Energy Transitions Commission

Frequently Asked Questions – *Power Systems Transformation*

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Section 1: About the ETC

What is the Energy Transitions Commission and what is its mission?

The Energy Transitions Commission (ETC) is a global coalition of leaders from across the energy landscape committed to achieving net-zero emissions by mid-century in order to limit global warming to well below 2°C and as close as possible to 1.5°C.

Our Commissioners come from a range of organisations – energy producers, energy-intensive industries, technology providers, finance players and environmental NGOs – which operate across developed and developing countries and play different roles in the energy transition. This diversity of viewpoints informs our work: our analyses are developed with a systems perspective through extensive exchanges with experts and practitioners. Our ambition is to inform the decisions of public and private decision-makers and support the leaders at the forefront of climate action to speed up the deployment of low and zero-carbon solutions.

A list of our commissioners can be found here: http://www.energy-transitions.org/who/
Our ambition is set out here: https://www.energy-transitions.org/ambition/

Who funds the ETC?

The ETC is primarily funded by the organisations with which our Commissioners are affiliated. Membership fee levels depend on the size and nature (for-profit or not-for-profit) of the organisation. Commissioners all have equal voice and representation on the Commission regardless of whether their affiliate organisation finances the ETC or not. In addition, some of the ETC's work programmes, in particular in China and India, are funded by philanthropic organisations.

The funding we receive finances the ETC's secretariat, analytical programmes, stakeholder outreach and communications.

Who are the Commissioners and how were they selected?

As of January 2025, the Commission's membership includes 60 leaders from energy companies, energy-intensive industries, technology providers, financial institutions, environmental NGOs and academia. They operate across developed and developing countries and play different roles in the energy transition. Commissioners are selected based on their commitment to working towards a net-zero-emissions economy by mid-century.

We endeavour to diversify the Commission's membership in terms of sector, nationality and gender. The Commission is chaired by Lord Adair Turner who works alongside the ETC's senior leadership

team. A list of Commissioners can be found on our website at: http://www.energy-transitions.org/who/

Are the organisations with which your members are affiliated backing this report?

This report constitutes a collective view of the Energy Transitions Commission. Members of the ETC endorse the general thrust of the arguments made in this report but should not be taken as agreeing with every finding or recommendation. The institutions with which the Commissioners are affiliated have not been asked to formally endorse the report.

How does the ETC balance achieving impact with the demands of fossil fuel members?

Commissioners all have equal voice and representation on the Commission. We believe it is critical that the ETC brings together voices from across all sectors, including energy-intensive industries, in order to design realistic yet ambitious pathways to net-zero emissions and mobilise all key stakeholders towards this goal. All members of the ETC have agreed to work together to pursue a global net-zero emissions target by mid-century. Our reports are anchored in robust quantitative and qualitative analyses, which are stress-tested and refined with a large panel of experts coming from both our members' organisations and a broader network. The ETC creates a unique space for open dialogue, creating the right conditions for change and advancing the climate agenda.

Does the ETC speak to the challenges of both developed and developing countries?

The ETC develops global roadmaps while highlighting differences between regional pathways. We work with local partners – in Australia, Canada, China, Europe, India, Japan, India, Indonesia and the United States – who have deep country knowledge and play a key role in strengthening and stress-testing our global analyses in light of regional specificities.

Many of the routes to decarbonisation are relevant in all countries; and in many sectors – such as steel, aviation and shipping – a global policy approach would be ideal. Much of the ETC's work has therefore focused on global trends in technologies and costs. But there are important differences between regions and countries. ETC's research speaks to countries of different natural resource endowments, different economic fabrics, different income levels and very different current emissions; and they start from different positions – for instance, in relation to existing coal generation capacity.

Section 2: About the report and its impact

Who is the paper aimed at? Who is your target audience?

This report is aimed at policymakers, business leaders and investors to help inform their strategies and anticipate the profound market transformations that climate action will generate in the global economy. It provides civil society, economic, political and social thought-leaders with guidance on energy pathways to achieve net-zero.

What makes this report different to others?

This report looks beyond power generation costs to tackle the real system-level challenges of high-renewable grids, like balancing variability, grid expansion, and total cost. It models real-world scenarios across diverse country archetypes and shows that reliable, clean, and affordable electricity is achievable with today's technologies and the support of smart policy.

How much of the paper constitutes new analyses vs. integration of previous publications?

This new major report builds on the ETC's previous work on clean electrification, demand-side flexibility, grids, planning and permitting, and broader body of work outlining how to build a net-zero global economy by midcentury. It provides a comprehensive roadmap for transforming power systems to achieve a reliable, affordable, and clean energy future.

Our 2021 report *Making Clean Electrification Possible: 30 years to electrify the global economy* sets out why it is essential but also feasible and affordable to multiply by 5 the size of the global power system while shifting to renewable-based electricity provision.

Who has carried out the underlying analysis?

The underlying analysis for this report was developed by the ETC Secretariat, provided by Systemiq. It brings together and builds on past ETC publications, developed in close consultation with hundreds of experts from companies, industry initiatives, international organisations, non-governmental organisations and academia. The reports draw upon analyses carried out by ETC's knowledge partner Systemiq, alongside analyses developed by BloombergNEF, The Energy and Resources Institute (TERI), International Energy Agency (IEA), CurrENT, Ausgrid, Pacific Northwest National Laboratory (PNNL), Tsinghua University Institute of Climate Change and Sustainable Development (ICCSD), Climate Change Committee (CCC), and AFRY.

How does this report contribute to the ETC's wider work on power systems?

Previous ETC publications within the *Barriers to Clean Electrification* series have addressed several hurdles to scaling up wind and solar, including the need to address planning and permitting, supply chains and materials requirements, as well as finance needs. This report addresses the question of how electricity systems with a very high share of wind and solar generation can balance supply and demand, how grids need to change, and what the implications will be for the cost of electricity. It explores;

1. The technical ability to ensure grid stability with high proportions of wind and solar
2. The system balancing challenges of purely wind and solar generation power systems and the implications for total system generation cost in different regions.
3. The need for grid scale up and the implications for grid costs per kwh
4. Bringing this together to infer the long-term total cost implications of a max renewable system by region
5. Key enablers for cost effective power system transformation

Section 3: Power Systems Transformation – key challenges and actions

What are the critical actions for governments, policymakers and industry?

- **Strategic vision and planning:** Governments should develop an integrated strategic vision, including whole system planning frameworks, that set clear, time-bound targets and coordinate investments across renewables, storage, flexibility, and grid infrastructure.
- **Market design:** Governments and Industry should reform electricity market structures to enable emerging flexibility and grid technologies to compete on equal terms with incumbent assets.
- **Grid regulations:** Governments and Policymakers should modernise regulatory frameworks to unlock timely investment in transmission and distribution infrastructure and accelerate project delivery by streamlining grid connection processes.
- **Data, AI and smart grids:** Industry and government should leverage AI and advanced digital tools to improve power system planning, optimise grid operations, and enhance system stability and safety.
- **Supply chain and workforce:** Governments and Policymakers should address critical bottlenecks by aligning national infrastructure plans with long-term demand signals to enable anticipatory investment in key technologies (e.g. transformers, HVDC systems, battery storage).
- **Consumers:** Government and Industry should empower consumers to provide flexibility by building trust in smart energy technologies, ensuring strong data privacy protections, and offering intuitive, automated products.

How can power systems reliably manage the hour-to-hour variability of wind and solar?

Balancing hour-to-hour variability is already feasible using today's technologies: short-duration battery storage, demand-side flexibility, interconnections, and flexible generation. These, in particular battery storage and demand-side flexibility, provide fast, responsive support that maintains grid stability at a low cost. In many countries, battery and flexibility costs are rapidly declining, making them increasingly cost competitive with traditional fossil generators.

How do balancing needs differ between low-latitude countries and the rest of the world?

Low-latitude, solar-rich countries (like India or much of Africa) primarily need short-duration (<8 hrs) balancing, shifting solar from day to night. High-latitude, wind-heavy countries (like the UK) face ultra-long duration (>50 hrs) balancing needs to cover periods of low wind in winter. The costs and technologies differ, but both are manageable with the right mix of solutions.

How much investment is required for the scale of grids described?

Global grid investment will need to more than double, from $370 billion in 2024 to over $850 billion per year in the 2030s and 2040s. This includes both transmission and distribution. However, per-kWh grid costs can stay stable, or even decline if electrification accelerates alongside grid expansion, and innovative grid technologies alongside demand side flexibility solutions are adopted at scale. For example, ~35% of grid expansion costs (equivalent to $1.3 trillion in Europe) could be avoided between now and 2050 through the usage of innovative grid technologies such as advanced conductors and software solutions like dynamic line rating.

How can digitalisation and AI improve system operations and cost-efficiency?

Digital tools including AI-based forecasting, smart meters, and grid automation can significantly improve reliability, reduce congestion, and optimise system operations. They help balance variable renewables in real-time, enhance fault detection, and unlock demand-side flexibility. This drives down both infrastructure costs and electricity prices over time.

You claim the costs of transition will fall in the long term, but transitional costs are real and in many regions, renewables still struggle without public support. Shouldn't we be more transparent about the risk of higher bills and stranded assets?

Transitional costs are real, but depend heavily on how the transition is planned, including cost of financing and scale of transition. The cost of bills is heavily dependent upon demand keeping pace with the buildout of renewables and the grid. If it does not, then there is a risk of higher cost to consumers as the total TWh of demand is smaller than expected and the distribution of costs will be more concentrated.

In the short term, a combination of legacy policy frameworks, historical investment patterns, and outdated pricing structures can also lead to distortions that increase electricity bills.

To mitigate these effects, the report outlines several policy levers:

- Reducing the number of hours where gas sets the wholesale price;
- Rebalancing levies away from electricity bills and towards gas or general taxation;
- Using time-of-use pricing and demand flexibility to lower peak costs;
- Supporting decentralised solutions like rooftop solar and storage;
- Spreading grid investment over longer timeframes to ease short-term impacts;
- Maintaining a pragmatic, flexible approach to the pace and sequencing of electrification. This requires clear long-term policy signals and managed phase-outs to avoid abrupt dislocations;
- Smarter use of the existing network through digitalisation, interconnection, and demand-side flexibility can substantially reduce the overall cost to consumers.

The report paints a rosy picture for India and China, but countries like Germany or the UK face significantly higher costs. Are you effectively saying some countries must pay more for the global transition, while others get to lead and profit?

Solar-dominant countries like India benefit from lower costs due to geography, falling solar prices, and mostly short-duration balancing needs. But higher costs in wind-reliant regions like the UK or Germany, due to the higher costs relating to ultra-long balancing (50+ hours, covering days, weeks or months) reflect specific system needs, not a flaw in the transition.

Importantly, these costs are still lower than today's fossil-based prices in many of these countries—and they come with added benefits:

- Greater energy security
- Reduced price volatility
- Significant economic opportunity in green technology export and leadership

The ETC highlights that different countries face different challenges and timelines. The transition must be pragmatic, with policy frameworks that manage costs fairly, ensure competitiveness, and prioritise long-term resilience over short-term cost parity.

Section 4: Geopolitics and the wider global context

How can countries pursue clean electrification without becoming even more dependent on China's supply chains given their dominance in solar manufacturing, batteries and transmission equipment?

The ETC acknowledges the current concentration of manufacturing in China, especially in solar PV, batteries, and components for transmission systems. This has played a vital role in driving down costs globally. However, they ETC's recommendation is not to retreat from global supply chains but to diversify them. We lay out six principles for near-shoring supply chains in our recent report on the role of *Global Trade in the Energy Transition*, and the importance of coordinated global carbon pricing to accelerate industrial decarbonisation globally.

Do current trade tensions mean the ETC needs to revise its modeling assumptions around solar and battery cost declines? If tariffs persist, how resilient is the transition timeline?

While short-term trade tensions may affect local pricing and supply chains, our long-term cost assumptions remain robust. The global trends driving solar and battery cost reductions (economies of scale, technological innovation, and competition) are still in force. Even in higher-cost regions, domestic and allied manufacturing is scaling rapidly, supported by industrial policy in the US, EU, and India.

That said, protectionist barriers can raise costs and delay deployment if not managed carefully. We advocate for strategic diversification of supply, not dependence on any one country, and continued public-private investment in global capacity. The transition is resilient, but governments must be intentional: climate ambition should not be a casualty of trade policy.

Given the growing divide in global energy politics, especially between fossil-rich and renewables-rich regions, how will ETC's roadmap avoid creating new energy "haves and have-nots" or "winners and losers", and what global governance is needed to ensure equity?

This report outlines the cost advantages of sun-abundance in VRE dominant systems. Many low-latitude countries, for example India, much of Africa, and Southeast Asia, have excellent solar potential. With the right investment, they can become clean energy leaders. However, access to finance is the real bottleneck. The ETC consistently calls for scaled-up concessional finance, public guarantees, and blended finance mechanisms through entities like the World Bank, MDBs, and new coalitions like GFANZ or the Just Energy Transition Partnerships. Cross-border collaboration and regional grids (e.g. African Power Pools, ASEAN interconnectors) can also reduce costs and prevent siloed development.

At the same time, high-latitude regions without year-round sun can remain competitive as well by leveraging:

- Innovation and funding in medium-to-long-duration storage (8-50 hours) and flexibility technologies
- Demand-side efficiency and digitalisation to keep system costs down
- Early leadership in green industries like offshore wind and grid technologies

Many of the new clean industries, like green steel, ammonia, or data centres, will benefit from location-agnostic factors, such as skilled workforces, logistics infrastructure, and supportive policy environments. This is not about shifting advantage from one region to another, it is about designing a globally inclusive transition where all countries can lead in different ways.

Recent reports highlight how Scottish wind generation boosts UK's grid, but Scottish people don't benefit, instead facing higher energy bills. Plans for zonal pricing have been scrapped and energy majors oppose the change. In general, should there be a role for zonal pricing or locational tariff systems to ensure clean energy producers also benefit?

It depends on the specific market context, its structure, and the timeline for delivery. In the UK, a decision has been made not to proceed with zonal pricing at this stage, providing short-term clarity. However, in other markets, the question remains open and should be assessed based on a careful weighing of tradeoffs.

Locational or zonal pricing can improve system efficiency by sending more granular price signals, reducing the need for costly network upgrades, and encouraging clean generation and flexibility where they bring most value. At the same time, it can create price divergence across zones, raise investment uncertainty, and prove difficult to implement fairly or rapidly—particularly for existing assets.

Our report outlines these tradeoffs in detail. As shown in the figure, advantages of locational marginal pricing include improved dispatch efficiency, stronger investment signals, and reduced network costs. On the other hand, potential drawbacks include uncertainty for investors, long implementation timelines, and possible revenue impacts for generators located in low-priced zones.

Ultimately, the role of zonal pricing should be considered as part of a wider package of reforms, tailored to the specific needs and starting point of each power system.

There is a locational tariff system already in place for transmission grid costs in Great Britain, called Transmission Network Use of System (TNUoS) charges. These charges are designed to reflect the cost of using the transmission network and incentivise efficient development of the system, but this is not to the same extent as the proposed zonal pricing. The UK government has plans to reform their Transmission Network Use of System (TNUoS) so that it reflects the true long-term system benefits of new generation will ensure that it sends an effective and predictable signal about where new investment should be located.