Energy Transitions Commission

Update on Power Systems Transformation report

ETC Representatives Meeting

15th May 2025

Agenda

Key messages from the report

Member comments

Power communications plan

There are 3 key questions on power systems with high shares of wind and solar

1) Technical operation challenge

Can you operate an electricity system with high shares of wind and solar without technical challenges? Including issues with frequency regulation, voltage control, and system inertia?

2) Balancing systems at all durations

What to do when the sun does not shine and the wind does not blow? How can we balance supply and demand in a low carbon way across days, weeks, months, and years?

3) Cost concerns

Can the transition to a system based primarily on wind and solar be cost competitive, also including the expansion of the grid required?

The ETC Power Systems Transformation report seeks to answer these questions, using the following structure

1

Managing System Balancing

Meeting balancing needs as the penetration of wind and solar grows

2

Building and optimising grids

Ensuring grids can increase 2-3 times in size and modernise to support demand growth and new generation

3

Ensuring low costs

Ensuring future clean power system costs are no higher than today's

5 key technologies are critical to building and managing grids of the future

Flexible dispatchable generation

Long-distance transmission

Energy storage

Demand-side flexibility

Innovative grid technologies

What are the key features of this report?

Establishing the scale of balancing needs, informed by in-depth modelling

- An in-depth understanding of **how much flexibility renewables-based power systems will need,** based on bihourly matching of modelled supply and demand, based on 30 years of global weather data

Techno-economic overview of technology solution landscape

- Understanding of all the main **technologies** that can help balance the system, including **detailed bottom-up cost estimates** by technology & by region
- Explores ways to optimise the need for new grid infrastructure through emerging technologies, including **innovative grid technologies and demand-side flexibility**

Total system cost perspective

- Holistic approach on understanding **supply and demand side drivers** affecting the transformation of power systems
- Focuses on the **full system cost** of building and running a clean electricity system, including detailed view on generation, balancing and grid build costs

Considerations for consumers and costs

- Acknowledges **key routes to reduce costs for consumers in the near-term as well as longer-term** (E.g. demand flexibility, policy levers for wholesale market and grids)

Key messages of this report

DRAFT

1. **Clean electrification is the foundation of the transition to a global net-zero economy, with electricity providing up to 70% of final energy in 2050, up from 20% today. Power systems will need to adjust to accommodate rising demand (3x+ today's levels) and high shares of wind and solar**.

2. **It is technically and economically possible to operate and balance power systems with high shares of wind and solar (e.g. 70-80%+) through technologies existing today, delivering system stability and round-the-clock electricity. This has been proven by countries already doing this today.**

   - **Maintaining the stability of grids with high shares of wind and solar is feasible but must be met through investing in new supporting technologies** (grid forming technologies, synthetic inertia, grid services from batteries) **and procurement models** (e.g. unbundled from generation).
   - **The costs of meeting balancing needs vary significantly by duration as well as by geography, with costs being significantly cheaper in China.** Short duration balancing (< 8 hour) costs are already competitive vs fossil in some cases, meeting longer duration balancing in a low-carbon way is costly.
   - **The lowest total system generation and balancing costs will be seen in "sunbelt" countries** (~$30/MWh by 2050) due to cheap solar and batteries
   - **"Wind-belt" countries will face higher costs** (~$80/MWh by 2050) due to more expensive generation and longer-duration storage assets. Full decarbonization to provide 'ultra-long' (50+ hour) balancing with low or zero-carbon options will entail significant costs. A limited use of unabated gas (paired with carbon pricing and offsets) provides the lowest cost for consumers. Strict guidelines should limit the use of gas in only ultra-long cases.

3. **Global grid length and annual grid investments could increase by 2-3x over the next 25 years, there is a significant opportunity to decrease investments by scaling up innovative grid technologies and maximising demand-side flexibility**. Grid rates paid by consumers shouldn't materially change as electricity demand rises in tandem.

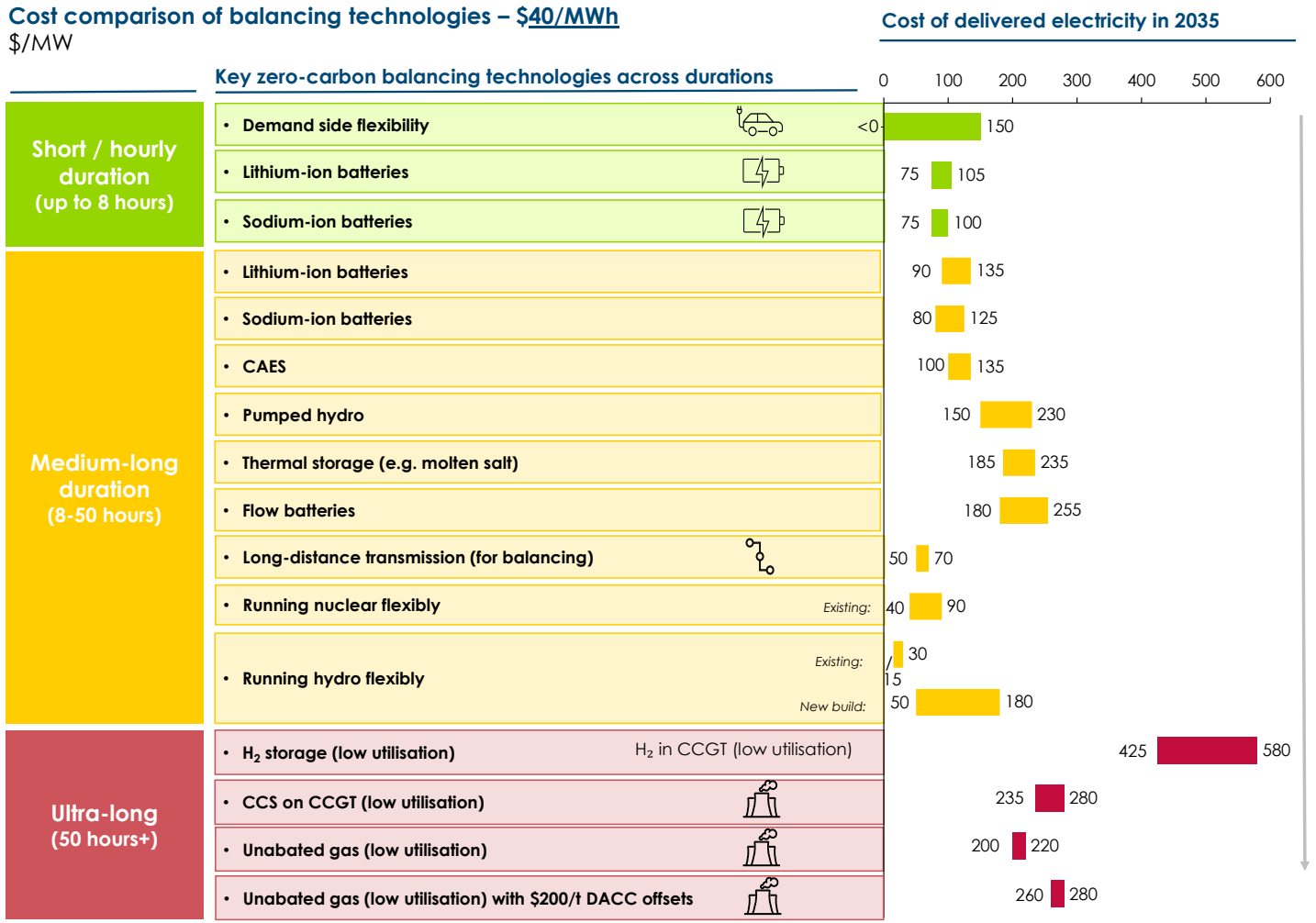
4. **In the long-term, total system generation, balancing and grid costs in power systems with high shares of wind and solar could be below or close to the cost of today's fossil fuel-based systems, and benefit from lower volatility, which is vital for energy security. In the near term, there could be rising costs associated with transition to high-CAPEX, low-OPEX generation, storage and demand-side technologies; it's critical for policy to minimise these costs.**

5. **Delivering capabilities to run clean, expanded power systems requires setting out a clear strategic vision, optimal power market design and grid regulation, the application of new grid management technologies, actions to overcome potential supply chain constraints, and key forms of customer engagement**.

Technologies exist to provide stability and balancing at different durations

			System operation	Short duration (<8hr)	Medium-long duration (8-50hr)	Ultra-long (50hr+)
Grid stability technologies		Synchronous condensers	✓			
		Inverter-based resources	✓			
Dispatchable generation	Other zero carbon	Hydro, nuclear	✓	✓	✓	✓
	Fossil	Fossil (or bioenergy) + CCS	✓	✓	✓	✓
		Fossil – low/very low utilisation	✓	✓	✓	✓
Interconnection		Accessing complementary weather patterns and time shifting generation	✓	✓	✓	✓
Energy storage		Pumped hydro	✓	✓	✓	✓
		Lithium-ion battery	✓	✓	✓	
		Other technology (i.e. CAES, liquid air, etc.)	✓	✓	✓	✓
		Power-to-X (i.e. H_2)	✓	✓	✓	✓
Demand side flexibility		EV (smart charging, V2G)		✓		
		Heating load		✓		
		Industrial load		✓	✓	

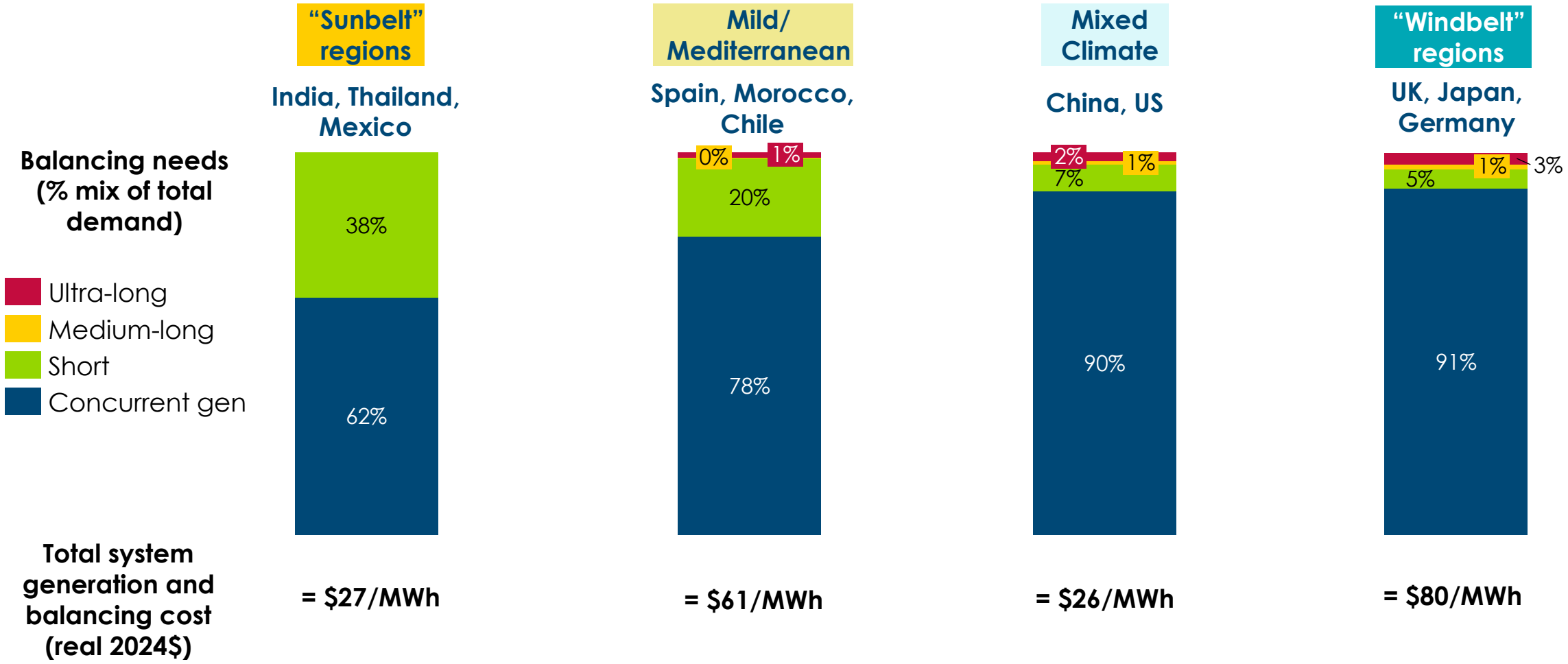
Batteries & demand side flexibility meet short duration balancing at low cost while ultra-long duration technologies are more expensive



Assumptions: The following assumptions are used for the following technologies: CCS on CCGT and unabated gas feature a utilisation rate of 5%. Hydrogen based on a 5% utilisation factor for OCGTs and a 20% electrolyser utilisation rate. Interconnectors: assume no electricity cost input. Source: Systemiq analysis for the ETC (2025); BNEF (2024) Energy Storage System Cost Survey; (2024) Long duration energy storage cost survey; PNNL (2025), Pumped Hydro Energy Storage; BNEF (2024), Electrolysis System Cost Forecast 2050: Higher for Longer, BNEF (2025), LCOE Data Viewer, Liu et al. (2021), Development status and prospect of salt cavern energy storage technology.

System balancing and therefore costs varies in sunbelt vs. windbelt regions

Balancing needs and costs differ by region and resource type:

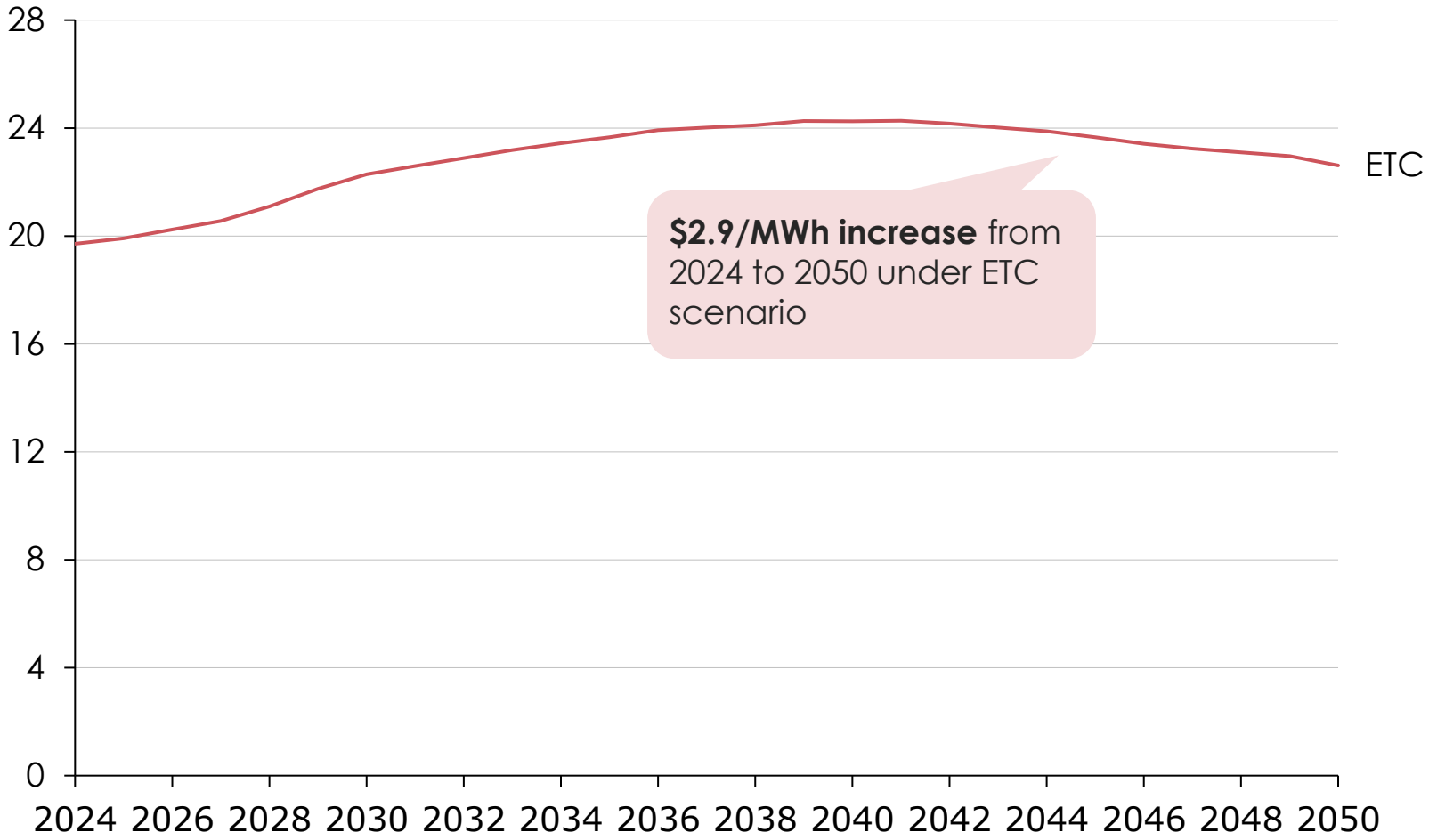


Source: Systemiq analysis fore the ETC (2025)

Grids will need to expand, optimisation is key: costs per MWh will only increase slightly to 2050, but can be reduced if we maximise flexibility

Grid Capex costs (transmission & distribution) per demand unit, global, 2024–2050

$/MWh (real 2024$) for payments per electricity demand; interest rate = 5%; 30-year repayment timeline



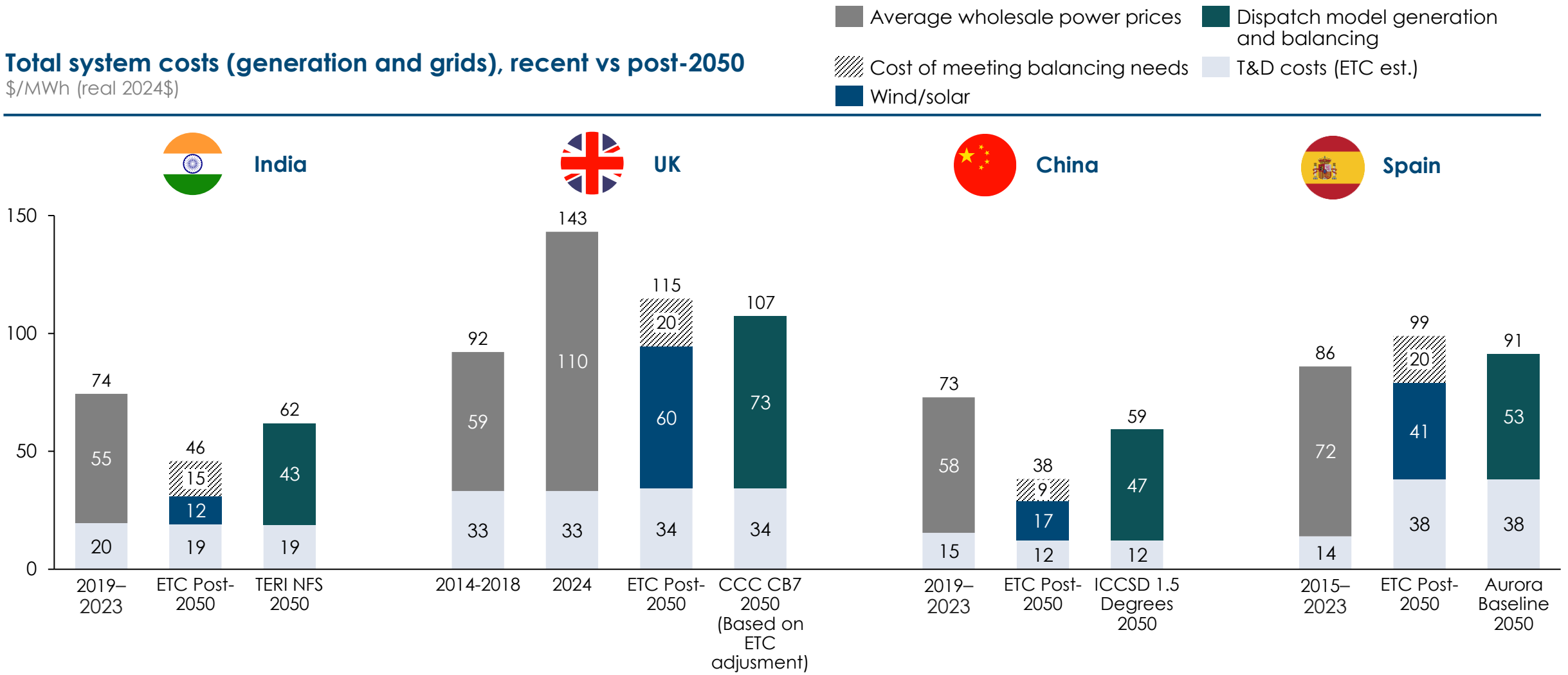
Source: Systemiq analysis for the ETC (2025), BNEF (2024) *New Energy Outlook 2024*

- **Grid capacity must grow by at least 50% by 2050** to meet electrification needs, even with all efficiency and optimisation measures in place
- The **initial increase in cost per unit of demand** is due to the upfront investments needed to build and reinforce the grid infrastructure in line with rising electricity demand.
- **The grid cost per unit of demand then decreases** because the fixed costs are spread over a larger volume of electricity consumption.
- **Grid optimization measures could further reduce** the need for additional grid build, lowering overall costs.

Total system generation and grid costs could be lower than current wholesale prices

Total system costs (generation and grids), recent vs post-2050

$/MWh (real 2024$)



Note: T&D = Transmission and distribution. T&D costs per MWh have been assumed based on ETC modelling outlined in Chapter 2 across all presented here for consistency.

Source: Systemiq analysis for the ETC; 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;* ICCSD (2022), *China's Long-Term Low-Carbon Development Strategies and Pathways;* Aurora (2023), *Long Duration Energy Storage in Spain.*

Six key enablers for power systems transformation

Strategic vision & planning

- **Smart targets for deployment –** including renewables, grids, energy storage, and flexibility.
- **Accurate models and forecasting** – to help set targets and enable integration of new technologies.
- **Political will for the transition** – To enable both phasing down of fossil, and plans for flexibility deployment (including across borders).
- **Anticipatory funding** – shifting from short-term reactive investment to anticipatory, long-term whole-system planning.

Market design

- Market access
- De-risked revenue streams
- Pricing signals (incl. locational pricing, carbon pricing)

Grid regulations

- Reform of grid fees
- Evolution of connection rules
- Modernisation and harmonisation

Data, AI and smart grids

- Data and AI modernisation
- Advanced metering and digitalisation

Supply chain and workforce

- Supply chain resilience
- Workforce education

Consumers

- Consumer engagement and trust-building

Source: Systemiq analysis for the ETC.

Top actions for policymakers, businesses and investors to prioritise

1. **Wind and solar must scale rapidly to anchor net-zero power systems**
   - **Use two-way CFDs** to reduce investor risk and deliver low cost capital
   - **Streamline permitting and grid connection rules** to enable faster approvals
   - **Publish clear auction pipelines** to signal long-term market opportunity
2. **Ensure appropriate planning & investment in system operation and balancing solutions to enable lowest-cost route to high wind and solar systems**
   - **Develop system-level planning frameworks** to define the role of different generation, grid operation and balancing technologies under high-renewables scenarios
   - **Remove barriers** (e.g. market access, grid regulations) that hamper scaling of flexibility assets and wind and solar
   - **Implement targeted support mechanisms** to de-risk investment in early-stage storage technologies where addition support is needed, e.g. investing early into medium-long duration storage and channel private capital into these markets
3. **Support grid expansion and modernization to reduce system costs and accelerate electrification**
   - **Ensure investment signals for** flexibility and storage based on proximity to generation, demand centres and existing infrastructure, reducing the need for costly grid upgrades
   - **Deploy regulatory and incentive frameworks that enable practical rollout of flexibility and IGTs.** For example, **National Grid ESO's Pathfinder programmes** enable the procurement of non-traditional grid services and technologies (e.g. stability and voltage support using IGTs); Australia's DER reforms allow aggregators and distributed resources to participate in wholesale and ancillary service markets
   - **Mandate the use of advanced planning tools** that co-optimise transmission, distribution, generation, and storage at least-cost (e.g. National Grid ESO's DP3 framework that models future transmission needs under net zero scenarios)

Top actions for policymakers, businesses and investors to prioritise

3. Accelerate power market reforms to unlock investment and lower consumer costs

- **Ensure balancing assets can access multiple revenue streams,** including capacity markets, ancillary services etc. to enable their development
- **Reform market design to limit the price-setting role of gas** by expanding the role of flexibility and clean firm resources in meeting peak demand and ensuring resource adequacy

4. Address workforce and supply chain bottlenecks to enable delivery at scale

- **Develop national and regional strategies** to train and retain a skilled clean energy workforce, especially in grid engineering, storage deployment, and power system operation
- **Expand manufacturing and logistics capacity** for critical components like transformers, switchgear, power electronics, and advanced conductors through public-private partnerships
- **Simplify permitting and procurement processes** to accelerate the deployment of grid infrastructure and balancing assets without compromising on environmental or social safeguards

5. Contain near-term system costs

- **Maximise system efficiency** via digitalisation, demand-side flexibility, and grid-enhancing technologies
- **Align grid expansion with rising electricity demand** (e.g. from electrification of heat and transport), to ensure per kWh grid costs fall over time
- **Reducing costs for consumers via**: reducing the time where gas sets the wholesale price; rebalancing policy costs across gas and/or generation taxation; incentivising self-reliance across residential and industrial properties; extending amortisation periods for grid assets.

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Key points from member comments

Context

- Emphasize that balancing needs required only once renewable penetration exceeds 40% of generation – increasing wind and solar deployment should be the key priority

Technologies

- Clarification on role of hydrogen in power and CCS and role of unabated gas
- Emphasize importance of behind-the-meter assets, including commercial and district-level growing for balancing
- Emphasize the critical need for grid expansion
- Qualifying the difficulty of long-distance transmission

Costs

- Clarification on inflation impact of increases on consumer bills and on network cost increases
- Reflection on implications of a high-cost differential between sunbelt and windbelt
- Inclusion of different types of grid cost allocation (e.g. fixed fees vs time-of-use fees)
- Clarification on grid cost increase in Spain

Enablers

- The real constraint is not just supply chains, but institutional capacity to deliver
- Consideration of growing role of public funding for energy infrastructure
- Emphasis on benefit of strategic spatial energy planning
- Need for integrated planning across system – e.g. slower grid buildout and rising grid costs limiting demand growth

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Powering Up for Launch on 22 July - preview campaign kickstarted by recent events

Recent Spain and Portugal blackouts has put grid resilience high on the news agenda & we have used this to comment as a "trusted" source and preview the Power Systems work:

- **Journalists,** including The Economist, Financial Times & Reuters
- **Media panel with GSCC - 30 Tier 1/European media**

Preview campaign will continue in build-up to launch in socials, media, events (including LCAW) media and to partners.

During preview period, ETC will work on developing media ready messaging and materials to tell and sell the story.

Power Up:
become a Member Champion

The ETC is looking for members to champion our work on comms & engagement for Power Systems Transformation.
If your team can support with:

Social media

Media interviews

Engagement

Developing additional content

Events

Please get in touch with ETC's Director of Communications, Caroline Randle
caroline.randle@systemiq.earth

Launch – July 2025

Activity	Channel	Resources required
Media outreach	• Pre-briefings with journalists (under embargo and ongoing • Tier 1 international media • In country media	• ETC core team • ETC core team • Spanish speaking (Iberdrola)
Digital	• Social media campaign • Infographics • Video campaign	• ETC core team & spokespeople plus member amplification • ETC core team • Member support (ongoing)
ETC Newsletters	• ETC Matters (Special Feature) to 27k subscribers	• ETC core team
Direct engagement	• Pre-briefing GRA, IEA, GWEC etc • Mobilise comms partners (GSCC, Global Optimism, ECIU) to amplify	• ETC & Member support • ETC core team

Post-Launch (August – December) – On-going campaign

Activity	Channel	Resources required
Media Outreach	• Ongoing pitching (storylines_ • Op-ed(s) • Podcast opportunities • Use climate events as hook for story	ETC core team ETC core team ETC core team ETC core team
Digital	• Social campaign continues • ETC Insider & ETC Matters • Video (Talking Heads)	ETC core team (with member amplification) ETC core team Member support
Events	• Key climate events – NYCW, COP • Existing speaker opportunities – BNEF, FT • Partner with members • Member spokespeople (briefing pack provided)	• ETC core team • ETC core team • Member support • Member support
Direct outreach/partnerships	• Continue to follow up with key industry organisations & policy makers and brief them • Explore opportunities for collaboration eg. EU event/Iberdrola	• ETC core team • ETC core team/Iberdrola