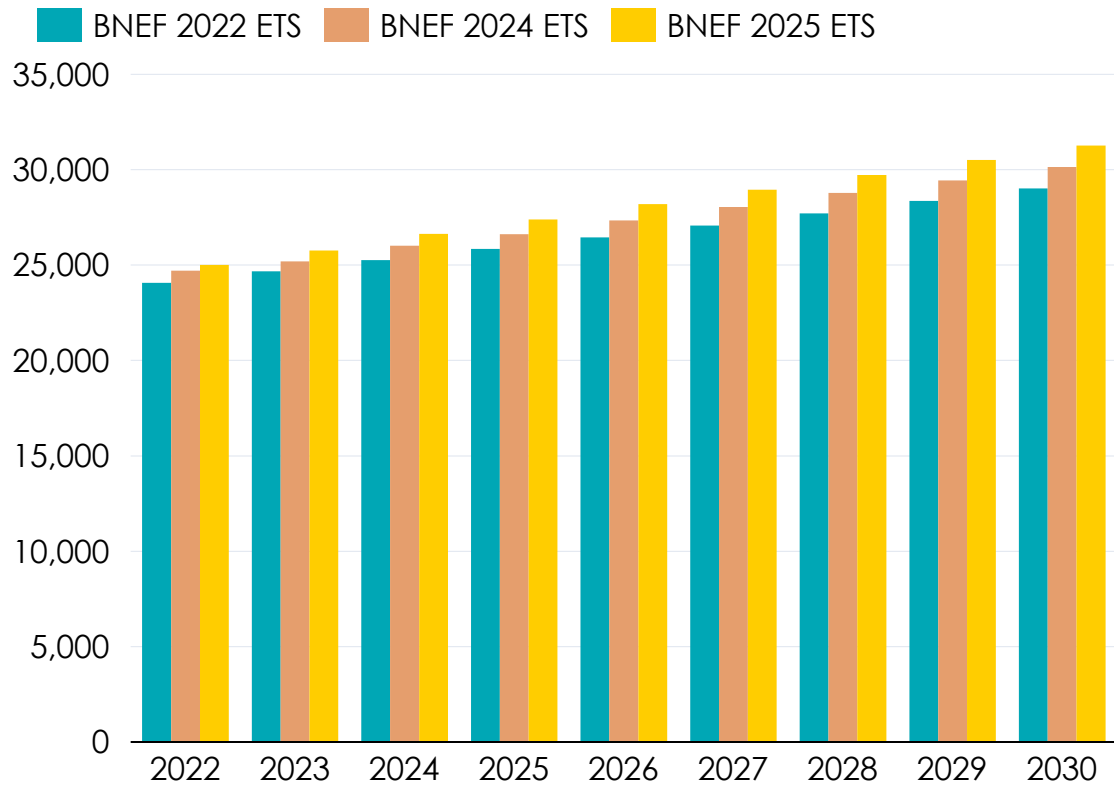
- **Expanding as a dispatchable renewable** with “always-on” potential
- **New technologies, such as Enhanced Geothermal Systems** broadening geographic reach
- **US DOE “Earthshot” programme** aiming for a 90% cost reduction target by 2035; Big Tech supporting early deployment
- **Challenges to be addressed:** Site-specific geology, drilling costs, early financing gaps



1. Power demand growth is rapidly exceeding previous outlooks; scenarios with expanded power systems show nuclear growing to maintain 10% share

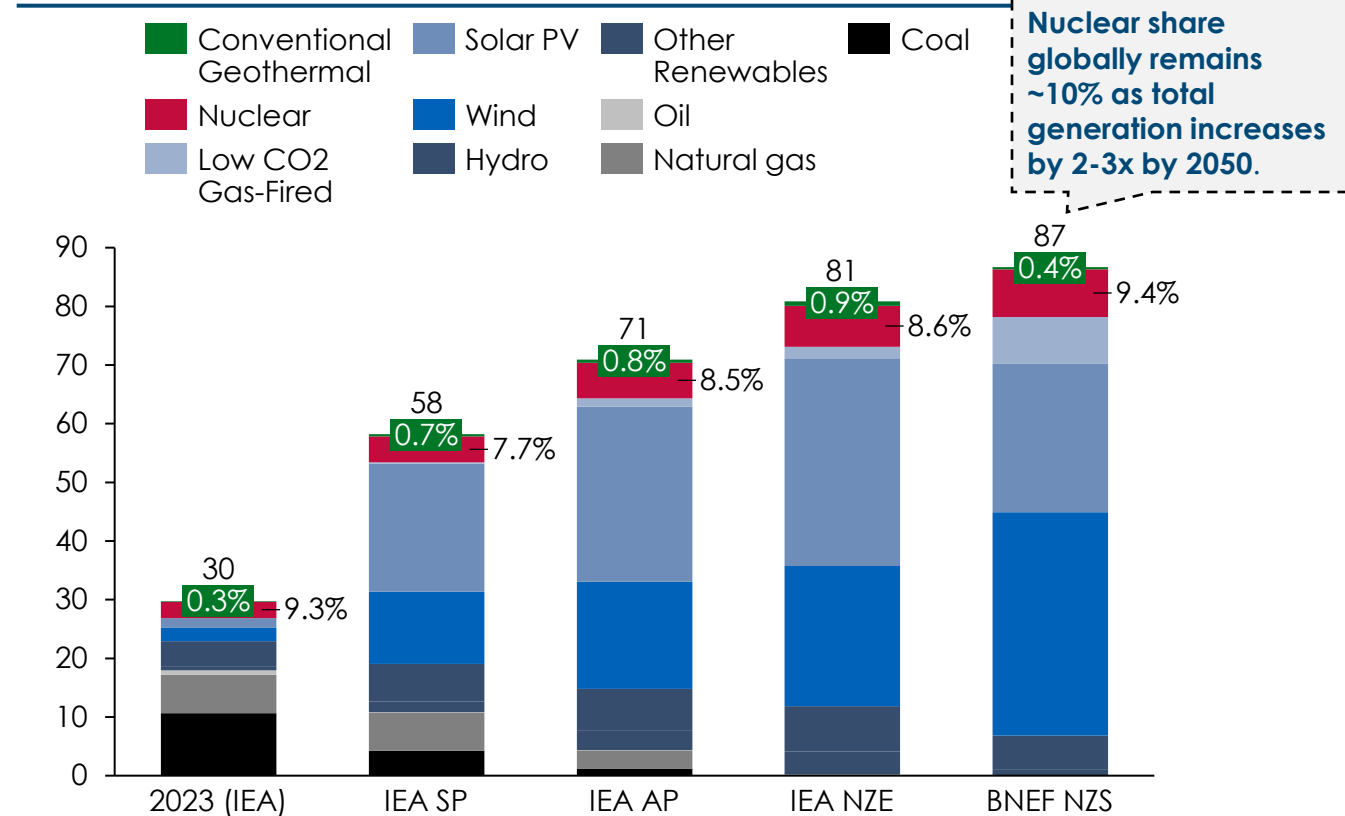
BNEF's ETS global demand projections by publication year

TWh



Global nuclear vs non-nuclear generation by scenario (2023 and 2050)

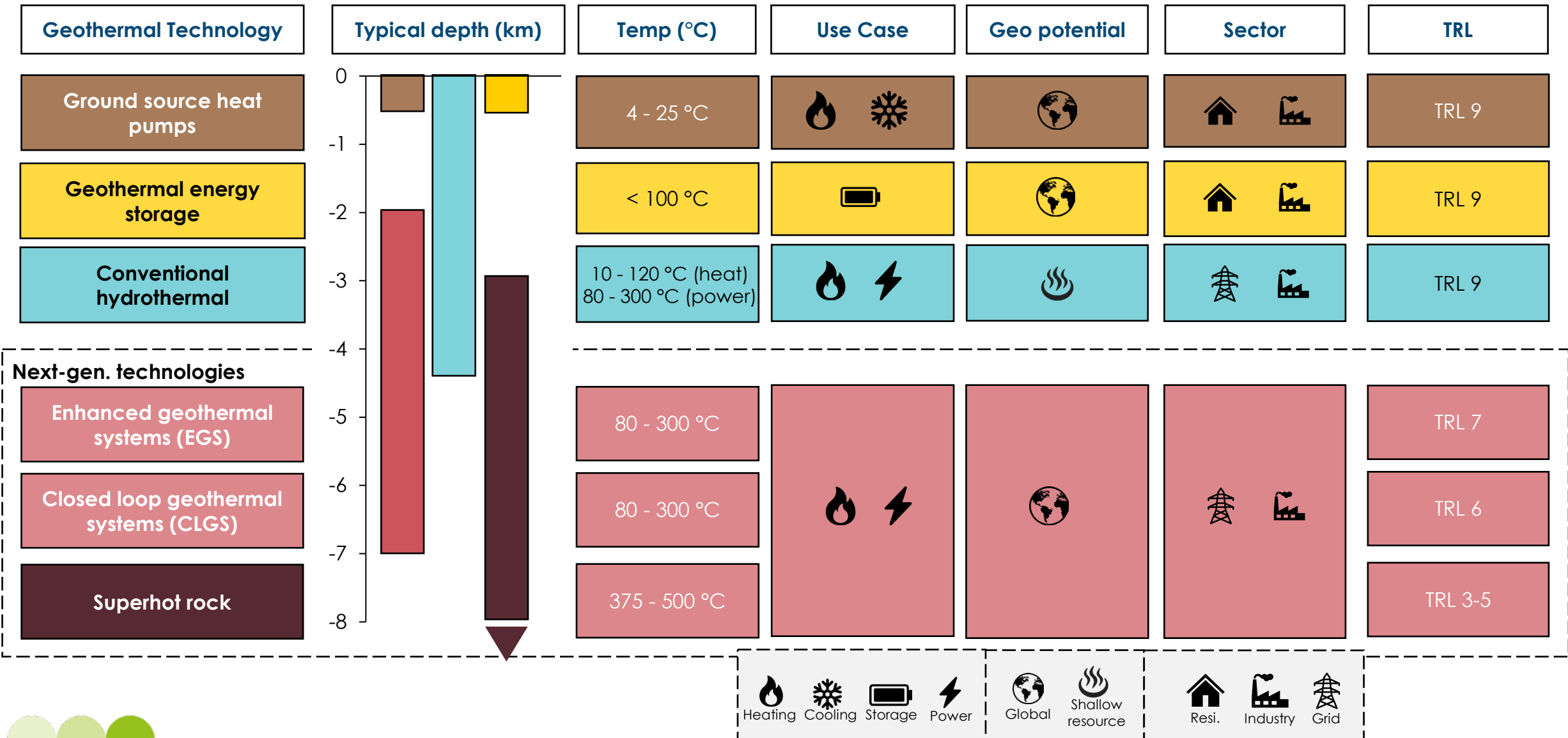
'000 TWh



Continuously increasing demand projections could require increased ambition to meet growing demand

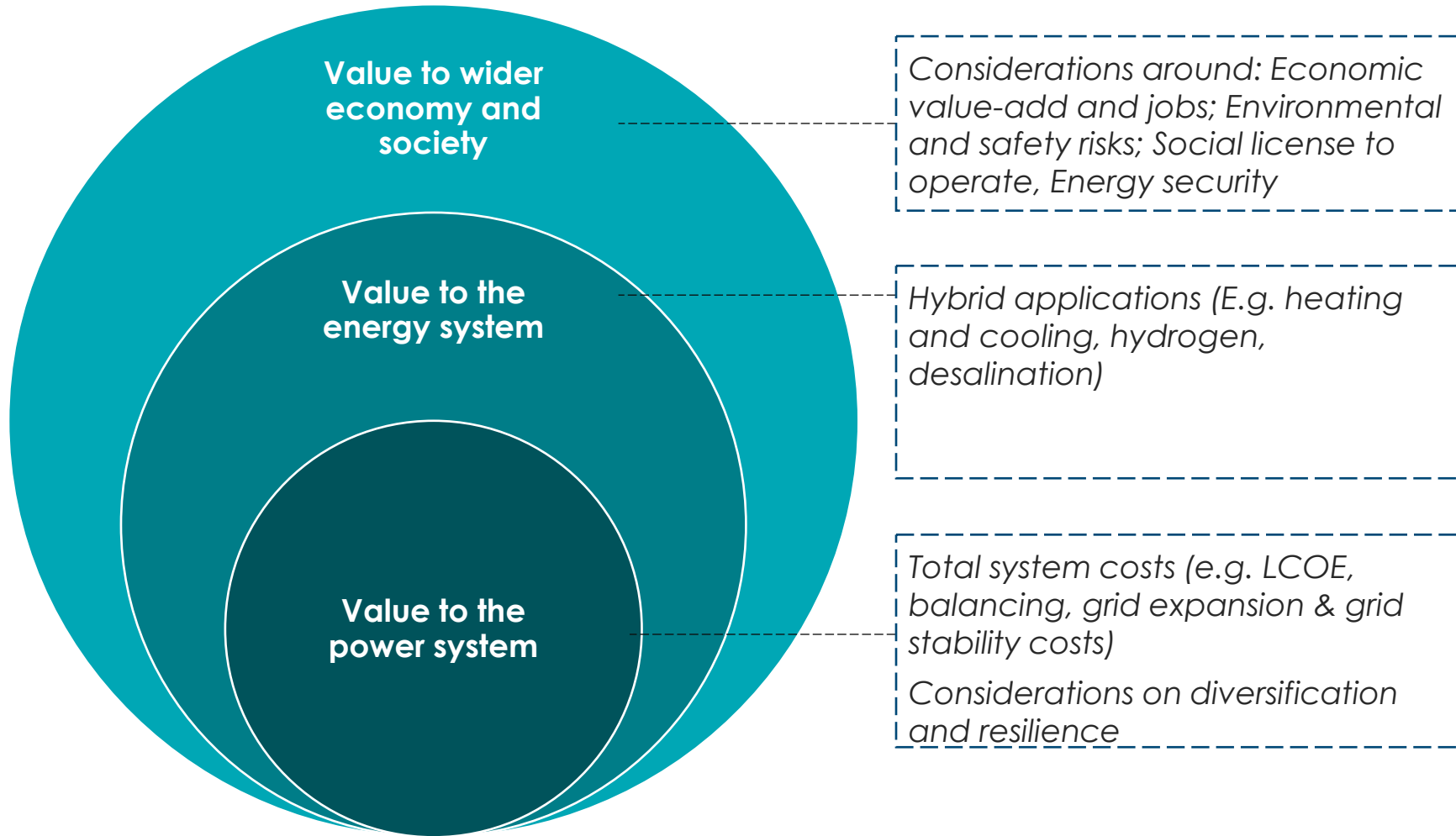
Notes: Nuclear generation includes conventional and SMR. Low CO2 Gas-Fired includes hydrogen and fossil fuels with CCS. SP = Stated Policies, AP = Announced Pledges, NZE = Net Zero Emissions, ETS = Economic Transition Scenario, NZS = Net Zero Scenario. Sources: BNEF (2025), New Energy Outlook 2025, IEA (2024), World Energy Outlook 2024

1. Geothermal energy includes power generation and direct heat provision; advanced technologies enable access to power/heat around the world



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

1. Value of Nuclear and Geothermal should be assessed holistically against other clean alternatives



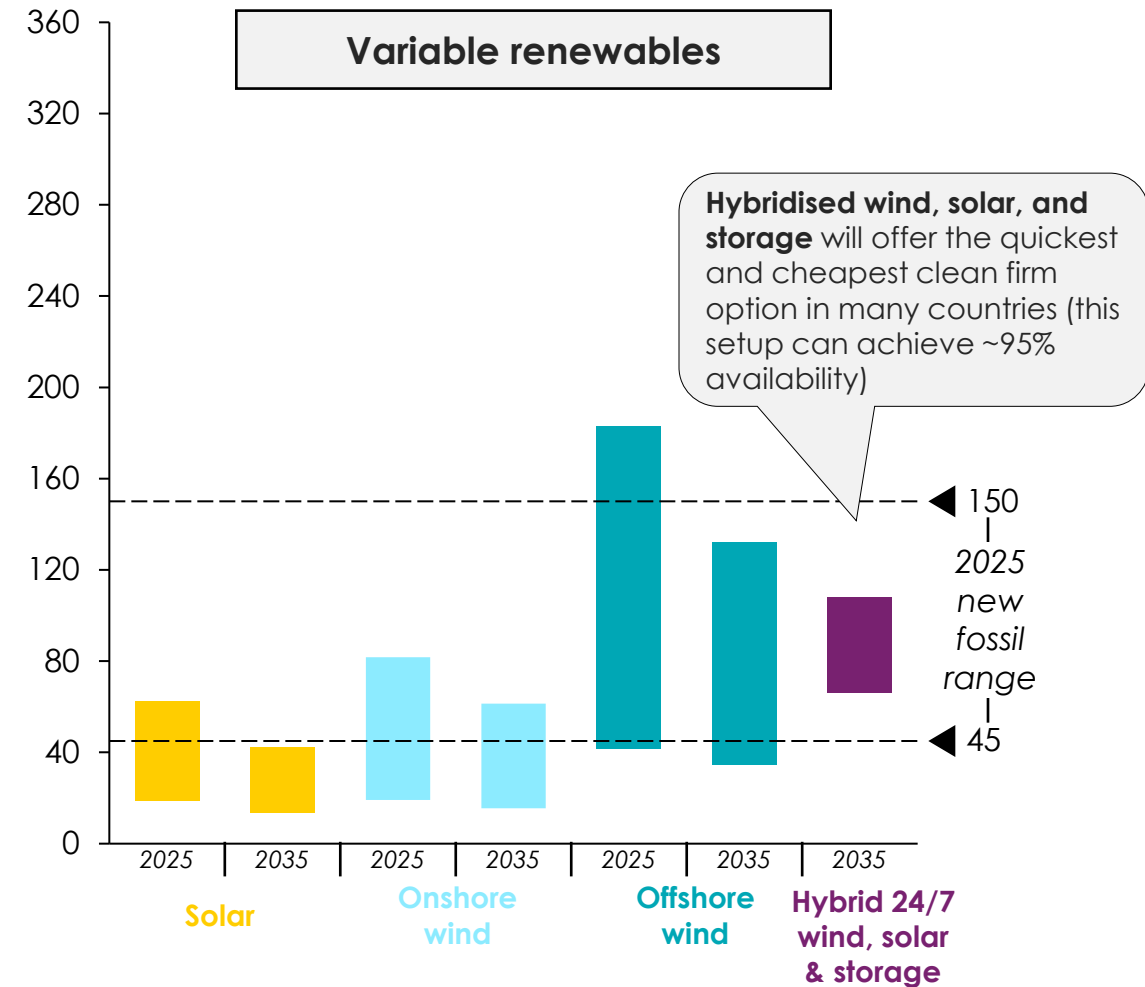
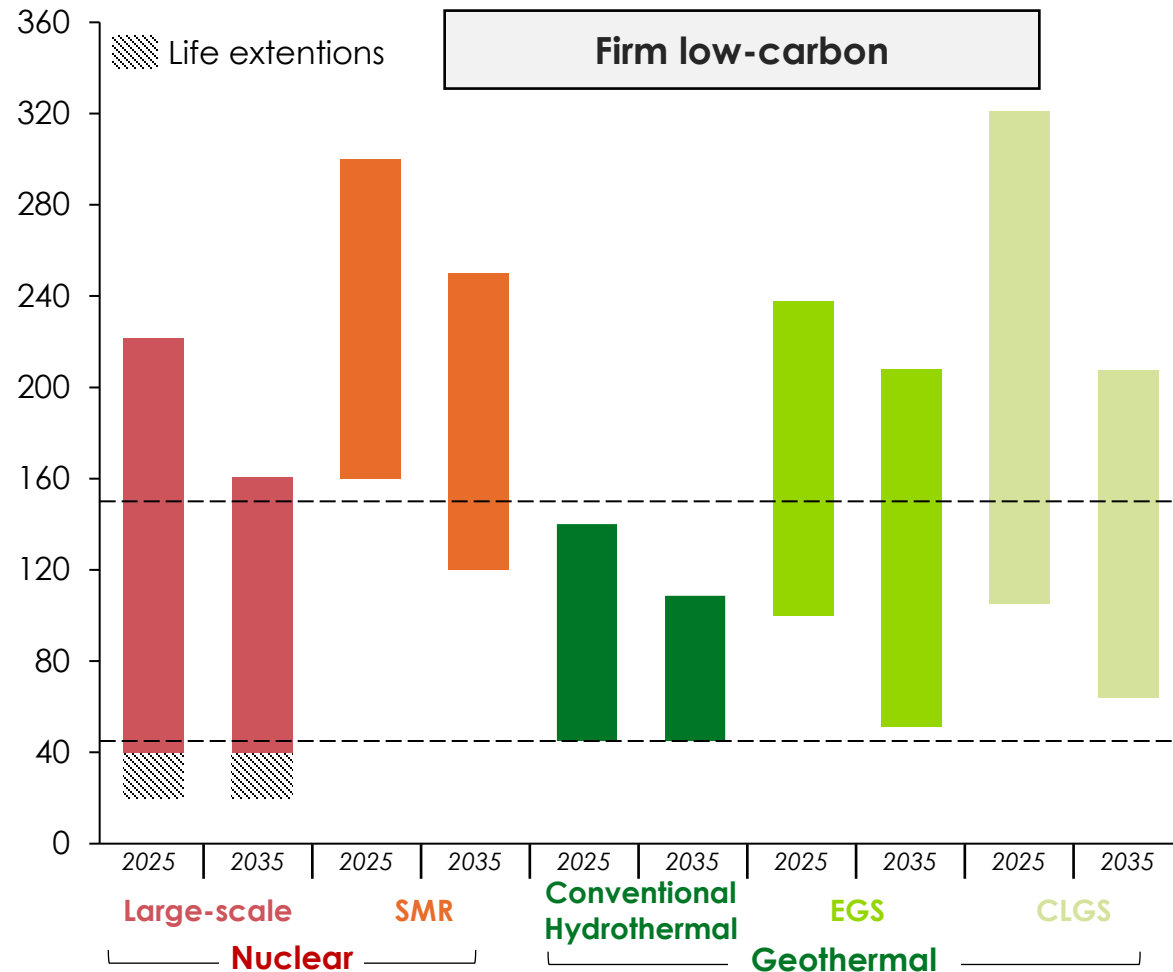
To understand how nuclear and geothermal can complement a high renewable system



2. Nuclear and geothermal 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)



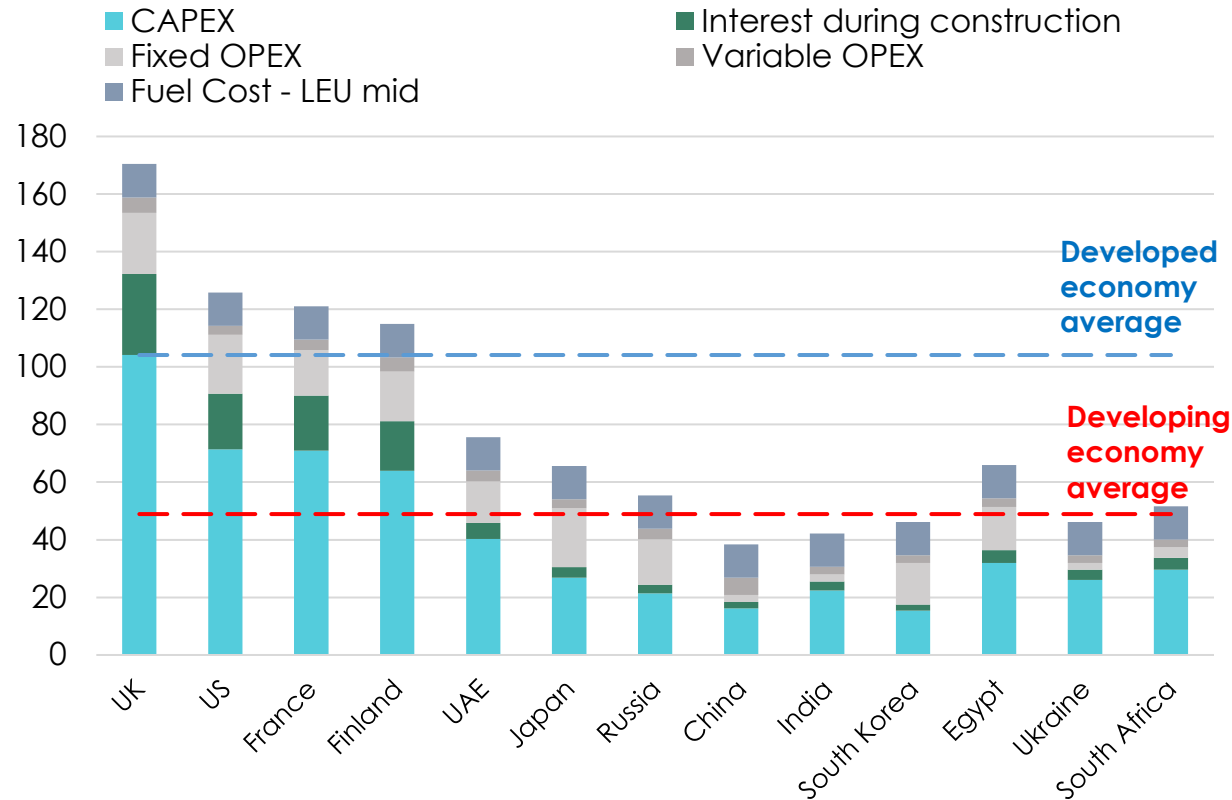
Notes: EGS = enhanced geothermal systems, CLGS = closed loop geothermal systems, SMR = small modular reactor. Life extensions only included for nuclear due to the large opportunity based on the ageing plants. Hybrid 24/7 wind & solar based on IEA 2035 STEPS estimates from China (lower bound) to the EU (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

2. Nuclear estimated LCOEs show clear divergence between US/Europe, ROW

Costs primarily driven by CAPEX and interest during construction, which vary significantly across countries

Current LCOE estimates by country, Gen III

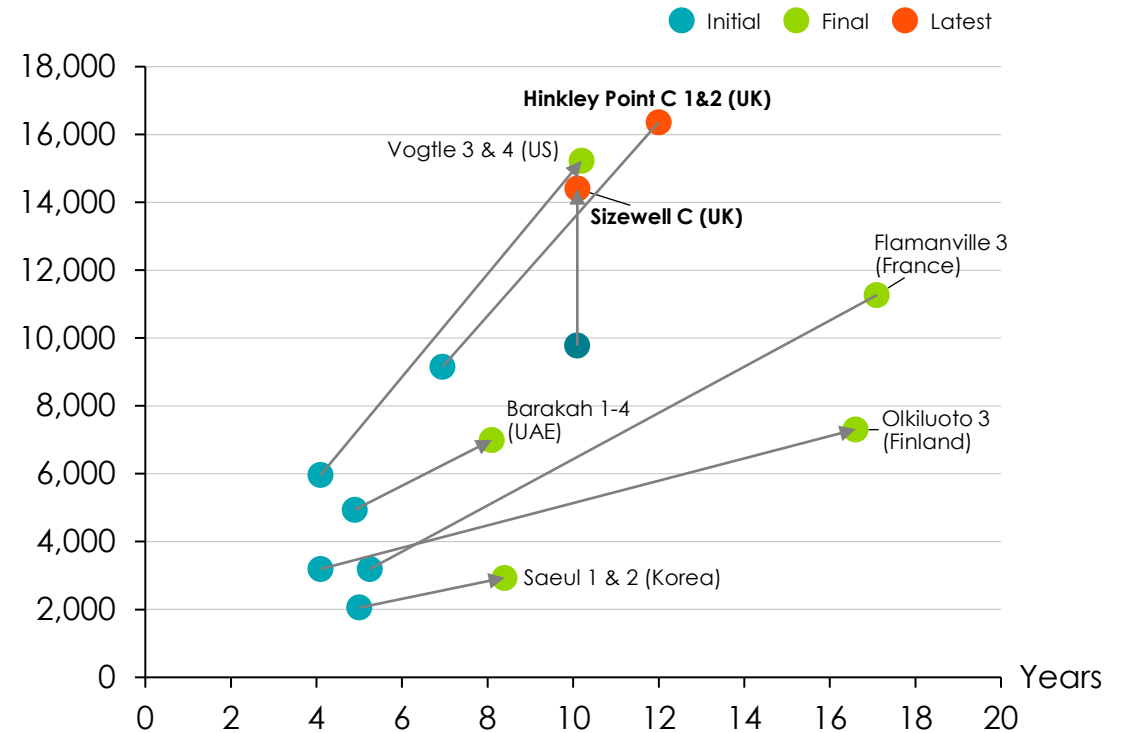
\$/MWh, real 2024



CAPEX influenced by availability of pipeline of replicable projects, project timelines, and regulatory regime

Initial and latest CAPEX estimates and construction times (Gen III+)

\$/kW, real 2024

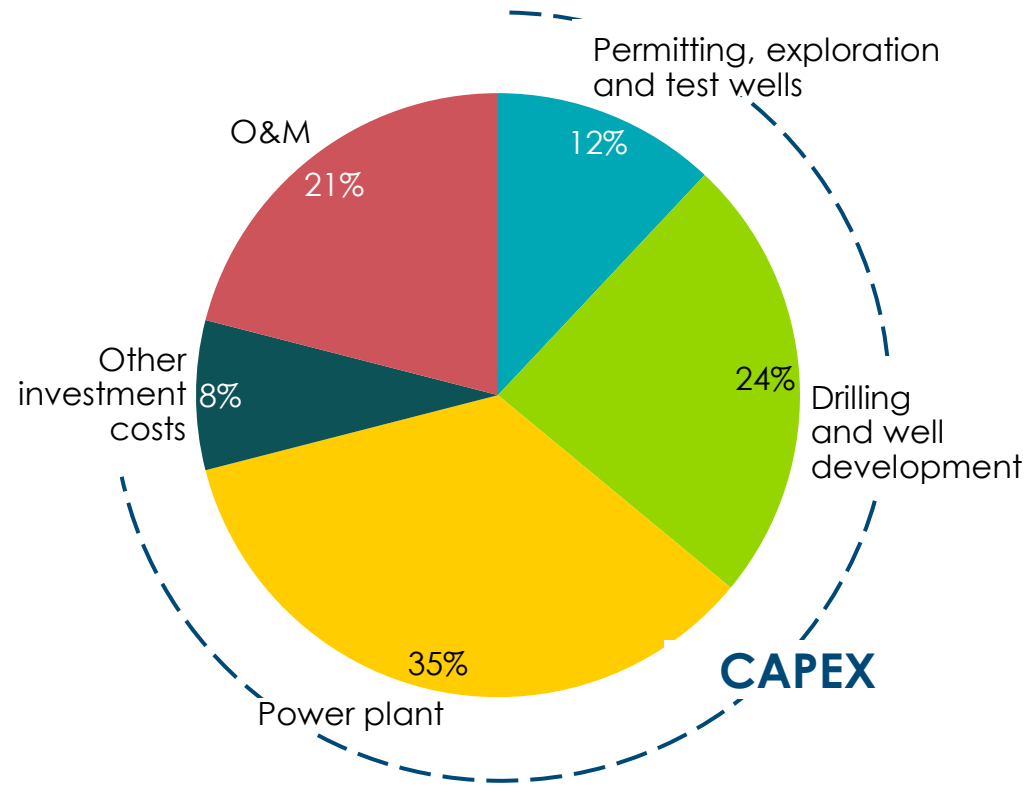


Notes: 5% WACC (real) assumed for all countries, to reflect likely government-backed loans/revenue models. Construction duration assumed to be 10y for US / Europe and 5y for RoW. Interest during construction (IDC) assumed CAPEX is spent evenly over construction duration (n), so the average interest accrues at WACC for n/2 years.

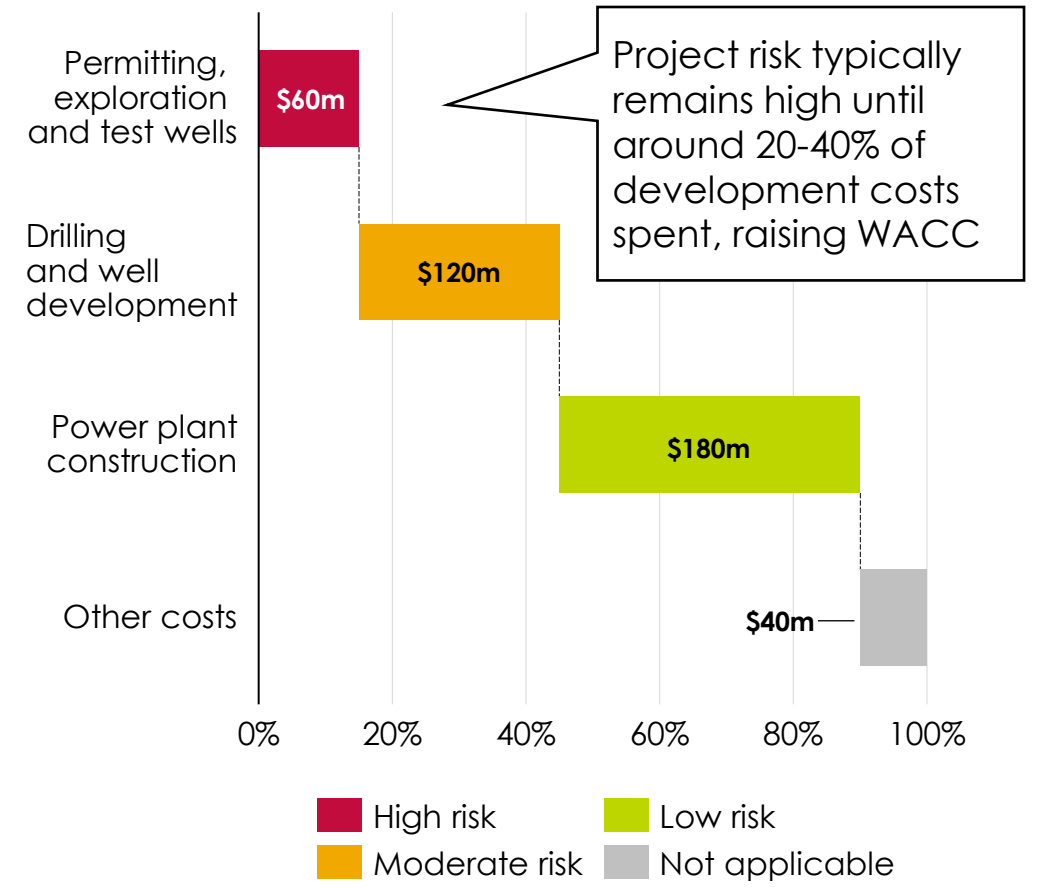
Source: Source: Energy Technologies Institute (2020), *The ETI Nuclear Cost Drivers Project*; BNEF LCOE Data Viewer, INL (2024), *Nuclear Energy Cost Estimates for Net Zero World Initiative*

2. Geothermal LCOEs dominated by CAPEX with high exploration risk, impacting WACC and project economics

Typical breakdown of conventional geothermal powerplant LCOE %



CAPEX shares and risks for plant development stages % , indicative values for 100 MW project - \$m

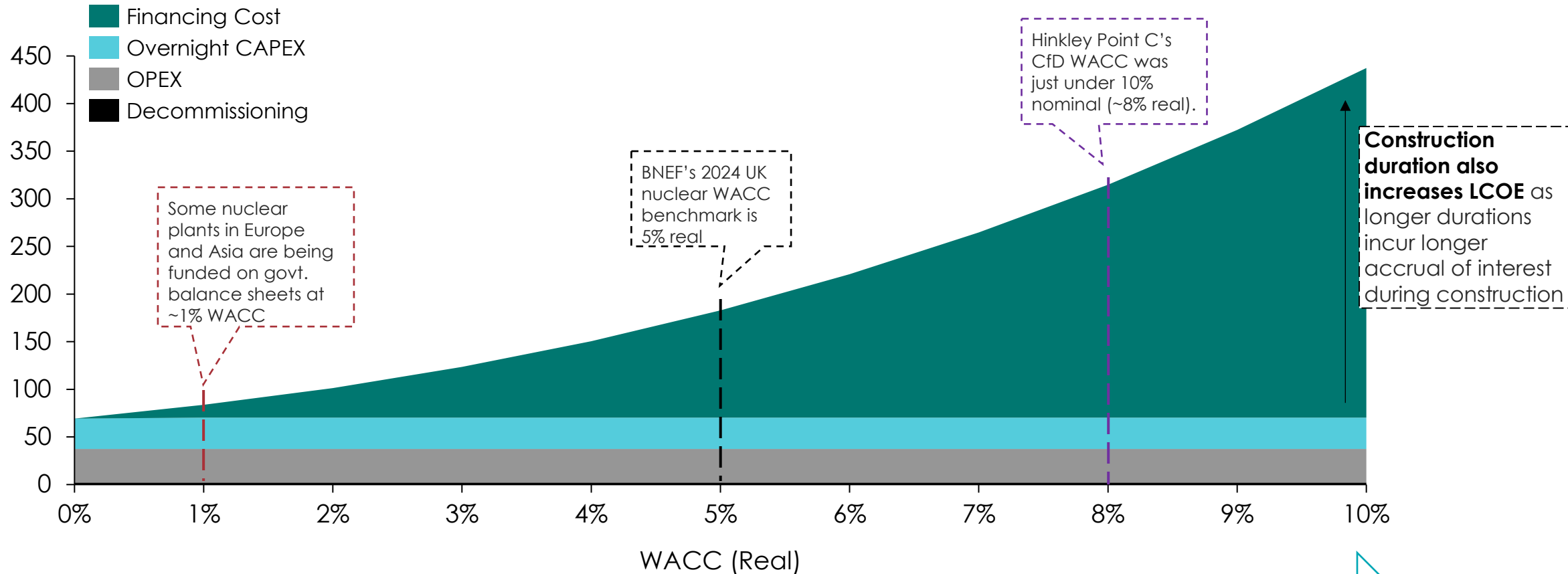


Note: Development expenditure is combined with capital expenditure (CAPEX), O&M = operations and maintenance. Risk assessments account for the possibility of cost overruns and delays due to finding geothermal resources of insufficient quality, lengthy permitting and unforeseen technical challenges
Source: IEA analysis based on data from IRENA, BNEF and NREL: IEA (2024) *The Future of Geothermal Energy*

2. The weighted average cost of capital (WACC) is a key sensitivity

Nuclear Example - UK conventional nuclear 2024 sensitivity to WACC

\$/MWh, real 2024



Higher risk = higher investor returns = higher WACC = higher LCOE

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.

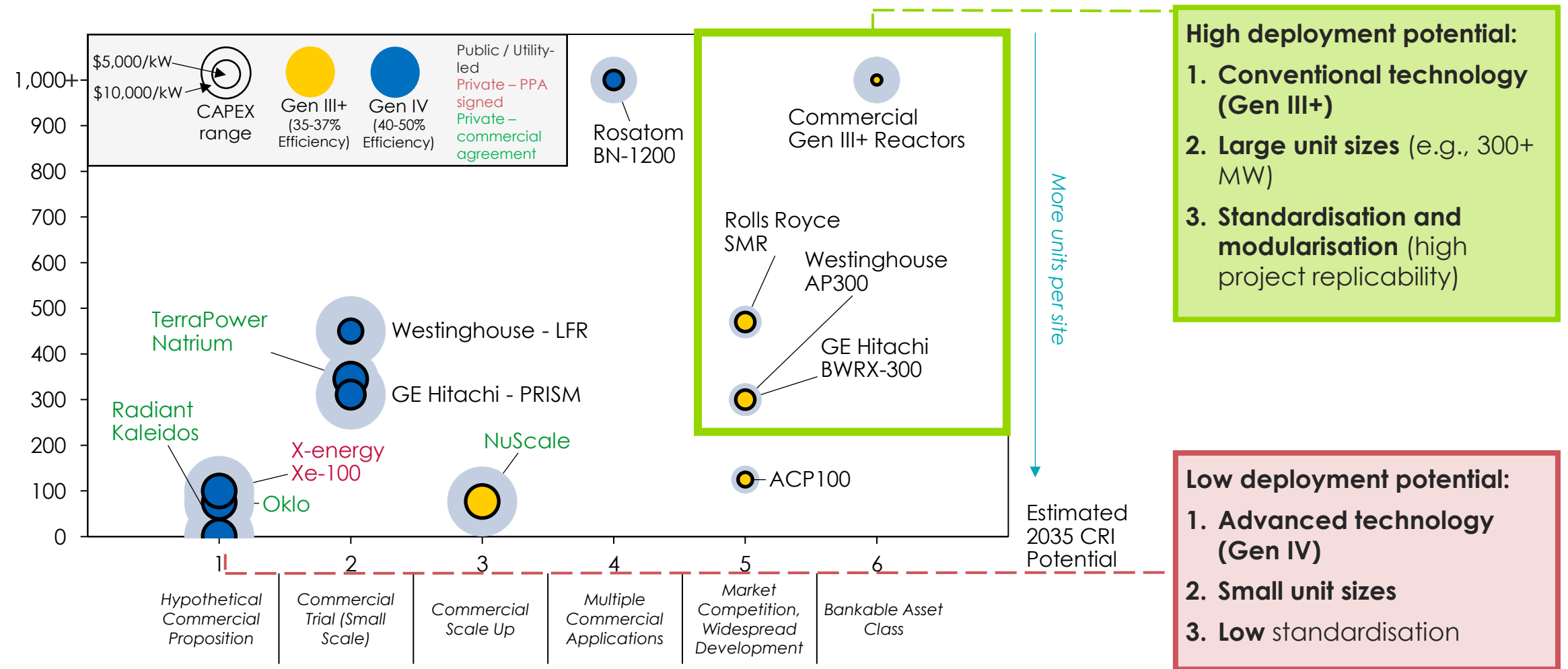
Source: BNEF (2025), LCOE Data Viewer, INL (2024), Nuclear Energy Cost Estimates for Net Zero World Initiative



2. Nuclear deployment the next decade will be dominated by designs using mature technology, large unit sizes, and standardised designs

Illustrative diagram of the unit size and Commercial Readiness Index (CRI) of selected designs

Unit Size (MWe)

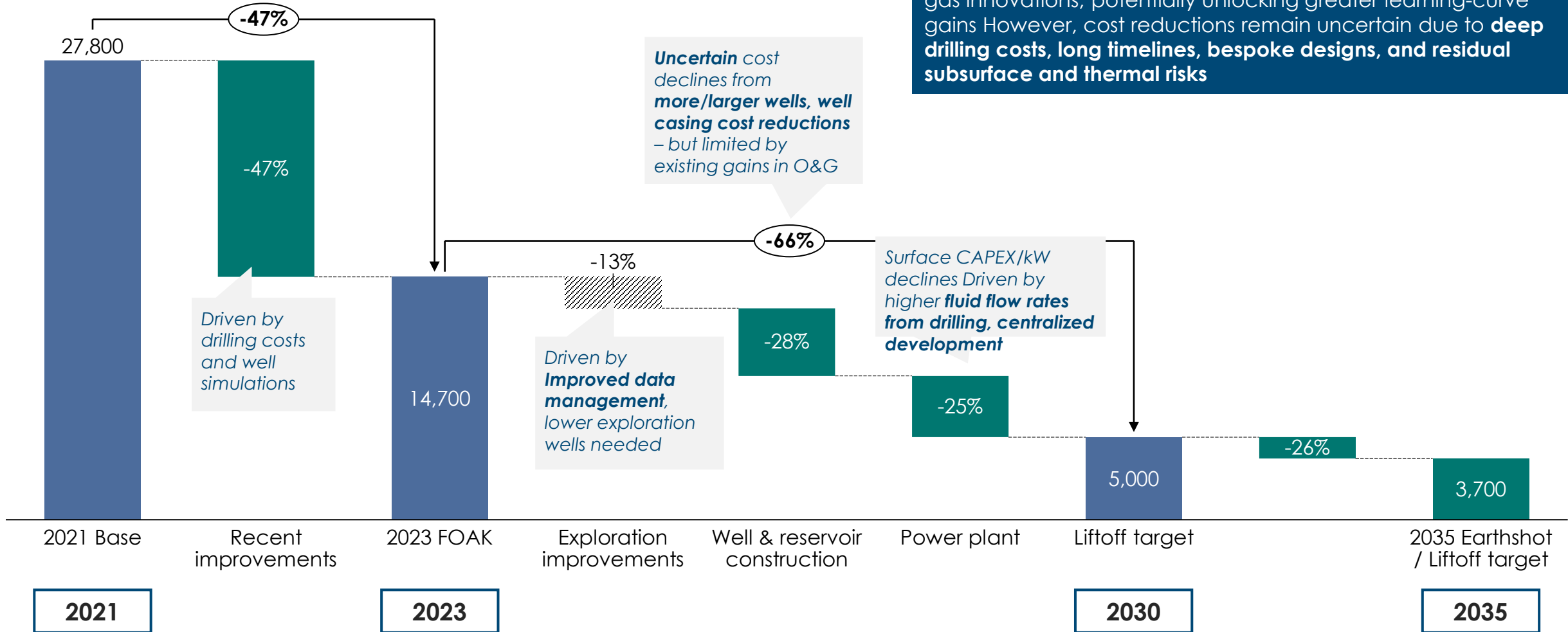


Notes: Circle diameter represents CAPEX scale. CRI 1 = TRL 2-8; CRI 2 = TRL 9. Commercial Gen III+ Reactors include reactors such as AP1000, EPR, APR-1400, HPR-1000. FOAK = first of a kind, NOAK = nth of a kind. Source: Systemiq analysis for the ETC (2025); ARENA (2014), Commercial Readiness Index for Renewable Energy Sectors

2. Next-generation geothermal potential cost declines would require significant improvements in drilling and power plant costs

EGS CAPEX decline drivers (based on US DoE data)

\$/kW_e, real 2024



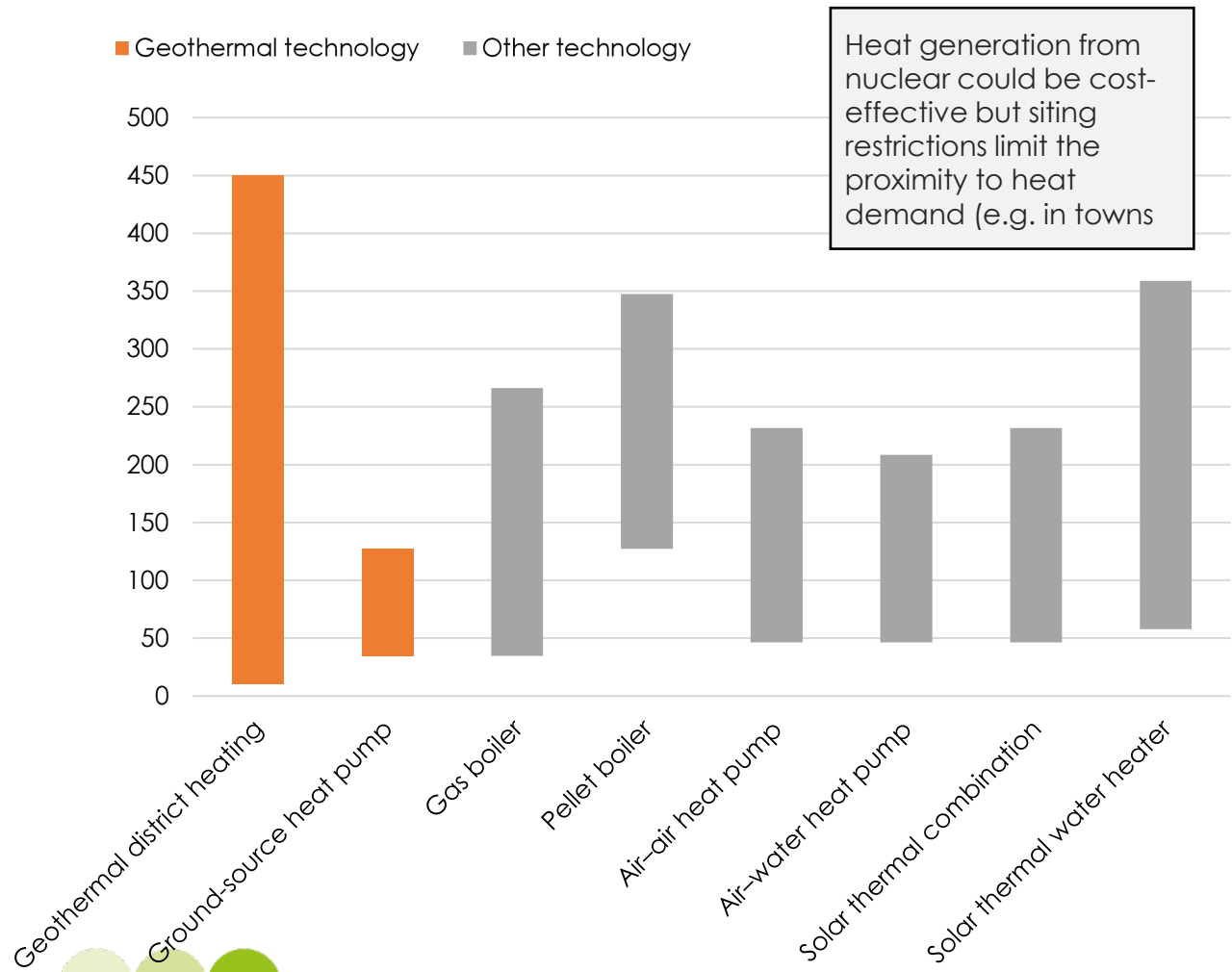
Next-generation geothermal shifts risk from subsurface uncertainty to engineering performance by leveraging oil and gas innovations, potentially unlocking greater learning-curve gains. However, cost reductions remain uncertain due to deep drilling costs, long timelines, bespoke designs, and residual subsurface and thermal risks.



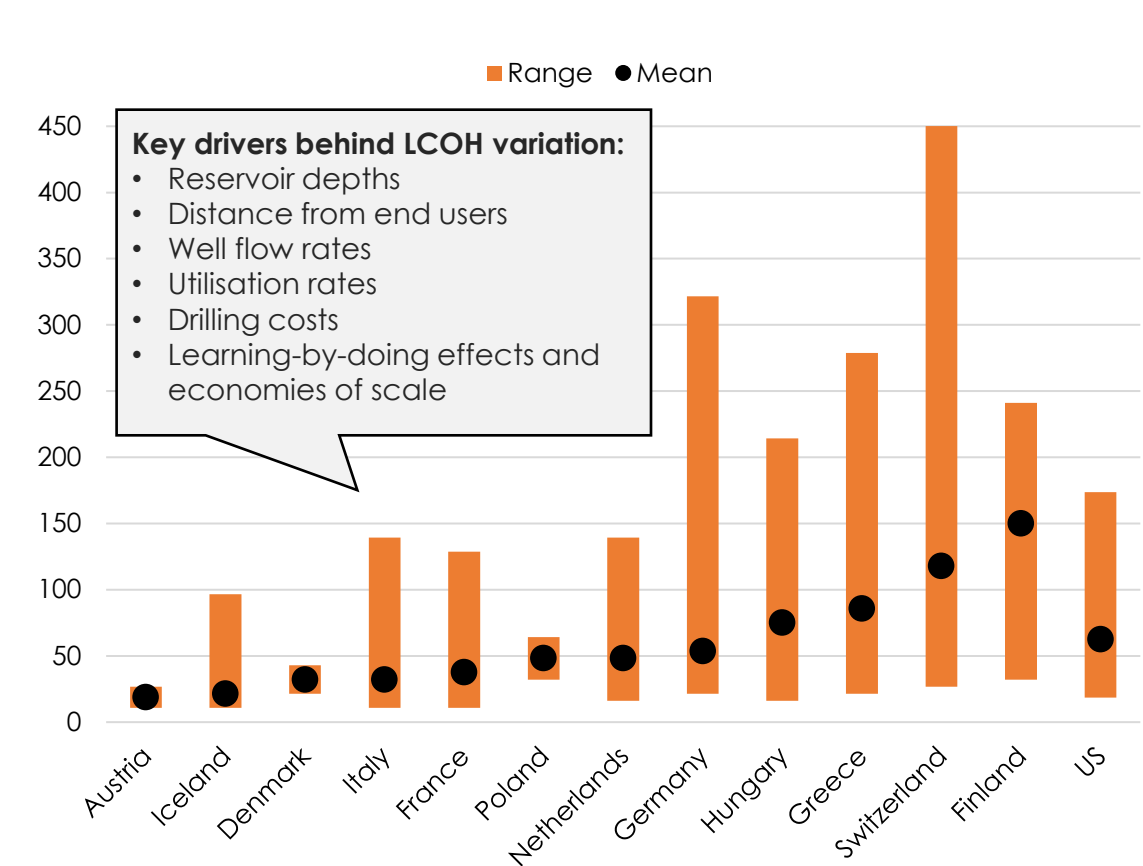
Notes: EGS = enhanced geothermal systems
 Source: US DoE (2024) Pathways to Commercial Liftoff: Next-Generation Geothermal Power Updated

2. Geothermal levelised costs of heat (LCOH) for residential uses competitive with alternatives although upfront costs higher; costs range geographically

European LCOH range by technology, representative of early-2020s costs
\$/MWh_{th} (real 2024)



Geothermal district heating LCOH range by selected country
\$/MWh_{th} (real 2024)



Note: LCOH ranges for geothermal district heating do not include network expenditure, therefore are mainly reflect drilling costs. Geothermal district heating systems typically use ground source heat pump technology. Source: KEARNEY ETI (2025), Geothermal energy, turning up the heat

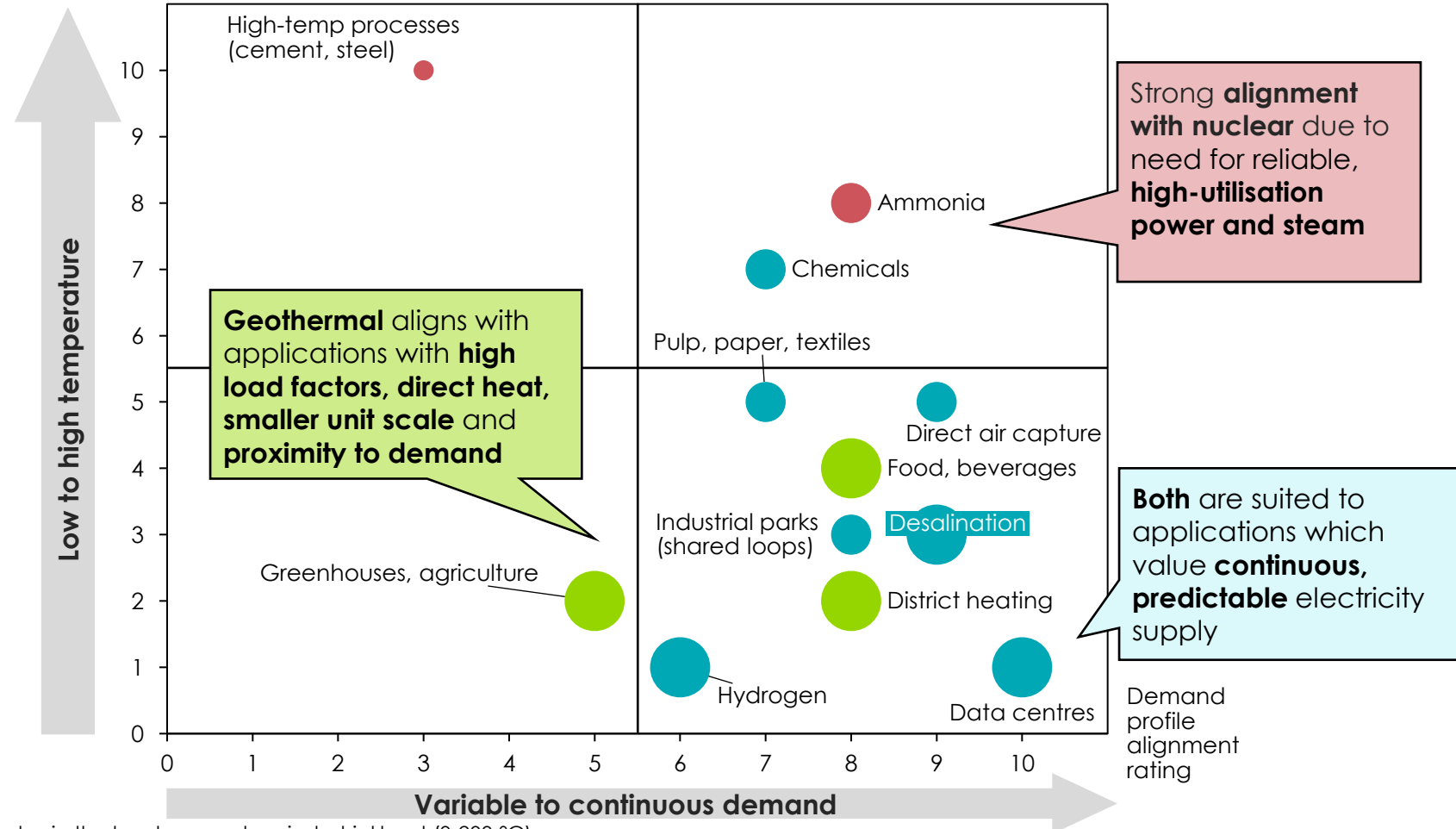
2. Next-generation technology could enable specific niche use cases

Best-fit nuclear and geothermal industrial co-location applications based on load and heat need
Temperature low to high scale (/10)



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

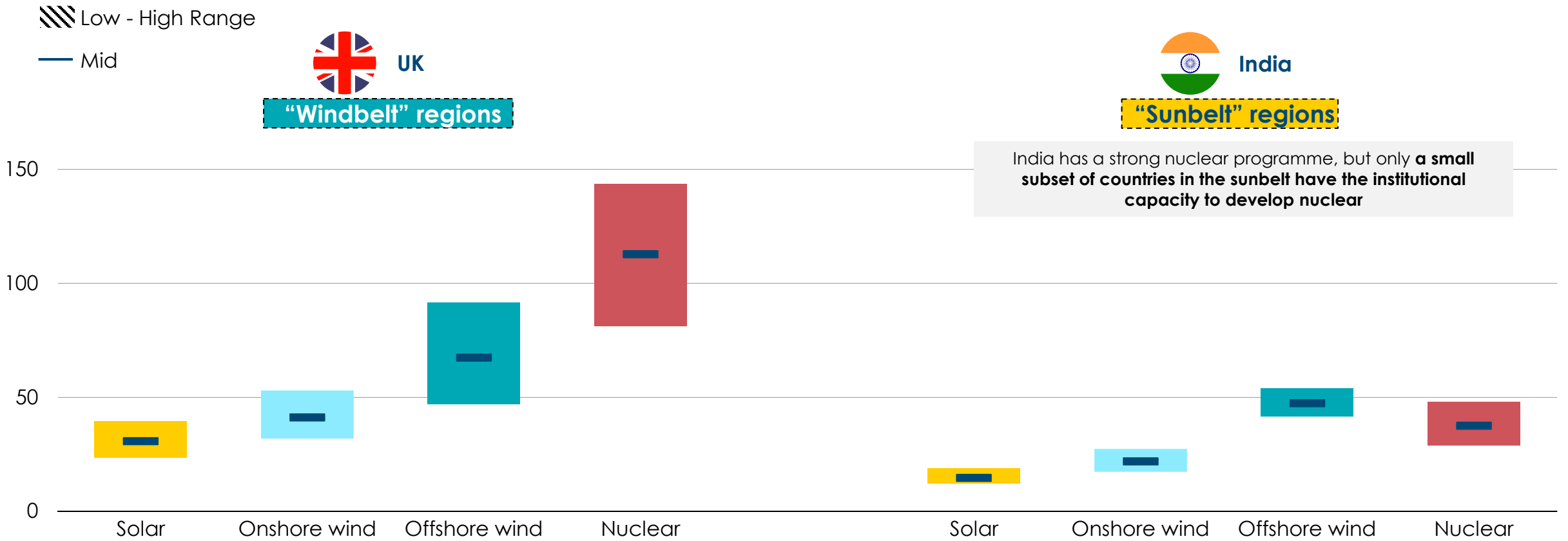
- **New build site** because of site development impacts
- **Constant load** to align with economic high load factor supply
- **Heat demand co-location** to improve project economics



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*

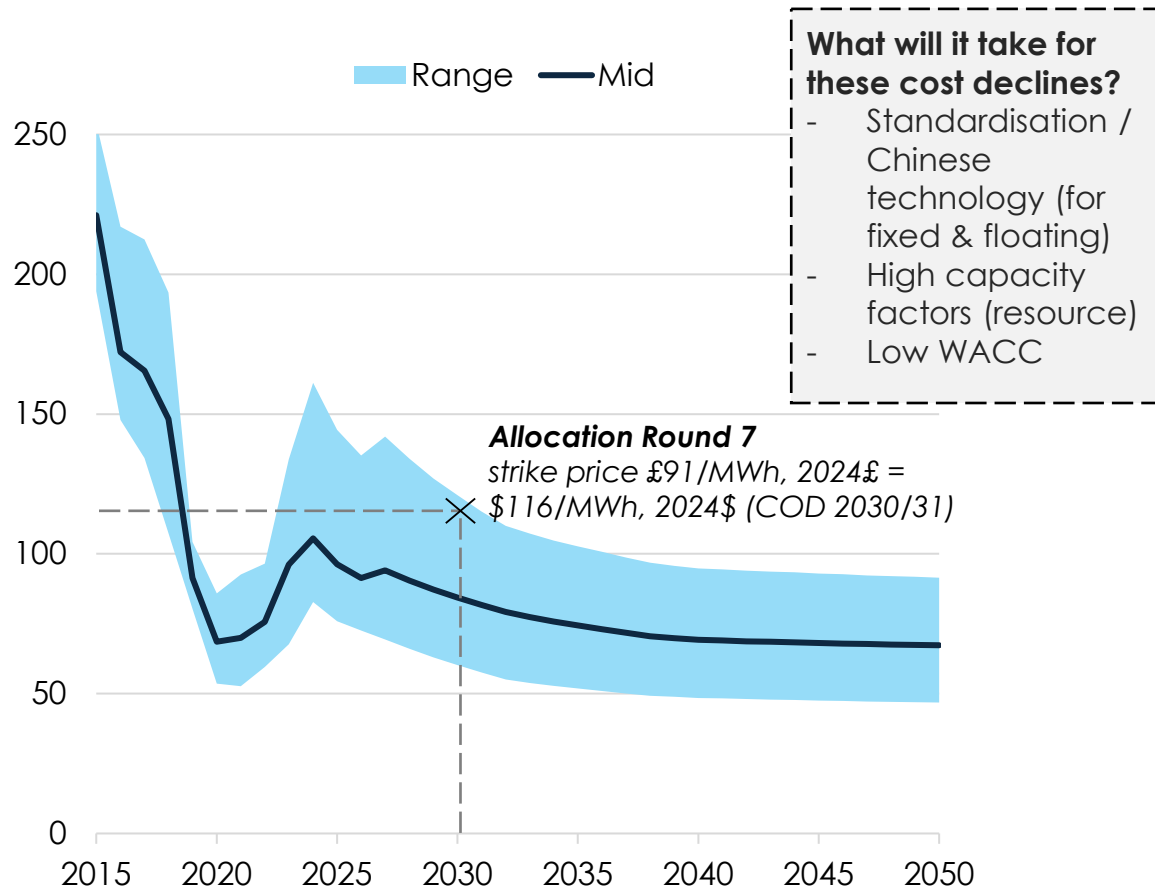
3. Technology costs differ by region ('windbelt' vs 'sunbelt')

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

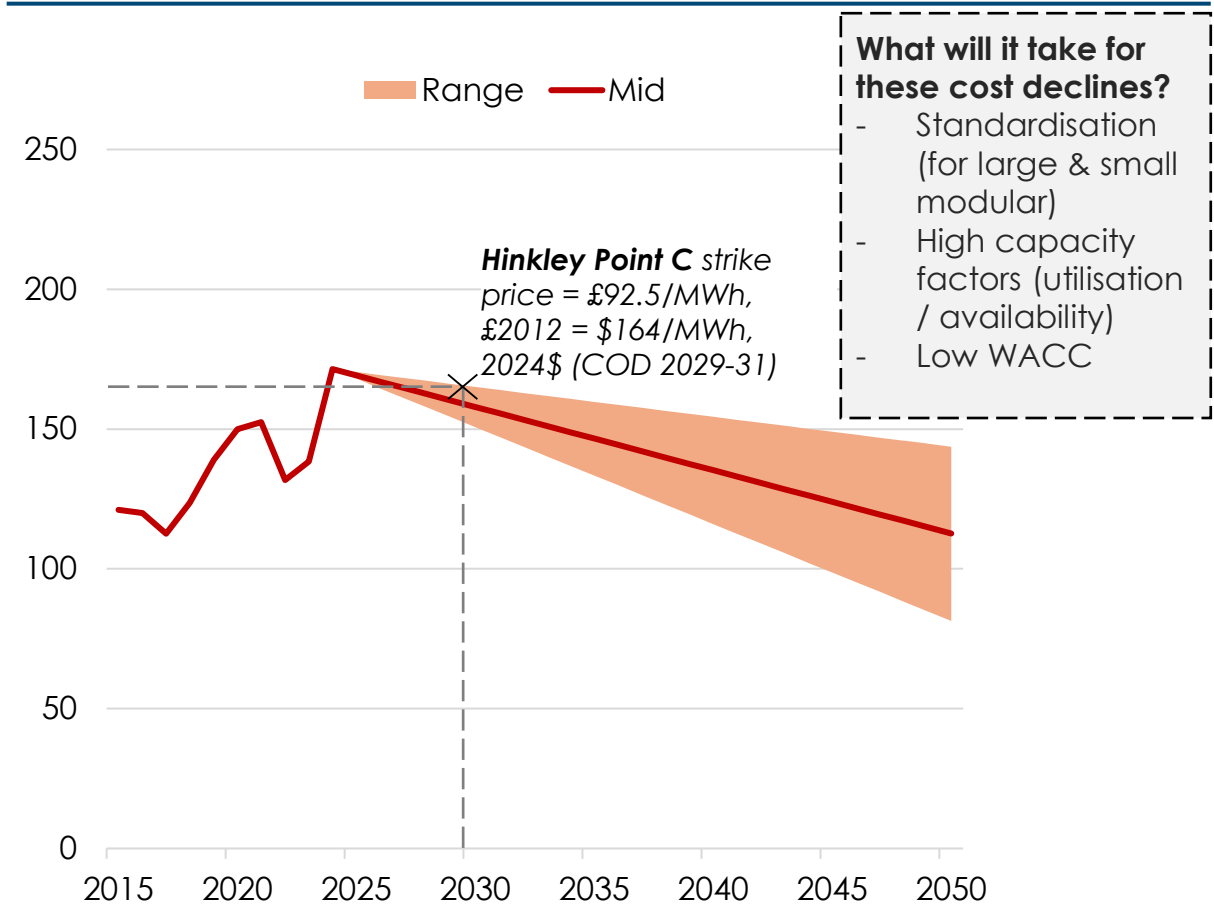


3. System cost modelling assumes LCOE reductions for both offshore wind and nuclear

UK offshore wind levelised cost of energy estimates over time
\$/MWh (real 2024)



UK nuclear levelised cost of energy estimates over time
\$/MWh (real 2024)

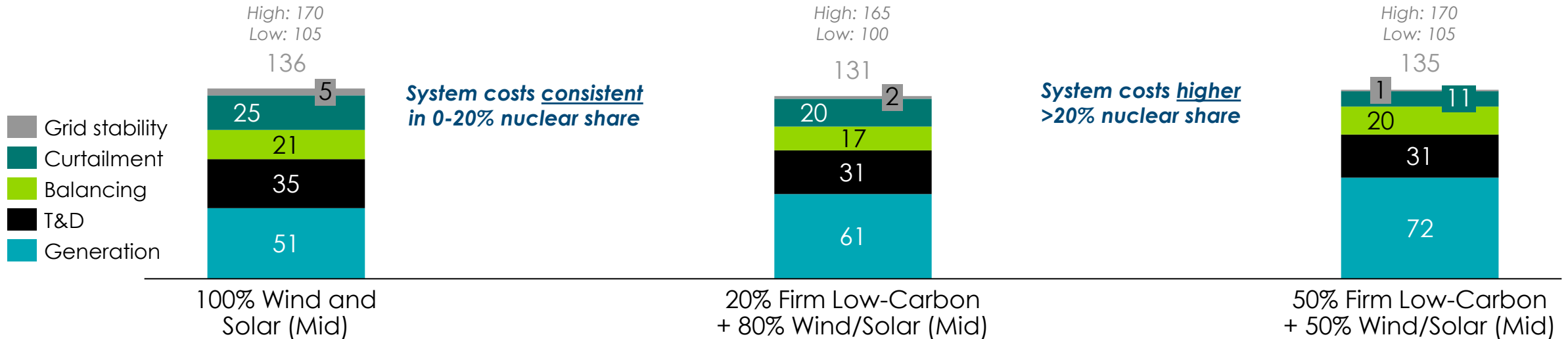


Notes: WACC = weighted average cost of capital; COD = commercial operations date. It should be noted that some of the difference between LCOE estimates and strike prices values could be explained by differences across financing assumptions, capacity factors, transmission costs, etc. Source: Systemiq analysis for the ETC (2025); BNEF (2026) LCOE Data Viewer, UK Government (2018), Hinkley Point C, UK Government (2026), Contracts for Difference (Cfd) Allocation Round 7: results

3. Firm low-carbon can deliver comparable power system costs if deployed at limited shares (e.g. 10–20% generation)

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

\$/MWh of final electricity demand (real 2024\$)



Key LCOE assumptions (mid):

Offshore wind:
 - 2024: \$110/MWh
 - 2050: \$70/MWh

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

Systems with Firm Low-Carbon...

- **Increase generation costs:** Firm Low-Carbon raises weighted average LCOE
- **Can lower (but not eliminate) balancing costs at low nuclear penetrations:** as ultra-long duration balancing needs fall; as the share of Firm Low-Carbon 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 curtailment costs:** need to overbuild generation decreases when Firm Low-Carbon is added
- **Can lower grid stability and T&D costs:** Firm Low-Carbon (particularly nuclear) can provide a wider set of grid stability services than variable renewables

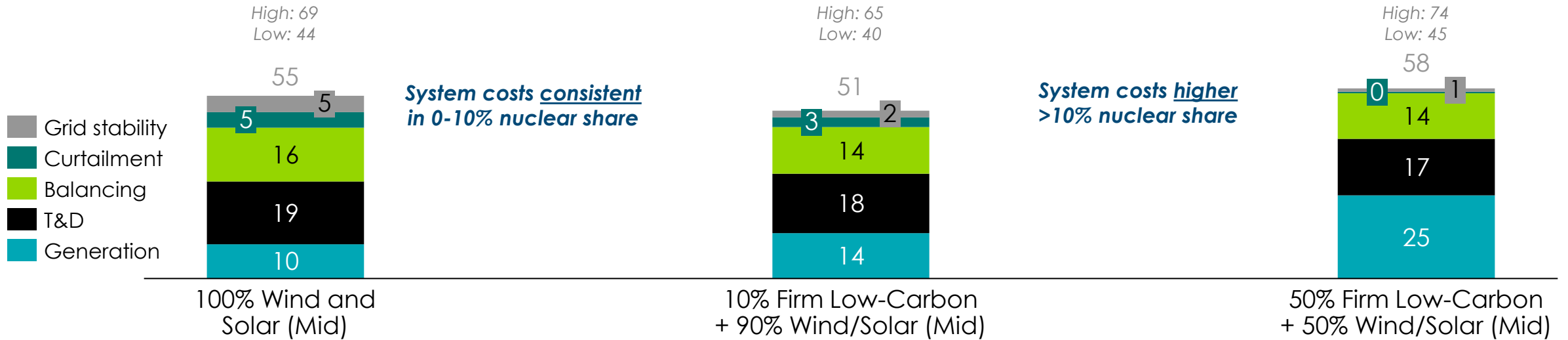
Notes: "20% nuclear" refers to the share of generation. T&D = Transmission & distribution. Sensitivities: Generation - BNEF's low, medium, and high 2050 CAPEX and OPEX estimates and assumptions for capacity factors, WACC, and lifetimes based on ETC modelling; Curtailment - surplus electricity at the 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



3. Firm low-carbon can deliver comparable power system costs if deployed at limited shares (e.g. 10% generation)

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

\$/MWh of final electricity demand (real 2024\$)



Solar:
- 2024: \$27/MWh
- 2050: \$15/MWh
Onshore wind:
- 2024: \$45/MWh
- 2050: \$22/MWh
Firm Low-Carbon:
- 2024: \$53/MWh
- 2050: \$38/MWh

Systems with Firm Low-Carbon...

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

Notes: "10% Firm Low-Carbon" refers to the share of generation, nuclear cost estimates used for Firm Low-Carbon inputs. 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



3. Geothermal shallow heat and storage applications could deliver system benefits by providing balancing or offsetting peak power demand

1) **Adoption of geothermal for heating (shallow ground source heat pumps (GSHP) could reduce strain on electricity grids peaks by flattening winter demand;** US case study shows high GSHP adoption scenario could reduce power capacity needs by 11% and transmission capacity needs by 20%.

2) **Geothermal energy storage routes could provide balancing at different durations**

- **Mechanical underground storage** could provide medium-duration (8-10h) power system balancing by turning deep rock formations into a pressure battery, but is low-maturity and uncertain costs will make competition with other, more mature storage technologies challenging
- **Underground thermal energy storage** store heat in closed-loop boreholes or open-loop formations such as aquifers and could provide seasonal storage, particularly in temperate, high-latitude countries; This could reduce the role for gas-based seasonal storage, e.g., In a **highly electrified UK energy system**, building out **20 TWh_{th} of seasonal UTES** could decrease peak winter **heating power demand by 5%** and reduce total **system costs by \$5b/year** in balancing costs and decrease average power system costs by ~\$5/MWh_e

Key tech providers:



4. Nuclear and geothermal do not consistently deliver greater economic or societal benefits than other clean technologies; risks must be managed

Nuclear

Geothermal

Economic value-add and job creation

- High GVA is driven by high costs rather than efficiency

- Impact on job creation is limited and varies based on supply chain depth
- Geothermal will not be able to absorb significant part of declining oil and gas workforce

Energy resilience and security

- Nuclear supply chain risk is concentrated in a few critical stages, most notably fuel conversion and enrichment – and there is also concentration in reactor designs and large components

- Geothermal is inherently home-grown so can form part of a secure energy mix

Safety and waste disposal

- Current nuclear waste disposal manageable and safe; long-term faces challenges as deep geological disposal faces permitting and cost challenges, political hesitation

- Effective risk management and community engagement are essential to maintain public acceptance of deep geothermal given seismicity perceived concerns

Resource concerns

- High water use in nuclear requires careful management under climate change impacts

- Some deep geothermal resource has significant CO2 emissions footprint (e.g. Turkey)

Political will

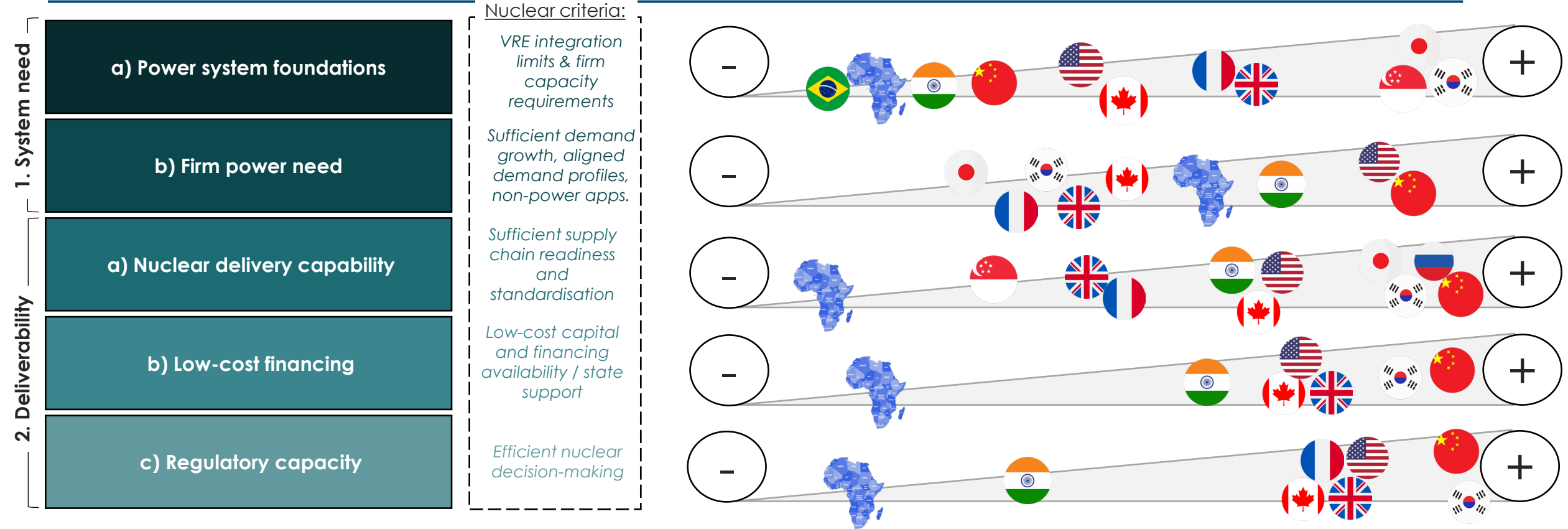
- Sustained political will crucial and highest in countries with legacy programmes

- Political will be key to developing early stage / first of a kind projects



5. Nuclear deployment should be guided by system need, deliverability, and risk, not ideology

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



Key countries
Indicative examples under current conditions

Low / no need for nuclear
Other APAC, Africa, LATAM

Nuclear is valuable but not essential
China, India, US, UK, Saudi Arabia, Canada, Russia, Germany

Clear role for nuclear
Japan, South Korea, France, UAE



Note: Regulatory capacity includes institutional credibility and public legitimacy (e.g., social license to operate).

Next steps



Workshop 3 - Key guidelines to scale nuclear and geothermal
March 2026



Report drafting with member reviews in the spring
April – May 2026

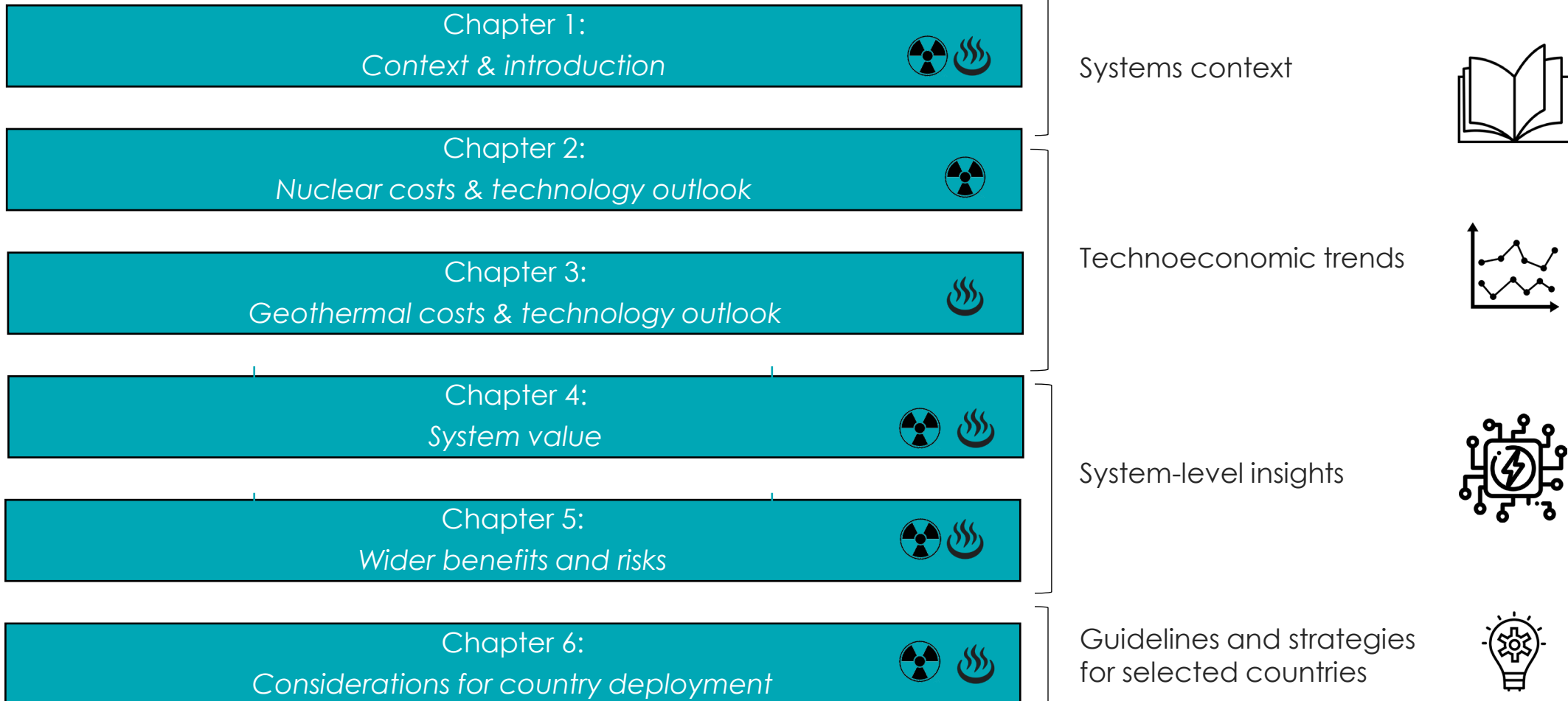


Report publication and communications campaign
Summer 2026 onwards



We propose a joint report covering both technologies

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



Notes:  is relevant for nuclear;  is relevant for geothermal

The report will be used as evidence base to address “mythbusting”, clearly laying out that the role of nuclear is important but constrained

Narrative	✓ / X	Reality
“We need nuclear and geothermal because power systems can’t run on renewables”	False	<ul style="list-style-type: none"> • Firm low-carbon power provides system value, but cost, delivery speed, and the declining costs of alternatives will limit it to ~10–20% of generation in most geographies. • ‘Baseload’ is increasingly a poor proxy for system needs.
“We need firm power for data centres and renewables can’t offer this.”	False	<ul style="list-style-type: none"> • Wind, solar, grids, and dispatchable gas (with declining utilisation) can meet reliability needs at lower cost and faster deployment timelines in many cases.
“Small modular reactors offer a game-changing route forward for low-carbon power”	Uncertain	<ul style="list-style-type: none"> • Most SMR designs lack evidence of sustained, multi-unit pipelines. • SMR size, cost, and operational characteristics remain closer to large-scale nuclear than to more modular technologies (like solar and wind).
“Next generation geothermal will unlock low-cost firm power around the whole world.”	Uncertain	<ul style="list-style-type: none"> • Significant technical, cost, and scalability risks remain. • The US has a near-term opportunity to commercialise next-generation geothermal.
“Nuclear power should be avoided, because it has security and safety risks that renewables avoid.”	False	<ul style="list-style-type: none"> • Nuclear safety and security risks are often overstated relative to safety statistics • Nuclear can play a complementary role in renewables-dominated systems where institutional capacity exists.
“Countries with an existing nuclear workforce are best off exploiting this opportunity, as this will lead to the lowest cost transition”	True	<ul style="list-style-type: none"> • The presence of an existing, trained workforce is a key enabling condition for successful nuclear project delivery.
“Nuclear delivers high employment prospects and economic growth compared to renewables”	False	<ul style="list-style-type: none"> • While nuclear projects can deliver high local employment during construction, long-term employment and gross value add are comparable to other clean generation technologies.

For discussion: plan to produce a complementary ~5 page “Q&A” style briefing note