Networks reimagined: Designed to deliver for customers and growth

Report Annexes

May 2026

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Introduction

These annexes provide the detailed evidence base, process insights, and Working Group outputs that underpin the Energy Network Innovation Taskforce's report: *Networks reimagined: Designed to deliver for customers and growth*. While the main report presents the five Innovation Challenges selected to guide network innovation through the upcoming price control period and Strategic Innovation Fund, these annexes expand on how those Innovation Challenges were generated and the breadth of thinking that informed them.

The Taskforce was built on extensive engagement with stakeholders from across and beyond the energy sector, bringing together perspectives from network licensees, system operators, innovators, technology providers, consumer representatives, and adjacent sectors such as water and telecommunications. Annexe 1 in this document describes that process: how the Taskforce organised its governance, how the Taskforce's Working Groups were convened and structured, and how the sector helped articulate both the opportunities and barriers that innovation must address over the coming decade.

Annexes 2 and 3 set out each Working Group's scope of exploration and their collaboratively developed depiction an aspirational 2040 energy system. Annexes 4 and 5 provide the full set of draft Innovation Challenges considered, potential areas identified for innovation and candidate solutions. These annexes capture the breadth of ambition expressed by participants and provide transparency on how ideas were progressively refined, consolidated, and prioritised to form the final set published in the main report. They also highlight areas of emerging interest, cross-vector thinking, and system-wide dependencies that may be relevant to future innovation activity. Annexe 6 contains example case studies of ambitious innovations from both the UK and internationally, used as inspiration for the level of world-leading innovation that the Taskforce aims to achieve through the Innovation Challenges. Annexe 7 provides a glossary of key terms specific to the ENIT process that have been used in these annexes and the *Networks reimagined: Designed to deliver for customers and growth* report. Finally, Annexe 8 gives acknowledgement to all of the people who have contributed their time, expertise and support during the Taskforce.

Together, these annexes and the main report form a comprehensive record of the Taskforce's work, providing both the strategic direction for energy network innovation and the detailed context behind it. The material presented here is intended to be a useful resource for industry, innovators, and policymakers to explore ideas as the sector prepares for RIIO-3 and the next phase of Strategic Innovation Fund delivery.

Annexe 1: Taskforce stakeholder engagement and governance

To identify the most transformational Innovation Challenges, the Taskforce sought to go far beyond the norm of comfortable engagement with familiar stakeholders.

The Taskforce set up a radically open process, overseen by a Steering Group of senior leaders, where Working Groups organised around key themes collaborated to define the highest-priority innovation areas. Ofgem and Innovate UK have been closely aligned with the Taskforce throughout the process of delivery, paving the way for the Challenges developed by the Taskforce to be adopted into the Strategic Innovation Fund.

The diagram below outlines the process followed by the Taskforce. The starting point was four overarching objectives, as shown in the diagram, which collectively articulate the results to be achieved by energy network innovation:

1. Drive down energy network costs
2. Serve network customer needs
3. Stimulate economic growth
4. Unlock decarbonisation

The initial phase of the Taskforce involved developing key themes, as articulations of the areas where innovation is required to deliver the objectives. Each theme defined the scope for one of the Working Groups, presented in more detail in Annexe 2. Five key themes were chosen:

1. Fast, seamless grid connections
2. Create a more adaptable and faster built network design
3. Achieve world leading grid operation
4. Simplifying customer journeys
5. A grid that is resilient to shocks and quick to recover

Every Working Group undertook a series of four workshops combined with offline activities, transitioning from exploration and idea generation to convergence and refinement on well-considered Innovation Challenges. The diagram below presents the high-level content of each workshop within the context of the wider Taskforce process.

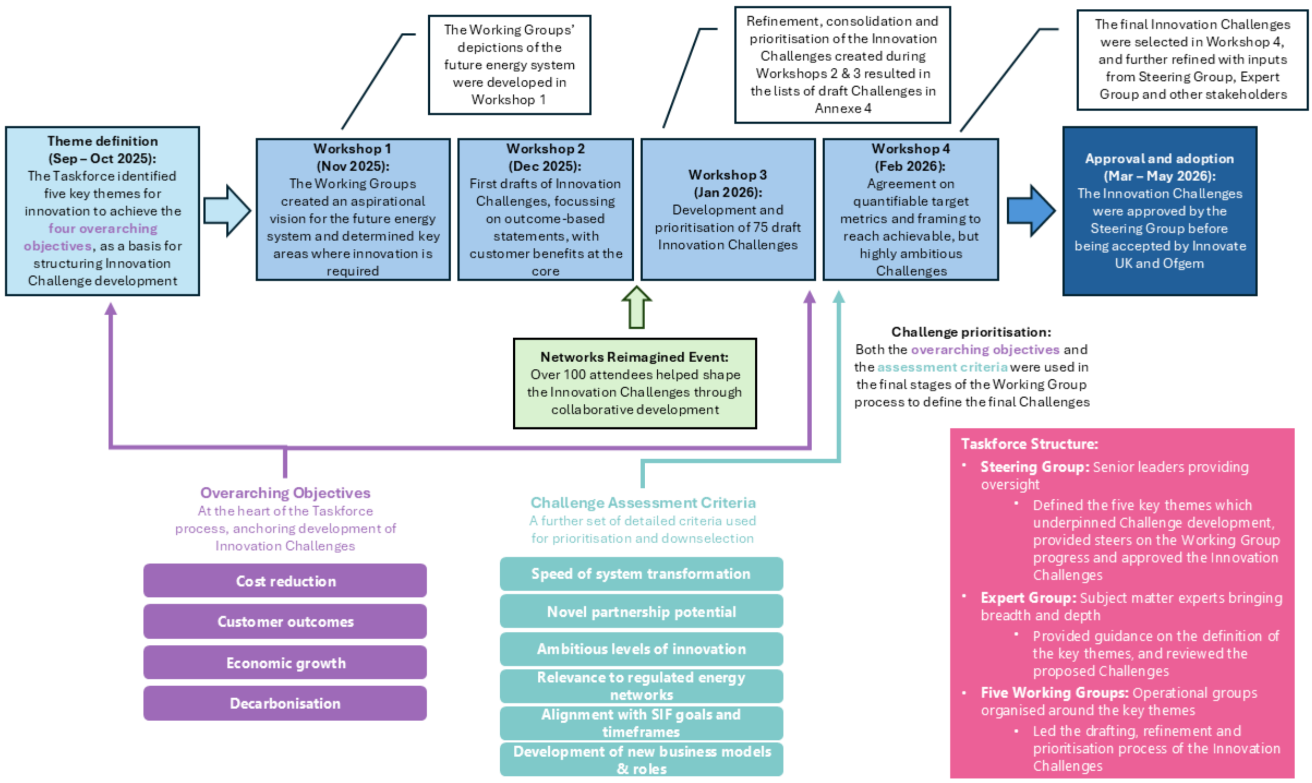
A key part of the process was to plan from the future, developing the Working Groups' aspirational shared visions of a future energy system. Each Working Group brought together network stakeholders, their customers, and the innovation ecosystem, spurring new partnerships and encouraging intensely ambitious thinking. Annexe 3 presents the outcomes of discussions from each group regarding their optimistic view of a future energy system.

To give critical feedback and fresh perspectives on the developing Challenges, an Expert Group was established with strong representation from energy network customer groups. Broader views on the nascent Innovation Challenges were captured from the participation of over 100 organisations at the Taskforce's engagement event in January 2026, titled *Networks Reimagined*.

Towards the end of the Taskforce process, the primary focus was on consolidation, prioritisation and calibration of draft Innovation Challenges, using both the overarching objectives and a wider set of assessment criteria, to yield refined outputs that were presented to the Steering Group with commentary from the Expert Group. The Steering Group ultimately selected the five Innovation Challenges that represent the recommendation of the Taskforce.

Although the Taskforce ultimately recommended five Innovation Challenges, the process did not presuppose that each Working Group would contribute one Challenge, and indeed the final Challenges represent a combination of thinking from across the Working Groups.

The framing of the Taskforce's Innovation Challenges followed a precise format, adopting best practices for challenge-led innovation. Each Innovation Challenge expresses an outcome for energy networks' customers, deliberately keeping open the innovations that could be developed to achieve it. To communicate more clearly the ambition of each one, the outcomes have been expressed in concrete and measurable terms which were quantified where appropriate. Each Challenge has a set date by which innovation should form part of business as usual, rather than stalling between early innovation and full realisation of benefits. Challenges have been selected where the target date for scale deployment falls between 2030-2040, representing innovations that are definitively beyond what is possible in current price controls.



Annexe 2: Working Group scope

The Taskforce established five Working Groups, with each given the remit to explore the priorities for innovation under one of five key themes. These key themes were defined by the Steering Group as critical areas in which innovation is required. The sections below present the key theme explored by each Working Group and a brief overview of the scope provided to the Working Group within the theme.

Although the Taskforce has ultimately recommended five Innovation Challenges, the Challenge development process did not presuppose that each Working Group would contribute one Challenge, and the final Challenges represent a combination of thinking from across the Working Groups.

Working Group 1: Fast, seamless grid connections

Working Group 1 was tasked with exploring the ambition of fast, seamless grid connections. The Steering and Expert Groups directed them to target the elimination of network access as a barrier to economic growth and decarbonisation, allowing customer connections to be unlocked through innovative solutions beyond network reinforcement. The group was required to address the urgent need to connect millions of new low-carbon assets, from gigawatt-scale industrial electrification to electricity generators and low-carbon gas suppliers, at a pace that current physical queues cannot accommodate. Furthermore, the members were mandated to explore how customers could better express their connection needs and receive prompt, viable offers tailored to their requirements. The Steering Group specified that connection offers should consider all energy vectors alongside planning and consenting processes, aiming to deliver the best value and fastest connections.

Key enablers highlighted to this Working Group included novel business models and infrastructure that allow customers to access affordable energy, as well as the development of new services or intermediaries to help find energy connections in suitable places at suitable prices. It was also emphasised that where capacity exists it should be exploited, and new capacity should be deployed quickly and cost-effectively to enable growth.

Working Group 2: Creating a more adaptable and faster built network design

Working Group 2 was established to investigate how innovations in the design and construction of energy networks could achieve an order of magnitude improvement to the time and cost of network build, maintenance and upgrades. Their core objective was to identify ways to enable greater flexibility in how networks are operated and to improve their ability to adapt to changing customer demands and physical impacts. A key expectation from the Steering Group was that the members would address long term uncertainty regarding energy infrastructure pathways and unforeseen disruptors across both the energy sector and the wider economy. Consequently, the group's ambition was framed around targeting innovations that accommodate rapid change and responsiveness to customer needs, while simultaneously maximising the usage of green energy.

To guide their efforts, the Steering Group and Expert Group requested investigation towards specific areas such as modular infrastructure build and robotic solutions for accelerating construction, inspection and maintenance. The underlying goal was to deliver a step-change improvement in the pace and impact of network upgrades. Participants also needed to consider the deployment of cross-vector solutions to manage capacity and constraints, alongside massively improving energy system change processes, ranging from small scale installation permissions to sector wide code or regulatory changes. Broader supply chain innovation was within the remit of Working Group 2, specifically the alignment of GB infrastructure with international standards to increase the attractiveness of the UK market and reduce component lead times. Lastly, the Steering Group encouraged the members to evaluate how cross-sector collaboration between energy, water and telecommunications could lead to radical new approaches for conducting infrastructure build and maintenance, ultimately reducing disruption and cost.

Working Group 3: Achieving world leading grid operation

Working Group 3 was convened to consider the future of energy system operation. The Steering Group highlighted that, as the level of digitalisation increases and networks become smarter, grid operation must adapt to accommodate increasing numbers of distributed network assets while optimising the usage of existing infrastructure. The Working Group participants were challenged to identify the tools and operational approaches that future energy networks will require to address the complexity of the system directly.

The Steering and Expert Groups stressed that the solutions under consideration should represent a step-change in capability from the largely centralised and static delivery models employed in the current system. As a key enabler, the group was asked to explore how digital technologies and distributed intelligence could play a key role in delivering this transition, ensuring that any new approaches are underpinned by robust guardrails for secure service delivery and the avoidance of unintended interactions.

Working Group 4: Simplifying customer journeys

Working Group 4 was given the remit to examine the relationships between customers and the energy system. The Steering Group emphasised the critical importance of creating smooth, quick and low-hassle interactions to build customer trust and accelerate the transition to Net Zero. The Working Group was directed to frame their thinking around the premise that customers must become central to the activities of networks, acting as both end users of energy and the vital energy resources that enable wider societal economic activity. Consequently, the group was challenged to determine how networks could transition into proactive solution providers for customers, rather than remaining traditional custodians of access to energy.

Furthermore, the scope stipulated that networks must become easily accessible to project developers of all kinds. The participants were urged to identify unified routes with consistent requirements across regions, noting the risk that disjointed processes could drive investment overseas. Finally, the Steering Group encouraged the members to explore mechanisms that foster a deeper understanding between networks and their customers, promoting the collaboration and co-design of solutions tailored to customer needs, and ensuring that all interactions are fundamentally designed around the customer journey.

Working Group 5: A grid that is resilient to shocks and quick to recover

Working Group 5 was assigned to explore how innovations could improve energy system resilience, allowing it to flex and adapt to shocks, and increase the speed at which service could be restored following an outage. The Steering Group stressed that increasing digitalisation requires the system to be more prepared than ever to cope with diverse threats, including physical, climate and cyber risks.

The Working Group was required to investigate how future networks could provide a reliable service measured against customer outcomes. Participants were challenged to question the status quo notion that all resilience must be delivered exclusively within the national infrastructure, whilst acknowledging the immense challenge of replicating today's built-in resilience. Because current standards protect customer welfare largely through gas linepack, the Steering Group directed the group to reimagine how these critical safety nets could be met in the future.

Finally, the remit emphasised that focusing on service outcomes allows decoupling from the specific physical nature of supply. Consequently, the Working Group was encouraged to envision how future energy systems could embed hierarchies of autonomous, localised cross-vector provisions for both energy and control, thereby fundamentally strengthening the system's ability to ride out disturbances.

Annexe 3: The Working Groups' depictions of the future energy system

Within the process set out in Annexe 1, the Taskforce was keen to avoid the creation of Innovation Challenges that would only lead to incremental or business-as-usual changes in the energy system. Therefore, as an initial exercise the Working Group members were asked to create a 'postcard from the future', writing to themselves in the present day from 2040, which they shared during Workshop 1. This encouraged Working Groups to move away from thinking about the technologies and challenges of today and aimed to move towards a far more aspirational vision of the energy system of the future. Participants were challenged to be as ambitious and creative in their postcards as possible, with the intent that this would remove constraints and boundaries from the devising of Innovation Challenges.

These individual views were then combined into a single vision of the future for each Working Group, with further refinement on these depictions at the start of Workshop 2. The final vision for the future created by each Working Group is given in the sections below.

It should be recognised that these visions do not represent the formation of any form of future policy target. They served only as a thought exercise to help stimulate novel and ambitious thinking towards future possibilities.

Working Group 1: Fast, seamless grid connections

By 2040, energy feels effortless. The system is more complex than ever, but that complexity exists to support homes, businesses, and industries. In the background of the day-to-day, yet accessible when needed, the energy system is no longer a constraint - it quietly enables life, commerce, and innovation.

Connections have been transformed. In the 2020s, grid queues stretched for years, projects stalled, and costs soared. Today, automated systems using AI and digital twins process connections in seconds. Customers submit requests via APIs; offers are generated in real-time. Optimisation engines model network conditions and market signals to ensure every new connection can be delivered robustly and adds value to the grid and wider society. Customers can choose based on their preferences for speed of connection, resilience and cost, and can elect to share the risk and rewards of new provision. The cost of a grid connection has changed to better reflect the true costs involved, and capacity adapts to customer needs so fluidly that there is no longer specific value in holding a connection offer.

Flexibility became the foundation. Fixed capacity gave way to dynamic allocation. Customers can leverage their smart tech to draw what power they need when it's most cost-effective. Real-time markets for capacity and flexibility smooth peaks and unlock latent potential. Transparent, competitive, integrated markets drive efficiency and resilience, maximising network utilisation. Local energy communities trade energy between homes, efficiently utilising distributed energy assets and reducing strain on upstream networks.

Customers are at the centre. Whether installing a heat pump or electrifying fleets, the journey is simple, fast, and predictable. Consumers enjoy greater choice and outcomes tailored to their needs. Anxiety about disruption has vanished; transparency and choice replaced uncertainty. Energy is no longer a headache - it's a service that just works, giving customers the energy they want, at the time and location that they need it and at the lowest cost. Customers experience high-quality service maintained through strong performance standards and on-going monitoring.

Network utilisation has become more cost-efficient. Unit costs have fallen even as electricity volumes surged to power electrified heat, transport, and industry, as a result of more nuanced network management – balancing the pros and cons of high asset utilisation, and carefully deploying effective investment where needed. Networks can anticipate outages, adapting, and self-healing, reducing disruption and making full use of the installed infrastructure.

Networks evolved into platforms. No longer passive infrastructure, they became ecosystems for innovation. Regulation aligned profits with speed, cost efficiency, and productive capacity. Network operators face more responsibility and scrutiny, but performance and collaboration in the service of system value are rewarded, supporting network operators to become high-performing, trusted and respected enablers of decarbonisation. Industry became a partner, not just a customer. Manufacturers and data centres co-design connections for both parties' benefits, integrating on-site generation and storage, and contributing to grid stability. Transparent frameworks and competitive markets fuel domestic investment, strengthen UK supply chains, and position Britain as a global clean energy leader. Technological innovation blossoms nurtured by these open market environments, with networks quickly adopting effective solutions from international peers and home-grown solution providers.

Whole system planning is central. Interoperable platforms link electricity, gas, and transport systems for whole-system optimisation, taking a multi-vector and multi-sector view to deliver most value. Intra-sector relationships between transmission, distribution and between regions are strengthened and streamlined providing effective coordination between decentralised systems. Market mechanisms incentivise all players to behave in concert to deliver system value. AI tools guide asset placement (generation, storage, heat), balancing technical and societal priorities. Planning and permitting are automated, slashing timelines and removing bottlenecks. AI and APIs anticipate demand from reindustrialisation, electrified transport, and emerging technologies. Locational signals guide investment to maximise societal value - revitalising communities, supporting growth, and reducing disparities. Markets increase competition for connections and accelerate renewables integration.

Working Group 2: Creating a more adaptable and faster built network design

By 2040, energy is silent, sustainable, and seamless. Homes, cities, and industries hum in harmony because networks anticipate needs before they arise and adapt to mitigate problems before they manifest. What once seemed an impossible climb to Net Zero is now reality - built on integration, collaboration, and relentless innovation.

Integration beat isolation. Electricity, hydrogen, biomethane, and heat networks operate as one optimised system, unlocking flexibility, avoiding waste, and offering endless options for consumers and businesses. Hybrid demand and reverse-flow gas systems are standard, sparing carbon-negative biomethane and seasonal storage in salt caverns. Curtailment is history; electrons and molecules flow where needed. Whole system planning, enabled by markets to communicate the true costs and options available, has optimised network operation and design resulting in modular parallel decentralised systems which coordinate across the whole network. But plans are dynamic and respond in real time to the needs of network customers – as is the regulatory layer of the system, which adapts to enable innovation and simplify deployment.

Construction is fast, fair, and safe. Modular design, with streamlined requirements aligned with international markets, delivers low-cost substations and energy corridors like Lego bricks - precise, interoperable, with common design languages, and ready to plug and play on short lead times. Mobile low-carbon factories produce components on-site, cutting transport miles and reducing logistical delays. Robotics plays a far more substantive role – from conducting surveys and monitoring, handling excavation and assembly, to load-carrying and confined-space working. Since taking over some of the most dangerous jobs from humans, injury rates have been slashed and productivity boosted. Where humans do get involved, augmented reality guides tasks, keeping things straightforward and safe. Upgrades now occur on live networks, minimising disruption. Weather no longer halts progress - adaptive canopies and smart scheduling keep projects moving. Every decision balances biodiversity and social impact transparently through streamlined engagement and evaluation tools.

Data is the lifeblood. A unified digital framework connects everything, from community projects to national planning. Planning and permit consents are tied into digital framework accelerating the process through pre-construction. Plug-and-play standards feed granular data upstream and downstream, informing investment and flexibility decisions. NESO's strategic tools integrate with local plans for real-time coordination. Transparency and interoperability aren't aspirations, they're the foundation of confidence and investment. Satellite surveillance and distributed network sensing can detect faults before they happen, monitoring system operation in incredible detail and ensuring a highly adaptable system.

Consumers are empowered. Networks are trusted partners, not disruptors. A single point of contact orchestrates home upgrades; tech bundles with flexible payments minimise costs. Customers play a greater role in supporting the network – local energy communities and energy management can provide local balancing services and are well rewarded for doing so. Markets send clear price signals to customers ensuring energy assets are sized optimally for the whole system, serving both the consumer and the grid. Self-sustaining islanded microgrids can be connected and disconnected in anticipation, reducing demand on upstream networks and helping the network divert available power to where it is needed most.

Storage is critical across the system. Homes store energy where they can; the nation holds reserves for a winter, although we have never needed more than a couple of weeks. Ultra-long storage clusters and cross-vector solutions increase energy security. Resilience is designed in. From critical infrastructure to microgrids, assets withstand shocks such as extreme weather or geopolitical tension. Private infrastructure supports public networks during emergencies, creating adaptability. Community operators and industrial clusters, supported by effective standards, reinforce national stability, and permit new network operating models that can be deployed to manage different scenarios. Rapid underground infrastructure maintenance and upgrades are completed by ever-present roving robotics, which keeps roads intact and minimises disruption while repairs are made.

Costs remain fair. Renewable energy isn’t free, but integration, modularisation, and shared investment keep bills low. The UK avoided underutilised assets, repurposed infrastructure where effective and became a global leader in decarbonisation, exporting expertise in hydrogen, biomethane, and smart power systems.

The workforce is world-leading. Faster, digitally enabled and higher calibre training produces a population of energy system experts, capable of responding to the changing needs of the system. Greater emphasis is placed on digital skills and training, while augmented reality, robotics and other technologies support the more manual tasks and increase productivity. The increasing complexity, interconnectivity and digitalisation means the industry is seen in a different way, with energy becoming a highly attractive field in which to work.

Working Group 3: Achieving world leading grid operation

Imagine waking up in 2040 to a home that feels alive. You don't buy kilowatt-hours, instead you subscribe to carbon-free comfort and convenience, a seamless experience where energy *just works*. Behind the walls, automation makes grid complexity invisible. Your EV, heat pump, and appliances communicate autonomously with the network, orchestrated by AI at asset level and in the wider system, optimising millions of variables for lowest cost and highest sustainability. This is the property-to-grid concept realised: households monetising flexibility through real-time markets and selling surplus storage without lifting a finger.

Step outside, and infrastructure has transformed. Regional control centres gave way to hyperlocal distributed systems, enabling neighbourhood microgrids and energy communities. Consumers play a greater role in network operation, with decentralised energy management optimising each home's own assets and those around it in real time to maximise the benefit to the consumers and the system. It is a bottom-up resilient system, where every layer – from homes to substation – self-manages and balances flows before escalating needs. The NESO control room steps in on rare occasions at the most critical junctures – getting energy management right at every level of the network has resulted in only a few residual actions being centrally needed.

Streamlined governance enables freedom. Forty-six overlapping institutions became three, enabling agile decisions. Restructuring of key sectors and streamlining complex regulation by targeting the right "layer" has unlocked innovation and productivity, with competition between frameworks preserving efficiency. This has slingshot the progress of smart-tech which is now ubiquitous. Cross-sector relationships are smooth with clear interfaces provided by effectively governed energy institutions. Planning and procurement constraints have been removed and regulation is now agile and appropriate, making it far easier for customers from multi-gigawatt generators to homeowners to install the technology they want, where they want.

Digitalisation underpins everything. Digital twins and data monitoring predict maintenance and isolate faults instantly, preventing outages. Advances in quantum computing simplify the coordination and management of entire networks, enabling optimisation that was previously impossible. Traditional back-office processes of the energy networks have been fully digitalised and automated: from network design and connection applications to control room operations – the once manual, cumbersome systems have been revolutionised and replaced by agile, automated solutions that can respond better and faster than ever before.

Customers receive a seamless experience. Energy is no longer a constraint, but a backbone of everyday life - the UK moved from managing scarcity to enjoying abundance, achieving energy independence through low-cost renewables. It is easy to connect new technologies, energy companies are innovating and providing customer-first experiences, and the whole system works together for the benefit of the customer. New housing is plug-and-play, integrating into local flexibility schemes to allow every home and consumer to play a greater role in strengthening the grid's resilience. But the customer doesn't have to worry about the details – this all happens seamlessly behind the scenes, enabling customers to just get on with life. Industry became an active partner in grid operation. Electrified and low-carbon industrial processes – from biogas and hydrogen-enabled steel and chemicals to smart data centres and advanced manufacturing – flex their electricity and gas demand in harmony with the system. Industrial users no longer consume energy passively; they co-optimise production schedules, on-site generation, storage and fuel switching in real time, providing deep, reliable flexibility that underpins system stability. Low-cost, dependable energy has boosted UK productivity, attracting globally competitive industries and enabling firms to run cleaner, faster and more efficiently. The boundary between energy system operation and industrial performance has dissolved – a smarter grid has become a direct engine of economic output.

Culture shifted. Scepticism became participation. Energy companies are lifestyle enablers, not bureaucratic hurdles, with customer outcomes a much higher priority. Trust is built on advanced cybersecurity and open data platforms. All stakeholders from supply chain right through to customers came together in the surge towards a new paradigm. Benefits of automation and flexibility are shared across urban, rural, and vulnerable communities – ensuring fairness as well as progress. DSOs play a far more proactive role, orchestrating the service and coordinating with national, regional and local aggregators and energy service providers. Autonomous cyber security systems play simulated war games continuously, identifying vulnerabilities and issuing resolutions well ahead of any adversary's awareness.

A focus on value, rather than cost. "Lowest cost" gave way to low-cost delivery of best value solutions – aligning economics with environmental goals and driving global competitiveness. All parts of the system strive for delivering better value, from streamlining standards and aligning them internationally to benefit from scale, to recognising where more integrated deployments can deliver richer outcomes over the long term. Everyone can afford the energy they need, and energy is cost-competitive with the rest of the world. Every customer from corner shop owners to industrial corporations receive a service that delivers far beyond the bare minimum. The UK has a world-leading grid, and other countries are now looking to us in envy – energy innovation has created jobs in clean transport, AI and quantum computing. Exports of our expertise and technology have become a major part of the economy, and our energy sector workforce is now the spearhead of energy systems transformation globally.

Working Group 4: Simplifying customer journeys

By 2040, customer interactions with the energy system are completely frictionless. While the underlying infrastructure has grown in complexity, this is entirely invisible to the end user. For households, businesses, and communities, energy is no longer a source of friction - it is trusted to quietly enable life, commerce, and comfort. In the 2020s, energy felt rationed due to rising costs of living and business. Vulnerable customers were left behind, logistics faced decades-long delays, and communities were locked out of planning. The system was siloed, reactive, and opaque. Thanks to a step change in collaboration, supported by enabling regulation, today those barriers are gone. Customers see the outcomes, not the complexity and bureaucracy underneath.

No one is left behind. Secure, consent-based data-sharing and AI agent interoperability lets networks, advice providers, and local authorities coordinate seamlessly. Vulnerable households don't lag behind, instead they are supported to lead the way in decarbonisation and new technology uptake. A single portal maps needs and connects customers to tailored solutions - heat pumps, insulation, or home batteries for medical resilience. Green finance options make upgrades easy. Boiler funeral plans ended anxiety and provide clarity about future electrification. Like clean water, energy is seen as a necessity to life, and no one is left behind.

A customer-centric system. Communities plan collectively through interactive hubs showing future local generation and infrastructure. Energy planning is as intuitive as checking the weather. Seamless service and delivery reduce customer costs and deliver greater value. Customers are empowered to make their own choices through new propositions and greater, but easily digestible, information. Everybody can choose their own Energy Companion, a secure digital agent that understands their lifestyle, habits, and needs. Consequently, each person's Companion handles the complexity of energy system players and gives plain English and straightforward advice that can be relied on. Domestic, industrial and commercial customers are all handled through the same system with their levels of engagement and options guided by their Companion. The Energy Companions will even handle management of your installs and upgrades.

Connections are instant. One portal, one login, one click. Behind the simplicity, automation and AI orchestrate millions of variables in milliseconds. Customers choose priorities - cost, carbon, resilience - and the system delivers. Connections are codesigned between customers and networks – solutions are tailored to what the customer needs, recognising their flexibility and behaviour – reducing cost and complexity for consumers and supporting the network in the process.

Industry thrived. Logistics, once crippled by uncertainty, now runs on predictability. Freight decarbonisation is complete, powered by anticipatory investment and integrated flexibility. Warehouses generate and store energy, feeding the grid. Energy costs are stable, low, and fair, unlocking global competitiveness without sacrificing sustainability. Cross-sector planning is now commonplace – rather than operating as silos, different businesses and sectors can collaborate to secure connections and infrastructure that benefits everyone. Energy vector choices are made clear and green gas and hydrogen are used in their optimal applications.

Trust and data sharing became the currency. In the 2020s, mistrust of AI slowed progress. By 2035 modern AI governance caught up. We built an open, rights-based, interoperable data infrastructure. Data underpins the energy system, flows are trusted, permissioned and interoperable. Data is shared with consent, but is accessible to where it is needed. This wasn’t digitisation - it was democratisation. Finance, transport, property all connected. Flexibility markets scaled, planning became anticipatory, and waste vanished. Consumers pay less – or sometimes nothing – because they contribute value back to the system.

Infrastructure is everywhere, yet invisible. Wind farms rise without protest; planning reform turned opposition into celebration. Neural network-linked alert systems optimise EV routes automatically. Innovators swarm tech-hubs, crafting propositions that make energy effortless. The system is hyper agile, ready to adopt revolutionary innovation. Networks sweat every asset whilst timing upgrades perfectly. Cybersecurity is woven into every layer, making attacks futile. But all of this is done to deliver the primary goal - improving the outcomes and experiences for customers.

Working Group 5: A grid that is resilient to shocks and quick to recover

By 2040, resilience means more than “keeping the lights on.” It’s about keeping the whole system breathing: anticipating shocks, adapting in real time, and protecting people and the energy services they need. What began as scattered pilots in the 2020s matured into an integrated fabric of electricity, gas, heat, telecoms, and data - a living network that flexes with weather, markets, and society’s needs.

An anti-fragile network. When the grid was threatened, it didn’t fail; it adapted, learned and healed stronger. Grid-forming batteries initiated black starts; distributed flexibility tools created local islands; distributed AI agents held voltage and frequency while cyber defences rebounded automatically. Weekly backup drills - now as routine as fire alarms - make resilience proactive muscle memory, not emergency improvisation. An adaptable and constantly learning system has evolved which is equally well equipped to deal with uncertainty as it is with predicted risks. Before storms, early warnings pre-charge hospital batteries, stitch microgrids into support rings, and push updates to digital dashboards. Vulnerable customers are identified via secure shared data, shielded from price shocks, and prioritised for services and support in emergencies. Resilience is local – quiet, predictable, equitable.

Clear risk frameworks anchor resilience. Operators map interdependent risks across healthcare, logistics, water, and communications, updating mitigations continuously. Regulation aligns with a society that expects energy to power everything reliably. Ubiquitous sensing and enhanced controls tame renewable variability, sustaining today’s always-on digital identity.

Resilience moved to the grid edge. Battery costs fell; most homes store energy. V2X became standard; home and microgrid islanding is common, with EVs powering households during outages. Community energy hubs – our new “energy bunkers” – pair multi-megawatt batteries with air-conditioned shelter, heat, cooling, and emergency fleet charging. Vehicles move energy from hubs to hospitals, making electrons as mobile as fuel. When stable, hubs earn revenue balancing the grid; when strained, they protect communities.

Inter-sector harmony arrived. A national telecoms backbone is interwoven with the energy system, simultaneously reducing interdependence on energy and telecoms. Energy vectors are intelligently sited to provide greatest benefit and switch back and forth when needed. Biomethane, green hydrogen, batteries, and heat networks provide flexibility and seasonal storage. The value that cross-vector resilience solutions, such as heat networks, provide is recognised. Drones and sensors maintain assets autonomously. Wireless energy beams remain speculative – but innovation culture embraces the extraordinary. The UK leads on lowest energy bills in the OECD, but also has the most reliable energy system for business – powering growth while staying inside Net Zero.

Cocreation replaced command and control. Strategic planning sets direction, but local arrangements are tailored by customers, innovators, and operators using live and dynamic data which cuts across sectors: informing capacity, investment, demand, generation. Price signals are precise; protections targeted. Resilience is decentralised by design, balancing central supply with real-time local adaptation. Social value costs are socialised; elsewhere, competition drives efficiency.

We created resilience service offerings. Large users opt for interruptions - well-compensated and scheduled – so that households, SMEs, and critical services remain unbroken. Resilience is optional but priced, customised yet fair. Customers are given clear and easy to understand information on how opting for reduced resilience could really impact them, to allow them to make a fully informed choice. The whole system value of offering reduced resilience is factored into determining the service offerings – and often the wider benefits of keeping the economy running far outstrip the marginal resources needed to robustify the system. “Customer minutes lost” feels archaic; “critical service minutes lost” is the new metric with definition given to the criticality of different customers. Any outage is treated like a safety incident: rare, root-caused, and learned from.

Not everyone wants to be a prosumer. Real-time pricing, open data, and automated forecasting flattened the load curve, but for many, the greatest innovation was zero cognitive load. Smart thermostats and service providers manage consumption and storage remotely, lowering bills for those uninterested or unable to participate. Abundance comes from inclusion.

Annexe 4: Draft Innovation Challenges

To arrive at the five final Innovation Challenges, the Taskforce process involved multiple rounds of drafting, prioritisation and consolidation of draft Challenges. This took place both within the Working Groups and through feedback from the Steering Group, Expert Group and other external stakeholders.

This annexe contains two tables, representing the sets of draft Challenges under consideration at different points in the Taskforce process. The first table contains the 75 initial draft Innovation Challenges created by the Working Groups during Workshop 2. These were then scored by the Working Group members in a prioritisation activity that took place between Workshops 2 and 3. At this early stage of the process, many of the Challenges listed here required further development to refine the framing, target metric and timeline of the Challenge in order to create Innovation Challenges that met the criteria of being customer-outcome focussed with measurable, ambitious, but achievable target metrics and dates. As a result, the draft Innovation Challenges presented in this Annexe have the target dates and metrics enclosed in square brackets – this allowed the Working Groups to evaluate the premise of each Challenge and the potential impact it could have on the energy system and its customers, without focusing on the target, which could be developed later in the Taskforce process following industry baselining and rationalising.

During Workshop 3, the Working Groups de-prioritised the Innovation Challenges that did not score as highly during the prioritisation activity and merged Challenges which targeted similar outcomes. The resulting 39 shortlisted Challenges are presented in the second table below.

These shortlisted Challenges were again prioritised by the Working Group members, and the highest priority Challenges given further refinement, considering input from the Expert Group, Steering Group and external stakeholders, which culminated in the final set of Challenges recommended by the Taskforce.

Initial draft Innovation Challenges from Workshop 2

ID	Innovation Challenge	Key Theme Addressed
W2 IC1	By [2032], the connections process adds no time to install of heat pumps or EV chargers at existing domestic supplies	Fast, seamless grid connections
W2 IC2	By [2035] there will be an agreed menu of more flexible connection agreements with a range of prices and timelines	Fast, seamless grid connections
W2 IC3	By [2030], investigate and implement options to maximise green gas capacity on the network at lowest cost, to increase energy resilience and reduce CO_2 emissions e.g. storage, bi-directional energy flow	Fast, seamless grid connections
W2 IC4	Deliver a whole digital energy system control that provides real-time balanced and resilient energy seamlessly by [2040]	Fast, seamless grid connections
W2 IC5	Safely increase network utilisation by [35%] by [2035]	Fast, seamless grid connections
W2 IC6	Detailed connections optioneering/engineering sped up by [10x] (maybe using AI tools) by [2035]	Fast, seamless grid connections

ID	Innovation Challenge	Key Theme Addressed
W2 IC7	By [2035], developers can generate an instant grid connection offer based on their input parameters	Fast, seamless grid connections
W2 IC8	By [2035], we will unlock utility deliverability by rationalising/combining a shared infrastructure through new legislation, guidance and a GB wide platform for tracking all utility works	Fast, seamless grid connections
W2 IC9	Unified method for understanding regional capacity and connections to achieve [<10%] deviation from offer date to actual connection by [2032]	Fast, seamless grid connections
W2 IC10	By [2035] there is a way to validate a design of a new project faster. Faster planning and approvals across multiple orgs	Fast, seamless grid connections
W2 IC11	By [2035], networks have [100%] visibility of assets, control and pricing at all substations including LV	Fast, seamless grid connections
W2 IC12	From [2033], network operators will be incentivised to accommodate connection requests and will be able to use a risk-based approach that takes into account existing network headroom, generation and demand	Fast, seamless grid connections
W2 IC13	By [2035], non-domestic customers will have a standard route to release unused connection capacity back to the network	Fast, seamless grid connections
W2 IC14	By [2035], deliver UK wide one stop (backend) digital route through which [95%] of energy network connection journeys can be completed within [5 working days]	Fast, seamless grid connections
W2 IC15	By [2035], all domestic consumers will have the ability to instantly connect any demand or generation assets with zero constraints	Fast, seamless grid connections
W2 IC16	By [2035], every network asset installation will use a standard process to identify low-marginal cost work to future-proof and enhance network capacity	Create a more adaptable and faster built network design
W2 IC17	By [2040], [95%] of all construction, inspection, repair and maintenance is automated through robotics	Create a more adaptable and faster built network design
W2 IC18	By [2035], GB will have asset modularisation and an intelligent standardisation framework aligned with international TSOs and partners	Create a more adaptable and faster built network design
W2 IC19	By [2035], GB will have reduced by [50%] the time taken to build new energy network upgrades / reinforcements compared to 2025.	Create a more adaptable and faster built network design
W2 IC20	By [2040] create a unified digital framework that creates an adaptable network delivering [30%] improvement in system efficiency	Create a more adaptable and faster built network design
W2 IC21	By [2035] network design + build is entirely led by layered spatial data on existing and planned built infrastructure and consumer data	Create a more adaptable and faster built network design
W2 IC22	By [2035], local systems and grid-edge systems work in synergy with networks using a plug and play common data framework	Create a more adaptable and faster built network design
W2 IC23	By [2040], new modular network structures and operating models (e.g. virtual microgrids) are deployed at scale to meet national and local needs	Create a more adaptable and faster built network design
W2 IC24	By [2033] there will be integrated cross-vector coordination across the network from planning to generation and storage	Create a more adaptable and faster built network design

ID	Innovation Challenge	Key Theme Addressed
W2 IC25	By [2040] we will have an optimal (spatially, temporally and societally) approach to connect generation to high energy density loads	Create a more adaptable and faster built network design
W2 IC26	Increase network utilisation by [20%] while reducing losses by [50%] by [2040]	Create a more adaptable and faster built network design
W2 IC27	By [2030], minimise the network to meet future needs – maximise asset utilisation and repurposing while decommissioning where appropriate	Create a more adaptable and faster built network design
W2 IC28	By [2035] have a national portfolio approach to transmission build out, rather than a project-by-project approach	Create a more adaptable and faster built network design
W2 IC29	Develop skilled resources who understand how to operate an integrated whole system multi-vector system by [2033]	Create a more adaptable and faster built network design
W2 IC30	By [2040], GB will have meshed HVDC interconnection between regions of GB, offshore wind farms and international neighbours, through multi-terminal HVDC offshore substations.	Create a more adaptable and faster built network design
W2 IC31	By [2035] a standardised data format will be agreed for implementation across the energy sector	Create a more adaptable and faster built network design
W2 IC32	Consenting and approval processes will be reformed by [2030] through simplification and automation to remove bottlenecks and reduce delays to projects by over [50%] by 2035	Create a more adaptable and faster built network design
W2 IC33	Any new network technology deployed globally is assessed for use in the UK within [12 months] for first international FID	Create a more adaptable and faster built network design
W2 IC34	Every green electron is put to work by [2032]	Achieve world leading grid operation
W2 IC35	By [2040], every layer of the UK energy system thinks and acts for itself, creating a resilient, bottom-up self-balancing grid	Achieve world leading grid operation
W2 IC36	By [2035], local, regional and national energy actions should be coordinated on a second-by-second basis to meet the needs of every community	Achieve world leading grid operation
W2 IC37	By [2040], all assets and vectors utilise shared digital infrastructure to optimise and automate decision making in planning and operation	Achieve world leading grid operation
W2 IC38	By [2033], enable community energy groups to directly participate in local flex markets achieving [>90%] integration of assets	Achieve world leading grid operation
W2 IC39	By [2030], whole system governance analysis and recommendations have been completed for implementation by [2035]	Achieve world leading grid operation
W2 IC40	We have a whole system social cost & value decision making framework by [2030] to guide us through to the 2040s.	Achieve world leading grid operation
W2 IC41	The economics are right for customers to participate in a resilient grid and make buildings an active part of the network.	Achieve world leading grid operation
W2 IC42	All new towns are built with minimal physical grids.	Achieve world leading grid operation
W2 IC43	By [2040], GB's energy markets will operate continuously up to 5 minutes before real time, after which a fully automated system will orchestrate millions of distributed assets — from EVs and heat pumps to batteries and microgrids — to maintain balance and resilience without manual intervention.	Achieve world leading grid operation

ID	Innovation Challenge	Key Theme Addressed
W2 IC44	By [2035], energy storage is integrated at all levels of the network (domestic, LV, HV, C&I microgrids, transmission etc)	Achieve world leading grid operation
W2 IC45	A single bill / amount for water, power, council tax etc. by [2032]	Simplifying customer journeys
W2 IC46	By [2040] (or sooner), capacity is a commodity that can be traded in local markets without network participation	Simplifying customer journeys
W2 IC47	By [2035], energy becomes an invisible service that users don't think about	Simplifying customer journeys
W2 IC48	Consumers should not pay more on network costs, and ideally should pay less, while receiving a more reliable service by [2040]	Simplifying customer journeys
W2 IC49	By [2030], AI will deliver a clear route for LCT solutions for customers which meets their needs and reflects their lifestyle choices	Simplifying customer journeys
W2 IC50	By [2040], all GB properties are equipped with safe technology to make smart choices	Simplifying customer journeys
W2 IC51	Open energy ecosystem to reach full potential by [2040], customers need to feel confident that their data is secure and receive benefits personalised to them	Simplifying customer journeys
W2 IC52	GB's open energy app is widely adopted by both B2B + B2C users amid a strong appetite for digital energy experiences by [2035]	Simplifying customer journeys
W2 IC53	As a customer, I want a single personalised utilities agent (energy companion) for all my needs by [2030]	Simplifying customer journeys
W2 IC54	Improve understanding of the issues and solutions across customers. Improve the way we communicate to develop trust, so that consumers will work with us when we are developing plans and optimisation	Simplifying customer journeys
W2 IC55	By [2035], new innovative tariff propositions allow all consumers to maximise the benefit of their LCTs to receive cheaper bills and provide meaningful benefit to the networks	Simplifying customer journeys
W2 IC56	Develop an assessment tool to produce lowest cost / lowest emission choice for consumers within a multi-vector energy system by [2033]	Simplifying customer journeys
W2 IC57	By [2035], the data ecosystem exists to enable seamless customer participation and deliver what they value	Simplifying customer journeys
W2 IC58	By [2035], a common cross-vector, cross-utility digital twin will be available for use by all utilities to enable coordinated resilience planning and simulation at all spatial granularities	A grid that is resilient to shocks and quick to recover
W2 IC59	By [2040] most GB regions will have green gas supported energy continuity zones, capable of maintaining essential electricity supply	A grid that is resilient to shocks and quick to recover
W2 IC60	By [2040], GB energy system has enough storage to supply energy consumption for [30 days] during winter, which will be delivered through renewables.	A grid that is resilient to shocks and quick to recover
W2 IC61	By [2040] establish a trading operation for competitive grid-as-a-service available to all electricity supply	A grid that is resilient to shocks and quick to recover
W2 IC62	By [2040], zero critical energy customer minutes lost through cross-vector trading	A grid that is resilient to shocks and quick to recover
W2 IC63	By [2035], energy networks are redefined as a total energy system, combinable and configurable at local and national level, responding dynamically to balance day-to-day and to ensure resiliency	A grid that is resilient to shocks and quick to recover

ID	Innovation Challenge	Key Theme Addressed
W2 IC64	By [2035], [75%] of homes will be fitted with battery storage or V2H technology, capable of providing at least [2 days] of electricity demand to ensure zero impact on consumer.	A grid that is resilient to shocks and quick to recover
W2 IC65	By [2035] there will be a trusted/secure mechanism to reserve capacity across vectors for cold weather or low wind events	A grid that is resilient to shocks and quick to recover
W2 IC66	By [2035], demonstrate for a town or region a coordinated resilience plan and system restoration successfully implemented	A grid that is resilient to shocks and quick to recover
W2 IC67	By [2035] have a robust understanding of power stability roles in an inverter-based system with mitigating measures in place to ensure system robustness	A grid that is resilient to shocks and quick to recover
W2 IC68	By [2040], grid forming and control technologies will be commonplace across the network, enabling rapid black start of isolated parts of the network	A grid that is resilient to shocks and quick to recover
W2 IC69	By [2035], the entire grid will have the capability of restarting from a black out in less than [4 hours]	A grid that is resilient to shocks and quick to recover
W2 IC70	An AI/digitalisation resilience plan should be completed by [2030] to guarantee network operation in the event of catastrophic loss of AI or other digital technology	A grid that is resilient to shocks and quick to recover
W2 IC71	By [2032], portable power restoration packs should be deployed that can be used to rapidly restore power to affected substations or microgrids	A grid that is resilient to shocks and quick to recover
W2 IC72	All physical network assets should be able to withstand prolonged periods of all extreme weather phenomenon with less than a [5%] performance drop by [2040]	A grid that is resilient to shocks and quick to recover
W2 IC73	By [2035], implement an integrated, autonomous, self-healing system to deliver near-zero service interruptions and maximise asset efficiency	A grid that is resilient to shocks and quick to recover
W2 IC74	By [2040], ensure [100%] of new grid-edge connected devices can default to autonomous failsafe operation, eliminating cascading failures caused by connectivity loss	A grid that is resilient to shocks and quick to recover
W2 IC75	Enable homes/streets to operate in island mode during power cuts by [2035]	A grid that is resilient to shocks and quick to recover

Shortlisted draft Innovation Challenges from Workshop 3

The Working Groups consolidated and refined the draft Innovation Challenges in the table above through a prioritisation activity held between Workshops 2 & 3 and with further discussion and voting during Workshop 3 to reach the shortlisted Challenges in the table here.

ID	Innovation Challenge	Key Theme Addressed
W3 IC1	By [2032], project developers can obtain an instant multi-vector connection plan tailored to their needs	Fast, seamless grid connections
W3 IC2	By [2035], all domestic low-carbon technologies can be connected instantly and operate within safe limits	Fast, seamless grid connections
W3 IC3	By [2035], customers have easy access to unused capacity that others choose to make available	Fast, seamless grid connections
W3 IC4	By [2030], investigate and implement options to maximise green gas capacity on the network at lowest cost, to increase energy resilience and reduce CO_2 emissions e.g. storage, bi-directional energy flow	Fast, seamless grid connections
W3 IC5	By [2032], accepted connection offers at all network tiers must be fulfilled within [10%] of the original predicted lead time	Fast, seamless grid connections
W3 IC6	By [2035], [100%] of the capacity of each energy network is available for use by customers	Fast, seamless grid connections
W3 IC7	By [2033], satisfaction scores for connections customers of energy networks will reach [80%]	Fast, seamless grid connections
W3 IC8	By [2035], unlock accelerated planning and connection offers in grid-constrained zones for data centres that are ‘utility neutral’, meeting standards and operational requirements for minimal impact on water and energy systems	Fast, seamless grid connections
W3 IC9	Deliver a whole digital energy system control that provides real-time balanced and resilient energy seamlessly by [2040]	Fast, seamless grid connections
W3 IC10	Safely increase network utilisation by [35%] by [2035]	Fast, seamless grid connections
W3 IC11	By [2035], every network asset installation will use a standard process to identify low-marginal cost work to future-proof and enhance network capacity	Create a more adaptable and faster built network design
W3 IC12	By [2032], strategic and local network planning will use cross-vector coordination to deliver [20%] energy cost reduction to customers	Create a more adaptable and faster built network design
W3 IC13	By [2035] enable the deployment of meshed HVDC interconnections between GB regions.	Create a more adaptable and faster built network design
W3 IC14	[20%] less disruption from street works by [2033]	Create a more adaptable and faster built network design
W3 IC15	Reduce network reinforcement and build-out by [30%] by [2032], whilst lowering whole-system energy infrastructure costs, through improved customer asset coordination	Create a more adaptable and faster built network design
W3 IC16	By [2035], halve the time to deliver network upgrades and reinforcement at only [10%] additional cost	Create a more adaptable and faster built network design

ID	Innovation Challenge	Key Theme Addressed
W3 IC17	By [2035], seamless integration of local and grid-edge systems enables networks to adapt and increase efficiency by [30%] while lowering costs to consumers	Create a more adaptable and faster built network design
W3 IC18	By [2036], every layer of the UK energy system uses decentralised control to independently self-balance and optimise its operation	Achieve world leading grid operation
W3 IC19	By [2030], a standardised data and digital infrastructure unlocks new propositions to deliver value to consumers	Achieve world leading grid operation
W3 IC20	By [2035], implement an integrated, autonomous, self-healing system to deliver near-zero service interruptions and maximise asset efficiency	Achieve world leading grid operation
W3 IC21	By [2033], flexibility markets are accessible to anyone from local to national scale, with clear financial benefits achievable from participation	Achieve world leading grid operation
W3 IC22	By [2030] network investment and operation decisions are driven by the whole-system value to consumers	Achieve world leading grid operation
W3 IC23	By [2032], consumers can benefit from the true value of their flexible assets in supporting network operation	Achieve world leading grid operation
W3 IC24	By [2030], innovative projects can test changes to governance and regulation across vectors and sectors in the real-world with clear routes to full adoption	Achieve world leading grid operation
W3 IC25	By [2032], consumers' engagement with products and services that they value has seamless integrations into energy-specific processes	Simplifying customer journeys
W3 IC26	By [2032], consumers understand and trust their part in the energy transition – across physical assets and digital/data systems	Simplifying customer journeys
W3 IC27	By [2032], all consumers can easily access tailored guidance on cross-vector decarbonisation pathways for their homes and businesses	Simplifying customer journeys
W3 IC28	By [2033] consumer have confidence that they will receive their energy services or redress if delivery fails	Simplifying customer journeys
W3 IC29	By [2035], new innovative propositions allow consumers to maximise the benefit of their LCTs to receive meaningful benefit for all	Simplifying customer journeys
W3 IC30	By [2032], heat decarbonisation services are trusted, with excellent customer service ratings whilst halving installation times and doubling service options	Simplifying customer journeys
W3 IC31	By [2040], network costs will fall by [20%] relative to today, while reliability will increase by [20%]	Simplifying customer journeys
W3 IC32	By [2040], capacity is a commodity that can be traded in local markets without network participation	Simplifying customer journeys
W3 IC33	By [2032], customers can easily manage energy network needs through smooth customer journeys	Simplifying customer journeys
W3 IC34	By [2033], [<1-hour] restoration of essential services after any interruption	A grid that is resilient to shocks and quick to recover
W3 IC35	By [2034], predictive maintenance and response enable proactive management before events occur	A grid that is resilient to shocks and quick to recover
W3 IC36	By [2035], networks can be recovered from adversarial actions to restore normal service within [8 hours]	A grid that is resilient to shocks and quick to recover
W3 IC37	By [2040], [zero] critical energy customer minutes lost	A grid that is resilient to shocks and quick to recover

ID	Innovation Challenge	Key Theme Addressed
W3 IC38	By [2040], homes and communities can continue to meet essential energy needs during extended system stress events for up to [4 days]	A grid that is resilient to shocks and quick to recover
W3 IC39	By [2035], networks can isolate, reconfigure and self-heal to deliver near-zero service interruptions to all customers	A grid that is resilient to shocks and quick to recover

Annexe 5: Potential innovation opportunities

During the process of creating the Innovation Challenges, Working Group members discussed a number of potential solutions that could address the Innovation Challenges, and highlighted other areas in the energy system where further innovation could lead to significant advances in the sector and deliver greater value for customers. The table below details some of these proposed opportunities for innovation, along with the key theme that would be addressed through innovation in each area.

ID	Innovation Opportunity	Key Theme Addressed
IO1	Cross-vector connections & solutions – both interim and enduring	Fast, seamless grid connections
IO2	Strong co-creation of solutions with customers	Fast, seamless grid connections
IO3	Updates to connection codes to support enhanced access	Fast, seamless grid connections
IO4	Novel & tailored connection propositions	Fast, seamless grid connections
IO5	Digital/AI solutions for determining connection offers	Fast, seamless grid connections
IO6	Mechanisms and processes for incentivising connection delivery to time and cost – and a penalty process for lack of delivery	Fast, seamless grid connections
IO7	'Menus' of grid connection options	Fast, seamless grid connections
IO8	Trading of unused network capacity	Fast, seamless grid connections
IO9	Connection of high density loads with generation	Fast, seamless grid connections
IO10	Industrial heat decarbonisation, and use of waste heat locally	Create a more adaptable and faster built network design
IO11	Circularity of water/wastewater or other vectors	Create a more adaptable and faster built network design
IO12	System-wide optioneering and anticipatory planning, including transmission–distribution coordination	Create a more adaptable and faster built network design
IO13	Regulatory and legislative arrangements for balancing customer rights and strategic national interests, under differentiated energy system access rights	Create a more adaptable and faster built network design
IO14	Sector coupling technical and commercial solutions to reduce capacity needs	Create a more adaptable and faster built network design
IO15	Collection and use of high-resolution data to support robust detailed designs at lower cost	Create a more adaptable and faster built network design
IO16	Robotics for automated construction, maintenance, inspection and repair	Create a more adaptable and faster built network design

ID	Innovation Opportunity	Key Theme Addressed
IO17	Modular construction and plug-and-play assets for rapid deployment of build and repair	Create a more adaptable and faster built network design
IO18	Standardisation with international supply chains to reduce component lead times and encourage more domestic manufacturing	Create a more adaptable and faster built network design
IO19	Streamlining of planning & consenting processes, including digital consenting to cut end-to-end delivery time	Create a more adaptable and faster built network design
IO20	Changes to regulation and procurement allowed through the price controls	Create a more adaptable and faster built network design
IO21	On-site manufacturing	Create a more adaptable and faster built network design
IO22	Modular network structures and microgrids	Create a more adaptable and faster built network design
IO23	Novel cable and transmission designs, including meshed offshore high voltage direct current (HVDC) networks and high temperature superconducting cables (HTSC)	Create a more adaptable and faster built network design
IO24	Cost-efficient undergrounding methods	Create a more adaptable and faster built network design
IO25	Rapid-deployment pipeline technologies for distributed green gas injection sites	Create a more adaptable and faster built network design
IO26	Modifications to procurement approaches to support closer supply chain engagement	Create a more adaptable and faster built network design
IO27	Expanding the roles of Independent Distribution Network Operators (IDNOs) and Independent Gas Transporters (IGTs) to deliver more contestable work, and further resolving the roles of independent operators of transmission assets	Create a more adaptable and faster built network design
IO28	Digitalisation of assets with automated low power and low latency data and control system architectures	Create a more adaptable and faster built network design
IO29	Improved bio-methane purification strategies to support broader asset availability	Create a more adaptable and faster built network design
IO30	Cross-vector system planning, decision making and organisational roles, including third-party connection asset owners	Create a more adaptable and faster built network design
IO31	Improved planning and coordination of cross-sector utility works to minimise disruption	Create a more adaptable and faster built network design
IO32	New engineering designs and novel, non-intrusive construction techniques for physical infrastructure to minimise work required	Create a more adaptable and faster built network design

ID	Innovation Opportunity	Key Theme Addressed
IO33	Harnessing data and automation for logistics and execution	Create a more adaptable and faster built network design
IO34	Standardised processes, data and communication	Create a more adaptable and faster built network design
IO35	Cross-sector interoperability of processes and information infrastructure	Create a more adaptable and faster built network design
IO36	Roles and obligations for cross-sector response orchestration and delivery	Create a more adaptable and faster built network design
IO37	New approaches to criticality factors	Create a more adaptable and faster built network design
IO38	Frameworks for assessment of new international technologies and processes against established domestic practice	Create a more adaptable and faster built network design
IO39	Robust vector-shifting control schemes to deliver virtual capacity by making use of existing capacity on other networks, e.g. hybrid heating	Achieve world leading grid operation
IO40	Interoperable distributed energy resource device management to automatically comply with capacity constraints	Achieve world leading grid operation
IO41	Development of digital and AI systems to support autonomous network operation	Achieve world leading grid operation
IO42	Rights of energy stakeholders and consumer protections under islanded operation	Achieve world leading grid operation
IO43	Redefinition of networks' roles to support effective delivery	Achieve world leading grid operation
IO44	Coordination models between local, regional and national system actors	Achieve world leading grid operation
IO45	Smart, bidirectional and scalable gas compression solutions	Achieve world leading grid operation
IO46	Management systems for orchestrating energy actions within and between system layers and across actors	Achieve world leading grid operation
IO47	Integration of edge computing controllers to network assets, and connected devices.	Achieve world leading grid operation
IO48	AI and machine learning models to better predict domestic energy device uptake, demand, supply, faults etc at granular levels	Achieve world leading grid operation
IO49	Increased visibility and coordination of grid-edge assets	Achieve world leading grid operation
IO50	Approaches for recognising the system value of connecting flexible demand through easy access to local flexibility markets	Achieve world leading grid operation
IO51	Eliminating curtailment of green energy	Achieve world leading grid operation
IO52	Decentralised asset coordination to support stability services, voltage disturbances, and ancillary services	Achieve world leading grid operation
IO53	Dynamic asset rating and demand side response innovations	Achieve world leading grid operation
IO54	New business models integrating decarbonisation and flex assets into the customer proposition	Achieve world leading grid operation

ID	Innovation Opportunity	Key Theme Addressed
IO55	Cross-vector network architectures to enable local operation without connection to higher pressure tiers/voltage levels	Achieve world leading grid operation
IO56	Business models for strategic energy reserve operation at national and local levels	Achieve world leading grid operation
IO57	Tailored decarbonisation plans for domestic and commercial properties	Simplifying customer journeys
IO58	Regulatory review of customer protections and rights	Simplifying customer journeys
IO59	Frictionless single-point customer interfaces	Simplifying customer journeys
IO60	Strong co-creation of solutions with customers, with solutions and services designed around customers	Simplifying customer journeys
IO61	User Experience paradigms and AI energy companions that help to automate consumer participation	Simplifying customer journeys
IO62	Single customer journeys for replacement of boiler and heat pump installation (or other LCTs)	Simplifying customer journeys
IO63	Digital service design	Simplifying customer journeys
IO64	AI Energy companions	Simplifying customer journeys
IO65	Business models to increase rewards for customers	Simplifying customer journeys
IO66	Regulatory innovation to support customer assets providing capacity	Simplifying customer journeys
IO67	Removal of constraints on low-carbon technology connection	Simplifying customer journeys
IO68	Vulnerability identification and welfare routing	Simplifying customer journeys
IO69	New rewards for customers and actors that participate in reducing whole energy system costs	Simplifying customer journeys
IO70	Combining self-sustaining islands at home/street/local area/regional scales with network re-routing/reconfiguration	A grid that is resilient to shocks and quick to recover
IO71	Digital twin models or other digital representations of physical network infrastructure for detailed cross-sector network design and resilience planning	A grid that is resilient to shocks and quick to recover
IO72	Time-critical recovery from gas pressure interruptions	A grid that is resilient to shocks and quick to recover
IO73	Cross-vector resilience strategies, including visibility and coordination post-fault	A grid that is resilient to shocks and quick to recover
IO74	Definitions of resilience focussing on maintenance of customer services in relation to their criticality	A grid that is resilient to shocks and quick to recover
IO75	Innovation of assets to withstand prolonged extreme weather events	A grid that is resilient to shocks and quick to recover
IO76	Digital/AI driven diagnosis and network reconfiguration	A grid that is resilient to shocks and quick to recover

ID	Innovation Opportunity	Key Theme Addressed
IO77	Event impact forecasting	A grid that is resilient to shocks and quick to recover
IO78	New approaches to security of service rather than supply	A grid that is resilient to shocks and quick to recover
IO79	Resilience planning against digital and AI system failure	A grid that is resilient to shocks and quick to recover
IO80	Grid-forming black start capabilities	A grid that is resilient to shocks and quick to recover
IO81	Community energy hubs	A grid that is resilient to shocks and quick to recover
IO82	Power hardware devices and configurations to enable smart and reconfigurable operations	A grid that is resilient to shocks and quick to recover

Annexe 6: Case Studies

The transition toward a fully decarbonised, high-capacity energy system requires an infrastructure overhaul at a pace and scale not seen since the industrial revolution. Incremental improvements to existing operational practices are entirely insufficient to meet the surging demands of widespread electrification, renewable generation integration, and national economic growth. To unlock hundreds of billions of pounds in pent-up economic value, the energy sector must look beyond its traditional boundaries. It must embrace radical, cross-sector innovations that fundamentally redefine what is possible in infrastructure deployment, system resilience, and customer participation.

This annexe presents a comprehensive compilation of 10 highly ambitious case studies. Each case study provides a proven, real-world blueprint for disruption, demonstrating how adjacent industries and pioneering enterprises are achieving step-change improvements. By synthesising these blueprints, energy network operators can accelerate industrial connections, halve construction timelines, eliminate system outages, and orchestrate millions of distributed energy devices with frictionless precision. The evidence collated here makes one fact abundantly clear: the technologies and methodologies required to build a dynamic, intelligent, and fiercely resilient energy platform already exist. The imperative now is rapid, uncompromising deployment.

Pakistan's solar panel boom

In Pakistan, a combination of soaring grid electricity prices and community skills sharing has driven an unprecedented, consumer-led surge in solar photovoltaic capacity. Over recent years, the country has imported approximately 50 GW of solar panels, fundamentally transforming its energy landscape.[1] Between 2019 and 2025, the total solar panel capacity imported exceeded Pakistan's combined power plant capacity by 2 GW, with the majority of these installed as small solar PV systems.[2] In 2024 alone, Pakistan imported 17 GW of solar capacity – contributing a substantial amount to the energy system's 40 GW total installed capacity.[3]

This rapid grassroots transition projects that 20 percent of the nation's electricity will come from solar by 2026.[2] This phenomenon demonstrates how decentralised, consumer-driven installation can fundamentally reshape a national energy system at breathtaking speed, entirely bypassing traditional top-down infrastructure planning.[4] For network operators, it serves as a powerful

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[1] Shedding light on Pakistan's distributed solar revolution - TransitionZero, accessed on May 5, 2026, https://www.transitionzero.org/shedding-light-on-pakistans-distributed-solar-revolution
[2] The Perfect Storm Fueling Pakistan's Solar Boom | World Resources Institute, accessed on May 5, 2026, https://www.wri.org/insights/pakistan-solar-energy-boom
[3] Pakistan's energy transition via solar power and batteries - The World Economic Forum, accessed on May 5, 2026, https://www.weforum.org/stories/2025/08/pakistan-energy-affordable-reliable-electricity/
[4] Africa aims to replicate Pakistan's extraordinary solar success - African Business, accessed on May 5, 2026, https://african.business/2025/08/energy-resources/africa-aims-to-replicate-pakistans-extraordinary-solar-success

reminder that if the grid cannot provide affordable and reliable power, consumers will autonomously procure their own solutions.

Estonia proactive digital state

The Estonian government has pioneered a world-leading approach to public administration, becoming a nation that has successfully digitalised 100 percent of its public services.[5] By seamlessly integrating data across government departments via sophisticated digital architecture, Estonia has created "zero form" applications where services are delivered proactively.

By automating these services, Estonia has reduced the time citizens take to apply for complex state services from an average of several hours to a matter of minutes or seconds – taxes can be filed within 3 minutes.[6] This frictionless integration has resulted in a saving of more than 820 years of working time for the state and citizens annually, freeing up critical state resources and generating an 82 percent satisfaction rate among users.[7] For the energy sector, this level of frictionless data sharing illustrates the immense potential for the fully automated participation of distributed energy resources. If energy networks adopt similar integrated architectures, consumers could provide valuable grid flexibility as an invisible, automated background process without requiring any active input.

Autonomous logistics via drone ports

Inteliports has redefined last-mile logistics by developing fully automated drone ports built into standard 20-foot shipping containers.[8] These rapidly deployable, mobile units handle automated landing, fast charging, and payload management for visiting aircraft, completely removing the need for manual support infrastructure on the ground.[9]

In live trials servicing the National Health Service, these autonomous systems reduced the time required to deliver critical medical supplies from four hours to just 15 minutes.[10] This extreme standardisation enables the flexible integration of hyperlocal areas into automated logistics

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[5] Bureaucrazy - e-Estonia, accessed on May 5, 2026, https://e-estonia.com/bureaucrazy/
[6] e-Estonia: Beyond digital, accessed on May 5, 2026, https://e-estonia.com/wp-content/uploads/e-estonia_presentation_14_01_26.pdf
[7] The Transformational Power of Digital Payments for Governments | Visa, accessed on May 5, 2026, https://www.visa.co.uk/content/dam/VCOM/global/run-your-business/documents/visa-kearney-the-transformational-power-of-digital-payments-for-governments.pdf
[8] Inteliports Tech | Transform with Autonomous Drones, accessed on May 5, 2026, https://www.inteliports.com/technology
[9] Inteliports Universal Connection System for charging UAS systems in drone ports, accessed on May 5, 2026, https://cp.catapult.org.uk/trig-project/inteliports-universal-connection-system-for-charging-uas-systems-in-drone-ports/
[10] Inteliports PORTAL - ESA Space Solutions, accessed on May 5, 2026, https://business.esa.int/projects/inteliports-portal

systems, unlocking on-demand delivery across wider geographies. Drone technology can achieve cost reductions of up to 40 percent on last-mile logistics, making it up to three times cheaper than traditional combustion engine vans, alongside immense environmental benefits.[11] For utility operators, this presents a blueprint for deploying unmanned aerial fleets for rapid fault response and component delivery across vast, remote network areas.

A coordinated space grid

SpaceX has overcome the global connectivity gap by deploying the Starlink constellation, an unprecedented array of over 6,200 active satellites moving at 17,000 miles per hour in low Earth orbit.[12] By relying on mass-repeatable manufacturing and software-managed operations, the constellation executes autonomous collision avoidance manoeuvres entirely without human intervention.

Between December 2024 and May 2025, the fleet performed 144,404 avoidance manoeuvres, successfully navigating a highly congested orbital environment. The satellites performed fewer than 50,000 manoeuvres over same period a year earlier. In 2021, just 2000 manoeuvres were required.[13] The rapid expansion of satellite traffic, with Starlink aiming to increase the number of satellites to 42,000, will exacerbate these challenges, and manual control interventions are not feasible. As asset numbers scale, decentralised infrastructure networks can monitor and protect themselves using artificial intelligence, completely eliminating the bottleneck of manual control room intervention.

Faster and cheaper geothermal energy

Fervo Energy in the United States has revolutionised enhanced geothermal systems by aggressively applying horizontal drilling and fibre optic sensing techniques transferred directly from the oil and gas sector.[14] By adopting best practice engineering methodologies from an adjacent industry, the enterprise achieved a 70 percent reduction in drilling times in a single year. At its Cape Station project, the company drilled its fastest deep granite well in just 21 days. [15] This immense increase in operational efficiency slashed drilling costs by nearly 50 percent per well, bringing expenses down from $9.4 million to $4.8 million. This closed-loop heat extraction

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[11] The Economics of Drone Delivery: Transforming Logistics in the Digital Age - FreightAmigo, accessed on May 5, 2026, https://www.freightamigo.com/en/blog/logistics/the-economics-of-drone-delivery-transforming-logistics-in-the-digital-age/
[12] Satellite Technology - Starlink, accessed on May 5, 2026, https://starlink.com/technology
[13] Heavy traffic ahead - Aerospace America - AIAA, accessed on May 5, 2026, https://aerospaceamerica.aiaa.org/features/heavy-traffic-ahead/
[14] Technology - Fervo Energy, accessed on May 5, 2026, https://fervoenergy.com/technology/
[15] Fervo Energy Drilling Results Show Rapid Advancement of Geothermal Performance, accessed on May 5, 2026, https://fervoenergy.com/fervo-energy-drilling-results-show-rapid-advancement-of-geothermal-performance/

technology demonstrates how adopting proven methodologies from other heavy industrial sectors can trigger unimaginable improvement curves, halving costs and timelines almost overnight.

Artificial intelligence driven weather forecasting

Google DeepMind has completely transformed meteorological science with GraphCast, a deep learning model that predicts weather patterns based on decades of historical data rather than attempting to simulate complex physics equations. Running on a single desktop computer, this software generates a highly accurate 10-day global weather forecast in under 60 seconds. In rigorous benchmark testing against the world's gold-standard physical simulation system, the ECMWF HRES, GraphCast outperformed the traditional model on 90 percent of 1,380 test targets.[16] By harnessing this level of artificial intelligence, energy network operators can predict renewable generation dips and demand spikes with unprecedented precision.

Building a hospital in two weeks

At the onset of the COVID-19 pandemic, the NHS Nightingale Hospital North West was constructed within the Manchester Central Convention Complex in an extraordinary 13 days. Following an instruction to proceed on 28 March 2020, the 750-bed critical care facility was ready for patients by 13 April.[17]

Rapid off-site manufacture and extreme workforce coordination allowed teams to install 30 metres of medical gas pipe every 150 seconds.[18] To guarantee the absolute resilience required for a critical care facility, engineers rapidly installed a second reserve electricity supply, coupled with automated monitoring and control technology[19]. This project demonstrates that when sequential planning is abandoned in favour of parallel processing, infrastructure operators can deliver highly complex, resilient networks in a matter of days.

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[16] GraphCast: AI model for faster and more accurate global weather forecasting – Google DeepMind, accessed on May 5, 2026, https://deepmind.google/blog/graphcast-ai-model-for-faster-and-more-accurate-global-weather-forecasting/

[17] Manchester's Nightingale Hospital cost £10.25m to build as leaders consider its future, accessed on May 5, 2026, https://www.manchestereveningnews.co.uk/news/greater-manchester-news/manchesters-nightingale-hospital-cost-1025m-18558545

[18] NHS Nightingale hospitals - Sir Robert McAlpine, accessed on May 5, 2026, https://www.srm.com/projects/nhs-nightingale-hospitals/

[19] Keeping Us Connected: How to build a hospital in nine days – Utility Week, accessed on May 5, 2026, https://utilityweek.co.uk/build-hospital-nine-days/

Driverless logistics for infrastructure

Oxa has developed autonomous vehicle software that integrates into heavy industry and logistics vehicles, removing the need for traditional manual driving in hazardous or repetitive environments. Utilising generative artificial intelligence to manage operations and optimise energy use, these driverless vehicles can monitor utility solar farms and energy processing sites continuously.[20]

Research further indicates that autonomous trucking and logistics can increase energy efficiency by up to 32 percent on highways, significantly cutting fuel emissions.[21] This offers immense potential for network operators to execute maintenance, security monitoring, and component logistics 24 hours a day with unprecedented efficiency.

Single supplier multi-utility networks

The traditional approach of coordinating separate utility providers for new property developments routinely causes crippling delays. GTC UK has circumvented this by providing a phenomenal single-supplier solution for the nation's largest housebuilders. The enterprise designs, constructs, owns, and operates heat, electricity, gigabit fibre, water, and gas networks entirely through one unified delivery model.[22]

By removing the friction of coordinating multiple distinct operators, GTC UK drastically reduces the complexity of site energisation. Furthermore, they are advancing the deployment of networked ground source heat pumps, providing a clean alternative to gas for tens of thousands of new homes without necessitating massive electricity grid upgrades.[23]

Australia dynamic solar management

Australia boasts the highest rooftop solar capacity per capita globally, with nearly 40 percent of homes on the main grid possessing installations. To manage the immense stability challenges caused by midday solar exports, Australia implemented the CSIP-AUS standard, requiring all new accredited inverters to enable two-way communication between distributed energy resources and grid operators.[24] This grants grid operators the capability to orchestrate assets dynamically,

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[20] Oxa Raises $103m in Series D First Close, Backed by National Wealth Fund and Leading Investors - Oxa, accessed on May 5, 2026, https://oxa.tech/news-and-insights/oxa-raises-103m-in-series-d-first-close-backed-by-national-wealth-fund-and-leading-investors/
[21] Research: Autonomous Trucks Can Reduce Emissions and Fight Climate Change - Aurora Innovation, accessed on May 5, 2026, https://ir.aurora.tech/news-events/press-releases/detail/94/research-autonomous-trucks-can-reduce-emissions-and-fight-climate-change
[22] Multi-Utility Services – GTC, accessed on May 5, 2026, https://www.gtc-uk.co.uk/multi-utility-services/
[23] GTC Partnership: Renewable Heating for New Builds | Kensa, accessed on May 5, 2026, https://kensa.co.uk/press/kensa-gtc-partnership
[24] What is CSIP-AUS? – CSIP-AUS, accessed on May 5, 2026, https://www.csipaus.org/about

allowing them to curtail exports during grid stress or offer consumers flexible export limits up to 10 kilowatts.

The success of pilots like Project Symphony proves that coordinating these assets into virtual power plants can create an estimated $920 million in value over the next decade, fundamentally proving the economic viability of decentralised system balancing.[25]

[25] Project Symphony findings to inform future of virtual power plants - Synergy, accessed on May 5, 2026, https://www.synergy.net.au/About-us/News-and-announcements/Media-releases/Project-Symphony-findings-to-inform-future-of-virtual-power-plants

Annexe 7: Glossary

Term	Definition
Cross-sector	Encompassing sectors related to, but separate from the energy sector, for instance: water and telecommunications
Cross-vector system	Wider than just electricity, this incorporates other energy vectors including gas and heat
Decentralised system balancing	Distributed control logic determining system operation on a regional or local basis, rather than a central control room optimising entire system operation
Domestic energy devices	In-home energy technologies, typically electrified or producing zero emissions, for example: heat pumps, EV chargers, smart appliances, solar PV and battery storage
Energy Network Innovation Taskforce	An independent group of industry experts who recommend Innovation Challenges for energy network ecosystem for endorsement by Ofgem
Energy outages	Instances where a customer does not have access to energy services. This shifts the focus from security-of-supply to security-of-service as local resources can minimise customer outages even when supply fails
Energy system	The network of processes and technologies used to produce, convert, store, and deliver energy across all vectors
Innovation Challenge	The strategic challenge which is recommended by the Energy Network Innovation Taskforce and endorsed by Ofgem to address the Problem to be targeted by Projects
Innovation Charter	The document created by the Innovation Delivery Group which will set out the sub-Challenges they will address, and types of Projects required. It will also set out the delivery plan for achieving the Innovation Challenge, including a stakeholder engagement plan, risk register and knowledge dissemination plan
Innovation Delivery Groups	A cohort of industry experts, third-party innovators and Licensees who focus on the coordination and delivery of an Innovation Challenges
Islanding	The capability to reconfigure an energy network into self-sustaining local zones
Low-carbon technology	See domestic energy devices
Network Innovation Allowance (NIA)	An allowance of that name provided to Licensees and NESO to take forward innovation

Term	Definition
Network Innovation Competition (NIC)	The Ofgem-managed NIC gave electricity and gas networks the opportunity to bid for funding for innovation Projects, but closed to new gas proposals in 2021, and new electricity proposals in 2023. The NIC was replaced by the Strategic Innovation Fund as the primary mechanism for innovation funding
RIIO	RIIO stands for (Revenue = Incentives + Innovation + Outputs). It is Ofgem's framework, stemming from the conclusions of the RPI-X@20 Project, implemented in network price controls
RIIO-3	The network price control which runs between 1 April 2026 and 31 March 2031 for gas transporter and electricity transmission Licensees, and between 1 April 2028 and 31 March 2033 for electricity distribution Licensees
Strategic industrial sites	Specifically designated new-build industrial sites where there is national importance to getting the site set up and operational quickly
Strategic Innovation Fund (SIF)	The RIIO-3 innovation funding mechanism of that name applied to strategically important innovation projects
Taskforce Expert Group	A group of energy system experts who sat between the Steering Group and the Working Group to provide critical feedback and review into both the Missions and the Challenges
Taskforce Steering Group	A group of senior leaders from across the energy sector who helped set key thematic areas for exploration in the Taskforce ENIT and provided review and approval of the Innovation Challenges
Taskforce Working Groups	Five groups of experts from across the energy system who participated in a series of four workshops to develop the Innovation Challenges

Annexe 8: Acknowledgements

The Taskforce would like to express its thanks for the support and input of so many people within the energy sector and beyond.

Name	Organisation
Aaron Gould	Association for Decentralised Energy
Caroline Bragg	Association for Decentralised Energy
Sarah Honan	Association for Decentralised Energy
Yselkla Farmer	BEAMA
Bas Sudmeijer	Boston Consulting Group
Kate Gilmartin	British Hydropower Association
Phil Proctor	Buro Happold
Chris Rison	Cadent
Jadie Lawley	Cadent
Mike Lapper	Cadent
Steve Fraser	Cadent
Tony Ballance	Cadent
Yasser Zadeh	Cadent
Robert Keast	Carbon Trust
Alice Williams	Citizens Advice
Andy Manning	Citizens Advice
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Sam Mathew	Microsoft
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Emma Fletcher	Octopus Energy
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Luke Ames Blackaby	Ofgem
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Daniel Norton	Ohme
Alan McMorran	Open Grid Systems
Anusha Shah	Plan for Earth
Kathleen Davis	PNDC, University of Strathclyde
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Frank Hodgson	Regen
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Luca Grella	UK Power Networks
Neil Madgwick	UK Power Networks
Suleman Alli	UK Power Networks
Daniel Saker	UK Power Networks DSO
Matthew White	UK Power Networks DSO
Sotiris Georgiopoulos	UK Power Networks DSO
Bethan Winter	Wales and West Utilities
Matt Hindle	Wales and West Utilities
Sian Rowlands	Wales and West Utilities
Craig Douglas	World Fund
Pete Clutton-Brock	Yottar

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