Beyond energy infrastructure:

A flexibility-first approach cuts costs and boosts security

Beyond energy infrastructure: A flexibility-first approach cuts costs and boosts security

Power systems across the world are entering a fundamentally different operating regime. Rapid electrification, accelerating renewable deployment, volatile fuel markets and growing geopolitical uncertainty are placing unprecedented strain on energy systems that were designed for predictability, not variability. In this context, energy system flexibility is no longer a technical optimisation or a niche market feature as it once was; this *invisible infrastructure* is a strategic enabler of affordability and security, while strengthening system reliability.

If you read nothing else: flexibility is not a future add-on to power systems; it is core infrastructure. Countries that quantify and embed flexibility early can reduce system costs, strengthen energy security, and avoid locking in unnecessary grid and generation investment[1]. Those that delay will pay more to retrofit later, which we cover here, providing insight into why this happens and how policymakers can drive change.

The 'build more' approach is often misguided

The traditional response to rising electricity demand and system stress has been to build more physical infrastructure: new generation and network capacity, alongside additional reserves. While necessary in many cases, at various scales, this approach alone is increasingly inefficient, slow, costly, and misaligned with the needs of renewable-led systems[2].

High shares of variable renewables increase system integration costs, shifting system value away from energy production and toward balancing and responsiveness. In this context, flexibility helps systems make better use of existing assets, reducing unnecessary overbuild while maintaining reliability. More grid investment will still be needed, but flexibility improves the timing, scale, and efficiency of that build-out. For policymakers facing fiscal constraints and rising scrutiny over public spending, it offers system-wide value that incremental capacity alone does not.

Policymakers need options that deliver system-wide value, not just incremental capacity. Flexibility across the power system directly addresses this challenge by allowing systems to do more with existing assets, reducing the need for over-build while maintaining reliability.

Guidance is fragmented and gaps persist

The pace of electrification, increased penetration of renewables, and heightened uncertainty in global energy markets are fundamentally reshaping power system dynamics. These changes create greater variability and stress, making flexibility not just desirable but essential for future energy systems.

---

[1] In Great Britain, the Carbon Trust's *Flexibility in Great Britain* analysis estimated that a fully flexible energy system could deliver net savings of **£9.6–£16.7 billion per year in 2050** (The Carbon Trust, 2021).

[2] Electricity network flexibility in Great Britain delivered an estimated **£300 million in savings for billpayers in 2024**, with projections of **over £3 billion in savings between 2025-2027** (Energy Networks Association, 2025).

Despite this clear case, guidance for policymakers remains fragmented. Many international reports articulate the need for flexibility but stop short of translating ambition into an investable economic case or actionable policy direction. To address the gap, we've synthesised recent evidence into a clear, decision-focused narrative tailored to national policy and planning contexts, focused on:

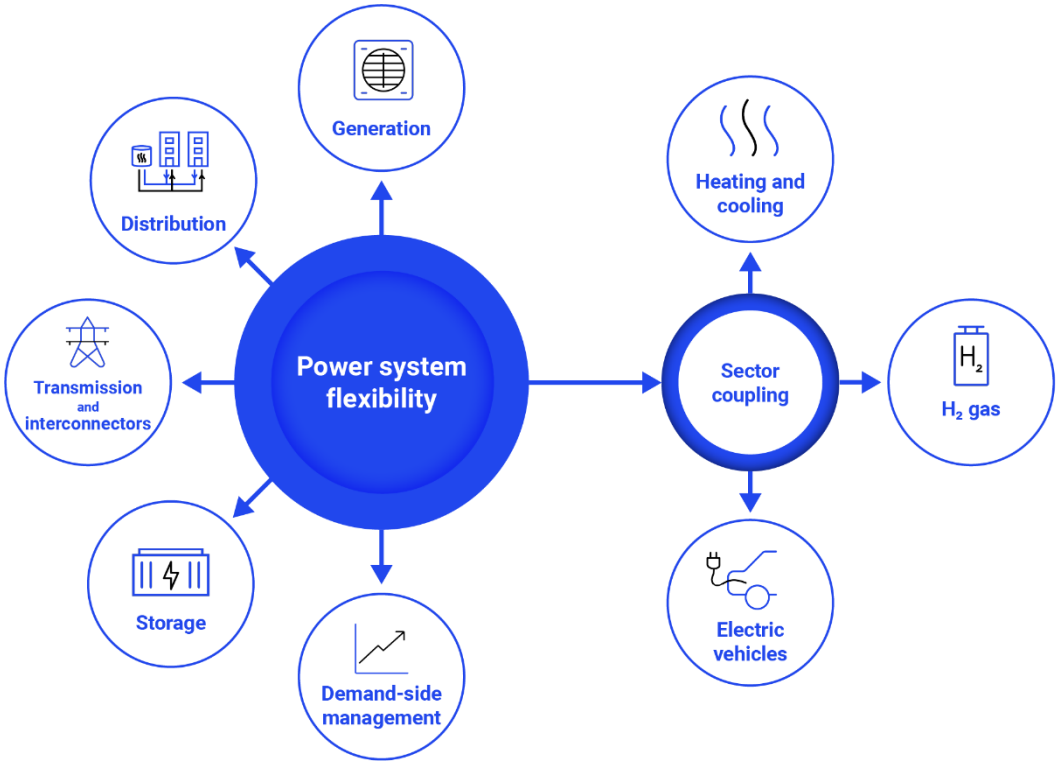
- Reframing flexibility as a strategic economic choice, not a technical add-on.
- Focusing on system-level cost, security, and reliability outcomes, not individual technologies.
- Drawing lessons from mature systems (notably the UK) while remaining applicable to emerging and transitioning markets.
- Explicitly addressing the trade-offs, sequencing, and policy choices that determine whether flexibility delivers value or underperforms.

This provides policymakers and decision makers with a much-needed bridge between high-level aspirations and practical implementation. The outlined points clarify the real-world value of flexibility, demystifying its economic case and highlighting the policy levers that unlock its benefits. This approach empowers leaders to make informed choices, prioritise impactful interventions, and navigate the complexities of system transformation with greater confidence and precision.

What is flexibility? Definitions matter

Before policymakers can act on flexibility, they need a clear and shared understanding of what it is, and what it is not. Ambiguous or overly narrow definitions have led to inconsistent policy signals, misaligned incentives, and missed value. A precise, system-level framing of flexibility is essential for effective national energy planning.

Power system flexibility enablers in the energy sector



Source: Adapted from Irena (2018)

Flexibility is a suite of operational decisions, market readiness and responsiveness, and digitally-led services that transform previously static and piecemeal operations into a dynamic system that absorbs system pressures. More formally, energy system flexibility refers to the ability of the power system to respond efficiently to variability and uncertainty across time and location. It is not a single technology or market, but a set of capabilities that allow supply, demand, and networks to adjust in response to changing system conditions. Flexibility operates across the power system, from how and when demand responds, to how networks are managed and supply is scheduled.

Critically, not all flexibility delivers the same value, it is not always inherently a 'system positive', and not all end-users will experience the same benefit. Poorly designed flexibility mechanisms can entrench fossil dependence and distort investment signals or shift costs without delivering real system benefits. Flexibility aligned with Net Zero pathways reduces long-term costs and risk, and policy design must prioritise system outcomes.

There is a clear distinction between a flexible system and the specific routes of implementation; the sum of its parts must remain in focus.

Flexibility aligned with Net Zero pathways reduces long-term system costs and emissions whereas flexibility that locks in fossil dependence does not. Policymakers must therefore distinguish between *enabling* progressive flexibility versus *transitional or misaligned* responses.

The UK's experience over the past decade illustrates why definitional clarity matters. Early flexibility initiatives delivered value, but inconsistent market signals and overlapping mechanisms also created complexity and inefficiencies. Progress has been significant, but the system is far from optimal despite its advanced global reputation. These lessons are highly relevant for countries designing flexibility frameworks today.

Building the economic case catalyses implementation

For policymakers balancing affordability, security, and reliability, flexibility delivers the greatest system value once renewable penetration begins to strain networks and system operation, but before infrastructure over-build is locked in. Acting too late drives higher retrofit costs, curtailment, and stranded assets; acting early allows flexibility to defer or avoid unnecessary investment altogether. The strategic opportunity lies in embedding flexibility as part of system design, not waiting until it becomes a corrective measure.

Setting out the value of flexibility needs to be grounded in key policy levers that will attract the necessary system agents and financiers around the same table.

Cost reduction
Flexibility in the power system not only drives down overall system costs but also enables avoided curtailment of renewables and mitigates network constraints. By allowing supply and demand to respond dynamically, flexibility helps to maximise the utilisation of existing infrastructure and renewable generation, reducing the need for expensive upgrades and limiting wasted energy.

UK flexibility impacts in 2024

Source: IEA, 2025[4]

Energy security
Flexibility reduces exposure to imported fuels by maximising the use of domestic renewable generation. This has become particularly salient in the wake of recent global fuel price volatility, where systems with higher flexibility were better able to absorb shocks[3].

System reliability
Flexibility helps maintain reliability by providing fast response and controllability without relying solely on high-cost, low-utilisation backup generation. In practice, this includes using demand response and storage to manage stress events and reduce the operational risk that arises as variable renewables increase[4].

The counterfactual is clear. Systems that fail to invest in flexibility face higher consumer bills, greater stranded asset risk, ballooning curtailment of renewables, and escalating public expenditure on emergency measures.

Without clear value, flexibility will remain a contingency and not a system enabler

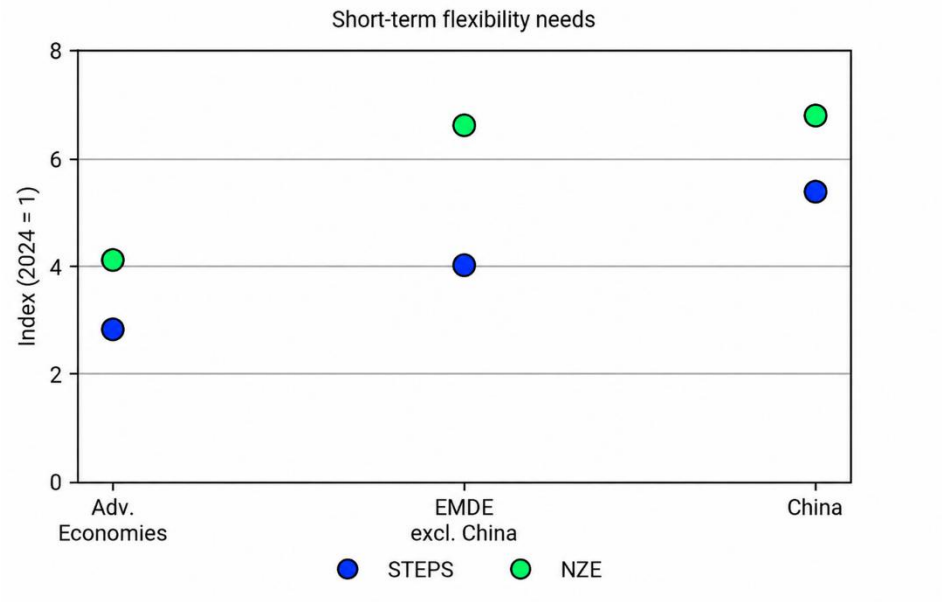
Too often, flexibility is treated as a fallback option: something to be called upon once systems are already under strain. This framing is both costly and ineffective. When flexibility is positioned as a contingency rather than a core design principle, it remains under-valued, under-invested, and poorly integrated into planning and procurement decisions. As a result, systems default to infrastructure-heavy solutions even where flexibility would deliver equal or greater value at lower cost.

The barrier is not technical potential but valuation: where the system-wide value of flexibility is not explicitly identified and modelled, it remains invisible in planning processes that default to conventional infrastructure.

The scale of the challenge is illustrated in the figure below. Short-term flexibility needs are projected to rise significantly by 2035 across all economies, using 2024 levels as the baseline. Under both the STEPS scenario, based on current policy settings, and the NZE scenario, aligned with Net Zero pathways (2050), flexibility requirements will rise, with the largest growth expected in emerging and developing economies.

[3] Flexibility for Resilience – How can flexibility support power grids resilience? (EU Commission, 2022)
[4] The Value of Demand Flexibility (IEA, 2025)

Batteries and demand response are expected to supply most of the needed short-term flexibility by 2035



Short-term flexibility needs by scenario, 2024–2035. Values are indexed to 2024 levels, showing how many times greater flexibility needs are projected to be by 2035 under the Net Zero Emissions by 2050 scenario (NZE) and Stated Policies Scenario (STEPS). Adapted from IEA (2025)[5]

Flexibility faces institutional resistance, not technical limits. In many power systems, planning, investment, and regulatory processes are shaped by long-standing infrastructure-led approaches and incumbent interests. These frameworks tend to favour capital-intensive assets with familiar risk profiles, even where flexibility would deliver superior system value. Recognising and addressing this political economy, rather than assuming a neutral decision-making environment, is critical to unlocking flexibility at scale.

Determining and modelling the value of flexibility is therefore a critical enabler of implementation. When assessed holistically, flexibility delivers measurable benefits across key system dimensions while also lowering total system costs and improving energy security. Crucially, these benefits accrue across sectors such as generation, networks, demand, and system operation, yet are often assessed in isolation, diluting their perceived impact.

Robust valuation changes this dynamic. In many markets, the costs of congestion and system stress are already significant; the IEA reports that grid congestion cost almost USD 8 billion in the United States and USD 4.5 billion in the EU in 2024, while renewable curtailment in the EU exceeded 10 TWh in 2024[4].

By embedding flexibility into system modelling, planning scenarios, and cost-benefit analysis, policymakers can reveal its full contribution to affordability, security, and reliability. This, in turn, strengthens the investment case, providing system operators, financiers, and market participants with

[5] World Energy Outlook (IEA, 2025)

clearer signals on where flexibility delivers the greatest value, and under what conditions. Where value is visible and bankable, investment follows.

Systems that fail to take this step risk locking in sub-optimal outcomes. Without quantified value, flexibility is deployed late, scaled cautiously, or excluded altogether.

Drive change where markets need it most

While the value of flexibility is universal, the pathways to unlocking it are not. Power markets differ widely in structure, maturity, and institutional design, and these differences materially shape how flexibility can be deployed. In some contexts, market signals already reward system optimisation. In others, particularly vertically integrated systems[6], flexibility will not emerge without deliberate policy intervention.

While coordinated delivery can be beneficial, these structures often bias decision-making toward familiar, capital-intensive assets and infrastructure-first solutions. In such settings, flexibility struggles to compete unless its value is explicitly identified and embedded within planning and investment frameworks. This is where valuation becomes especially powerful and for emerging and transitioning markets, this is increasingly practical[7].

In vertically integrated systems, determining and modelling the value of flexibility provides a common evidence base for decision-makers who control investment across the system. It allows policymakers and planners to compare flexibility directly against conventional build-out options, revealing where optimisation can defer or avoid costly infrastructure while maintaining security and reliability.

For key markets like vertically integrated systems, the opportunity is clear. By prioritising robust valuation and modelling, flexibility can shift from a marginal option to a central pillar of least-cost, resilient system design.

Flexibility will not scale on intent alone. It must be driven by policy

If flexibility is to deliver on its promise, policymakers must move beyond aspiration to deliberate system design. This requires clear priorities, aligned incentives, and an explicit shift away from infrastructure-first planning.

Power systems are under growing strain not because they lack capacity, but because they lack flexibility. Across many markets, planning and investment frameworks still default to building more infrastructure rather than using existing assets more intelligently. The result is higher system costs, avoidable grid congestion, rising curtailment, and increasing exposure to energy security risks.

---

[6] Vertically integrated systems refer to power sectors where generation, networks, and system operation are planned and operated by the same institution(s), rather than coordinated through competitive markets.

[7] The World Bank has published guidance for utilities and regulators on selecting and implementing demand response programmes specifically to support grid flexibility in developing countries (World Bank, 2024)

Flexibility is widely acknowledged as part of the solution but without clear valuation and deliberate policy direction, it remains marginal to decision-making. To change this, we recommend three immediate actions:

- **Make flexibility visible**. Quantify the system-wide value of flexibility and compare it directly against infrastructure build-out in national planning and investment decisions.

- **Design for flexibility, not just capacity**. Embed flexibility into planning frameworks, regulatory processes, and procurement, treating it as a core design principle rather than a contingency or retrofit.

- **Target the binding constraints**. Focus early policy effort where flexibility delivers the highest system value: peak demand, congestion, and reliability risks.

Our perspective is grounded in hands-on engagement and reflects lessons drawn from hands-on engagement across both mature and emerging power systems: flexibility delivers the greatest value when it is treated as core system infrastructure and assessed on a whole-system basis. Determining and modelling the value of flexibility is the critical step that shifts it from concept to implementation. When value is explicit, investment follows.

What matters now is execution. Flexibility will not scale by default, nor will it emerge evenly across all market structures. Policymakers, particularly in vertically integrated and infrastructure-led systems, must actively embed flexibility into how systems are planned and financed, and how investment decisions are approved. Doing so unlocks a future resilient and more affordable power system. The opportunity is not incremental optimisation, but a step-change in how power systems are designed and governed.

For further insights, please visit our Energy Transition sector vision and solutions page here.

Authors:

Masaō Ashtine
Senior Manager, Energy Transition
The Carbon Trust

Andrew Lever
Director, Energy Transition
The Carbon Trust

carbontrust.com
client.support@carbontrust.com