Policy brief

Navigating risk and building resilience in the UK's energy system: Three pillars for policy action

Summary

- Delivering the UK's legally binding net zero target by 2050 will require rapid, coordinated action. Despite progress, rising climate risks, system complexity and policy uncertainty threaten delivery. Strengthening system resilience is essential to meet climate, energy security and affordability objectives.

- Pillar I: Reducing energy demand should be central. Priority actions include raising ambition towards net-zero cooling emissions by 2050 through passive building retrofits, minimum efficiency standards, and financing tools such as green mortgages. Integrated, place-based building decarbonisation strategies can reduce emissions while improving thermal comfort and social resilience. Stronger heat-risk data, alert systems and Heat Resilience Impact Assessments should be embedded in planning and local decision-making.

- Pillar II: Scaling energy storage is critical to Clean Power 2030 and long-term resilience. A national strategy should rapidly expand storage capacity, diversify technologies across seasonal durations, and reduce exposure to critical mineral and supply-chain risks. Investment should target alternative battery chemistries, domestic manufacturing and recycling, and strategic international partnerships.

- Pillar III: Electricity market reform will shape how effectively flexibility, storage and low-cost renewables are integrated. Policymakers should clarify long-term objectives for market redesign, balance trade-offs between affordability and efficiency, and expand inclusive access to consumer-led flexibility. Transparent, participatory reform processes will be essential for a resilient, net-zero-aligned energy system.

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The UK has adopted a legally binding commitment to reach net zero by 2050. With over 80% of the UK's territorial greenhouse gases responsible for climate change coming from the use of energy, the transition to a zero-carbon energy system is the foundation for a stable climate.

The task of getting a zero-carbon energy system is urgent, yet also increasingly challenging. Ambitious targets are the starting point, but their delivery rests on effective implementation. Within the UK, continued progress towards its net-zero targets hinges on increasing the ambition of its climate change mitigation actions. While often a leader in global climate conversations, the UK's progress has also been undermined by inconsistent messaging and actions.

At the same time, continuing global warming and the increasing rate and magnitude of associated climate risks show that the UK must urgently build its resilience to climate change, particularly in its energy system.

These recommendations are based on the outcomes from the inaugural OPEN Forum on Risk and Resilience.[1]

Three pillars of energy system resilience

Energy system resilience can be organised around three interrelated pillars: demand reduction and flexibility, storage, and low-cost renewable generation. Energy demand provides an important entry point. As the UK's economy decarbonises and multiple economic sectors are electrified, lowering energy demand and improving the efficiency of energy use will be crucial for achieving net zero, decreasing environmental impact, and reducing energy costs.

- **A key component of managing energy demand lies in the building stock.** Much of the UK's built environment is among the oldest in Europe, possibly among the oldest in the world, and is therefore ill-suited to the demands of a changing climate. A timely policy response must channel new investments into technology and develop new energy demand policies, particularly targeting heating, cooling, and shifts in consumer behaviour, while ensuring a high quality of life for the UK's residents.
- Another pillar of energy system resilience is storage. As the electricity system transitions to a high share of intermittent renewables, the UK will need large-scale electricity storage to manage system resilience and end its dependence on carbon-intensive fuels. This challenge extends far beyond the UK's borders: similar storage needs are emerging globally as countries pursue net-zero targets, creating both competitive pressures and export opportunities for British innovation. Determining which technologies can meet these requirements, and at what costs, is necessary to evaluate how policy can best accelerate implementation at scale.
- **Renewables offer the third pillar.** In July 2024, the UK Climate Change Committee concluded that 'British-based renewable energy is the cheapest and fastest way to reduce vulnerability to volatile global fossil fuel markets.' At the same time, leveraging the multiple benefits offered by renewable energy entails unique challenges. In addition to switching to renewables, the UK electricity supply, transmission and distribution systems need to grow, as clean electricity replaces fossil fuels for industry, heating and transport. This increases investment requirements that need to sustain the test of geopolitical pressures and places additional stress on land use. Moreover, as renewables get added to the system, electricity markets need to be redesigned to simultaneously manage increased intermittency and deliver the benefits of low-cost renewable energy to consumers. With the reform of electricity market arrangements, the debate on affordability of electricity is at the forefront of policy agendas.

Moving forward with these pillars requires cross-cutting and continued two-way communication and collaboration between academia and policy. Not only is academic evidence critical to optimising policy, but an understanding of policy priorities and real-world challenges can help academics to streamline their research priorities and enable interdisciplinarity. Importantly, energy sits at the heart of the economy and society. The changing weather patterns require energy researchers and decision-makers to interact with new areas that conventionally were left out of the scope of energy system research. For example, new priorities might include assessing how extreme heat resilience correlates with a multitude of physical and mental health impacts and evaluating the implications of AI and cybersecurity improvements on effective energy demand management.

Overall, shifting the energy system will require a portfolio of approaches to guarantee resilience in the UK and more broadly in the global energy system, particularly as the complexity of contingent risks rises. Increased interactions between academics and policy professionals will help build more responsive and flexible policy systems in the UK and bolster its risk preparedness by balancing scientific evidence with the recognition of various policy synergies and trade-offs.

Energy demand [2,3,4,5,6]

Reducing energy demand is critical for delivering the UK's climate, energy security, and affordability objectives. For that, energy demand must be placed front and centre in UK energy policy.

The frequency and intensity of summer heat waves is intensifying, posing new challenges for the UK's energy demand system. The UK ranks among the top three countries globally in terms of the relative difference in heat exposure between 1.5°C and 2°C warming scenarios. Around 20% of the building stock in the UK

is at high risk of overheating due to poor ventilation or glazing. Without a more effective adaptation policy, heat-related risks in the UK could triple by 2050, increasing mortality and morbidity rates, reducing labour productivity, creating new pressures on energy, transport, and water infrastructure, and further compounding other environmental stressors.

Heating and cooling could be addressed as interconnected elements of a socio-technical energy system designed to deliver year-round thermal comfort. Increasing frequency and intensity of extreme heat events will add new load to the energy demand system from cooling, and it is important to ensure that it is met without further increasing greenhouse gas emissions. As one of the founding signatories of the Global Cooling Pledge, the UK has already demonstrated global leadership in action for sustainable cooling; leadership which would be deepened by raising its ambition to achieve net-zero cooling emissions by 2050. Delivering this goal will require passive cooling retrofits, minimum efficiency standards for existing homes, and financing instruments such as green mortgages. An integrated energy demand reduction strategy will be key for building multi-level resilience.

Decarbonising the built environment is central to energy demand reduction, and new approaches are needed to drive this shift. Sustainable solutions for the built environment have robust co-benefits, including increased extreme heat resilience, energy security, and reduction of energy system costs and bills for consumers. However, the poor condition of the UK's building stock means that deep retrofits are often costly and complex to implement at scale, while one-size-fits-all low-emissions heating technology rollouts may face uptake barriers and jeopardise equitable outcomes. Effective building decarbonisation policy will require an integrated, place-based policy approach that accounts for the differences in housing stock, local infrastructure, and community needs. Currently, the more popular fabric-first approaches, which prioritise demand reduction by upgrading insulation, airtightness, and thermal bridging, are insufficient on their own. A more comprehensive strategy would include combining fabric-first approaches with understanding-first approaches, where intervention choices are guided by detailed pre-retrofit assessment, occupant behaviour analysis, archetype modelling and in-use monitoring.

Social barriers can inhibit effective responses to extreme heat risks. Vulnerability to extreme heat is shaped by social factors, including age, income, and race, which influence households' access to critical social support systems, infrastructure, and the ability to respond to emergencies. Increasing social resilience amidst ongoing changes within the UK's energy demand system will require developing adequate heat risk alert and communication systems; strengthening evidence collection on internal temperatures, urban heat island exposure, and social vulnerability to inform decision-making; and supporting local authorities in incorporating thermal comfort into urban planning, including by mainstreaming Heat Resilience Impact Assessments.

Communication remains a major barrier for placing energy demand at the centre of the UK's energy policy to meet its multiple objectives. Lack of clear and actionable communication between researchers and policymakers has limited the attention to energy demand at the national and local policy levels and slowed necessary investments into energy demand reductions in the built environment. A clearer national strategy on energy demand reduction paired with citizen engagement will be critical to unlocking necessary funding and building democratic support for the energy transition.

Energy demand – Areas for future action

- Raise ambition to achieve net-zero cooling emissions by 2050 through passive retrofits, efficiency standards, and green mortgages
- Develop integrated, place-based building decarbonisation policies that reflect differences in housing stock and community needs
- Strengthen social resilience with heat alerts, better data, and Heat Resilience Impact Assessments in planning
- Set out a clearer national strategy on energy demand reduction with strong citizen engagement

Energy storage [7,8,9,10,11,12,13]

Massive scaling of energy storage is essential for the UK to meet its Clean Power 2030 goals and ensure long-term energy resilience, with the National Energy System Operator (NESO) estimating that at least 20GW of installed storage capacity will be needed by 2030. A coordinated, national approach to energy storage would be anchored in capacity scaling, technology diversification, critical minerals security, supply chain resilience and public trust.

The energy storage industry and battery technologies offer considerable economic opportunities for the UK. The current and projected trends of economy-wide electrification indicate that battery storage technologies can expect to benefit from economies of scale. These trends are global in nature. Developing new battery storage and closed-loop recycling technologies would help address current bottlenecks in the industry and offer the UK an edge in the rapidly growing battery industry.

A resilient energy storage strategy requires a portfolio approach, encompassing short-duration

(<6 hours), long-duration (6-160 hours) and seasonal (>160 hours) technologies. Seasonal storage – essential for balancing seasonal variability – is a key challenge due to low technological readiness and high capital costs. While pumped hydro remains the primary seasonal solution currently deployed in the UK, research and development of novel, high-risk, high-reward transformational technologies can help the UK diversify available options and increase the UK's geopolitical security.

Meeting the UK's domestic battery storage requirements necessitates overcoming critical raw mineral (CRM) bottlenecks and reducing supply-chain dependence on China. The supply of energy transition minerals is scarce and strongly geographically concentrated – with China a controlling power of much of the processed supply. The Chinese monopoly on critical raw materials for the energy transition has already triggered a global race over critical mineral mining and processing, contributed to raw material price volatility, and created disruptions across energy storage supply chains. However, the CRM supply pressures will not ease until at least 2040. The UK's dependence on China extends to battery manufacturing, further exposing the UK to supply constraints and geopolitical risks. To mitigate this exposure, the UK must not only invest in domestic manufacturing and recycling infrastructure but also – crucially for benefits to be realised in the mid- to long-term – forge R&D, manufacturing and supply chain partnerships with Europe and nations with world-class research capabilities and/or access to CRM outside of Chinese-controlled supply chains. Strategic collaboration with nations such as Japan, Germany, Australia, and those in Latin America will help diversify and strengthen the UK's supply base, reduce vulnerabilities and ensure resilience in the battery sector.

Alternative battery chemistries present a key strategic opportunity for the UK. Earth-abundant materials – including sodium-based batteries and Li-sulfur batteries – have strategic value, as they offer cost-effective and geopolitically secure alternatives to lithium-ion. Grid storage could justify development of a dedicated energy storage gigafactory by 2030, but further research is needed to assess their demand profile, commercial readiness and performance across use cases.

Developing a domestic battery recycling industry is essential to reduce reliance on raw mineral imports, lower lifecycle emissions, and capture second-life battery value. Without increasing recycling capacities and capabilities, the UK is likely to maintain long-term dependencies in the battery supply chain. Currently, there are no large-scale recycling operational facilities in the UK, though this sector is developing.

Over the next decade, as the volume Electric Vehicle (EV) market shifts away from nickel-manganese-cobalt (NMC) to lithium iron phosphate (LFP) batteries – which do not contain the more valuable metals found in NMC chemistry – the economic case becomes more challenging. The lower intrinsic value of recovered materials from LFP batteries may impact the commercial viability and scalability of recycling operations. More work is needed to assess the economic case for the longer term.

The UK should seize the opportunity to demonstrate battery material stewardship by investing in the research and development of new battery recycling technologies, to improve efficiencies and drive down costs, and incentivising second-life storage battery applications.

Engaging the public and building trust in battery technologies will support UK's energy resilience. While modern battery systems increasingly meet highest safety standards, public perception often lags behind technical realities. The absence of dedicated UK safety regulations for Battery Energy Storage Systems (BESS) can add to the risks and the perception of risks, leading to community resistance and planning delays. This highlights the need for novel community engagement approaches.

Energy storage – Areas for future action

- Anchor a national approach in scaling capacity, diversifying technologies, securing minerals, and building supply chain resilience
- Invest in R&D for transformational storage technologies and alternative chemistries such as sodium and Li-sulfur
- Expand domestic manufacturing and recycling, and forge partnerships with trusted nations to reduce dependence on China
- Develop a UK battery recycling industry, improve technologies, and assess long-term economic viability
- Introduce safety regulations for battery storage systems and strengthen community engagement

Energy markets[14,15]

Electricity market design will shape the UK's ability to deliver a flexible, low-carbon energy system. Meeting the Clean Power 2030 goals requires significant growth in both energy storage (from 1.5 GW to 31.7 GW) and consumer-led flexibility (from 2.5 GW to 10–12 GW). Ensuring that markets can support, enable, and fairly distribute the benefits and costs of this transformation will be critical.

Different retail market governance instruments carry significant trade-offs, making the optimal pathway for energy market redesign both contested and uncertain. Existing market arrangements have delivered important outcomes, including a high share of renewables generation and continued

private investment in generation and infrastructure. At the same time, emerging challenges – such as managing variability, enabling distributed flexibility, and maintaining affordability – are placing new demands on electricity markets that were originally designed for centralised, dispatchable systems. For instance, while levy-funded policies supported the expansion of renewable energy-based electricity generation and its integration into the grid, they failed to pass on the benefits of lower costs of renewables to consumers. Similarly, while consumer price caps protect affordability, they may constrain energy efficiency, innovation or voluntary engagement with more dynamic pricing models.

There is no single optimal model for electricity market reform. Different approaches to pricing (e.g. zonal vs. nodal), consumer participation, and cost recovery involve distinct trade-offs – between simplicity and efficiency, investment certainty and affordability, or national coherence and local responsiveness. These trade-offs must be considered **explicitly and transparently**, involving diverse stakeholder groups that include consumers, industry actors, local authorities, and regulators. Advancing research and evidence on flexibility integration, including lessons from international practice; clarifying the objectives of market reform, including how to balance affordability, decarbonisation, system resilience, and investment certainty in the long term; and facilitating a deliberative process with key stakeholders to assess trade-offs across reform options will be key for **reaching a democratic consensus over market reform.**

Retail markets, in particular, will need to evolve to support consumer engagement with flexibility. This includes expanding access to time-of-use tariffs and smart technologies, while ensuring that participation is voluntary and inclusive. Affordability must remain a central goal in the UK's energy flexibility policy, especially for vulnerable consumers who may face barriers to participation or lack access to enabling technologies.

Flexibility also introduces operational and regulatory considerations. Practices and protocols for grid balancing, market access, and control room operations need to be evolved to ensure that flexible resources, such as batteries, electric vehicles, and smart appliances, can reliably contribute under stress conditions, and build public confidence in flexibility and emerging technologies.

Electricity markets are central to the UK's net-zero pathway. Reform would benefit from being approached as a process of structured, inclusive decision-making that balances competing objectives and builds shared confidence in the flexible energy system.

Energy markets – Areas for future action

- Advance research on flexibility integration and draw lessons from international practice
- Clarify long-term reform objectives, balancing affordability, decarbonisation, resilience, and investment certainty
- Facilitate transparent deliberation with diverse stakeholders on reform trade-offs
- Expand inclusive retail flexibility through time-of-use tariffs and smart technologies
- Update operational and regulatory frameworks so flexible resources can reliably support the grid

Table 1: Policy recommendations for the three pillars of energy system resilience

Pillar I: Energy Demand	Pillar II: Energy Storage	Pillar III: Energy Markets
Raise ambition to achieve net-zero cooling emissions by 2050 through passive retrofits, efficiency standards, and green mortgages	Anchor a national approach in scaling capacity, diversifying technologies, securing minerals, and building supply chain resilience	Advance research on flexibility integration and draw lessons from international practice
Develop integrated, place-based building decarbonisation policies that reflect differences in housing stock and community needs	Invest in R&D for transformational storage technologies and alternative chemistries such as sodium andLi-sulfur	Clarify long-term reform objectives, balancing affordability, decarbonisation, resilience, and investment certainty
Strengthen social resilience with heat alerts, better data, and Heat Resilience Impact Assessments in planning	Expand domestic manufacturing and recycling, and forge partnerships with trusted nations to reduce dependence on China	Facilitate transparent deliberation with diverse stakeholders on reform trade-offs
Set out a clearer national strategy on energy demand reduction with strong citizen engagement	Develop a UK battery recycling industry, improve technologies, and assess long-term economic viability	Expand inclusive retail flexibility through time-of-use tariffs and smart technologies
	Introduce safety regulations for battery storage systems and strengthen community engagement	Update operational and regulatory frameworks so flexible resources can reliably support the grid

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Endnotes

1 See Acknowledgements.

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