Electricity System Operator

Innovation Strategy

2024/25

ESO

Contents

Introduction

As Great Britain's Electricity System Operator (ESO), we are at the heart of the nation's energy system. We make sure that the electricity network operates safely and efficiently around the clock, so that homes, businesses and industry always have the power they need. In the summer of 2024, we will become the National Energy System Operator (NESO). The organisation will be founded on the current activities and capabilities of the ESO, but we'll also take on new roles with a whole system perspective across energy vectors to ensure Britain's energy system is secure and affordable, as well as forging the path to a sustainable future for everyone.

Innovation is critical to helping us meet the challenges of transitioning to a net zero future. At the ESO, we work with partners from across the energy industry and beyond to harness new technologies, markets and ways of working to support the energy transition.

This refresh of our ESO Innovation Strategy sets out our innovation priorities for the year ahead (2024/25). These are longer term priority challenges, with projects that are typically higher-risk and have greater uncertainty in their outcomes, as opposed to our everyday activities – which our innovation projects will build upon and go beyond, to deliver benefits for the ESO, wider energy system and consumers.

Foreword

As we transition to becoming National Energy System Operator (NESO), our responsibilities and ambitions will undergo a significant change. With our new roles in strategic planning, market development, resilience, security of supply and advising across multiple vectors we'll be accomplishing something entirely new and crucial – NESO itself will be innovation. As the innovation team, we will have much greater accountability to truly drive the decarbonisation agenda for Great Britain.

This year we have developed a success statement for each of our innovation priorities and identified specific opportunities that we will explore to achieve our goals. This will help us prioritise our innovation efforts on opportunities critical to our longer-term decarbonisation objectives, which are further out than existing business plans and regulatory periods. It will also hold us accountable for delivering the right portfolio of projects against each priority and ensure that each of those projects aligns with the higher-level objectives of industry. We have also established a new strategy team to help our focus and accelerate the pace of innovation.

The future of our industry will rely on strategic, whole energy thinking and we must have a robust foundation of data to base our planning and operations. However, we face a significant challenge in synthesising and leveraging the vast amounts of information required for future projections.

Technology development will play a fundamental role in overcoming this challenge and will be at the heart of the energy and NESO transition. As part of this, Artificial Intelligence (AI) and Machine Learning (ML) solutions have become core components of our innovation portfolio. As a technology company, AI must be a central capability.

Our portfolio and strategy demonstrate the value of implementing AI at all levels and for all purposes. Our Dynamic Reserve Setting (DRS) model uses AI in the control room to access more data sources and react dynamically to better inform our reserve requirements, ensuring the most efficient use of resources. The Advanced Dispatch Optimiser (ADO) project will revolutionise our Control Room operations and future-proof a rapidly changing energy landscape through Adaptive AI. It will provide enhanced forecasting, optimised dispatch, improved monitoring and better management of increasingly complex grid operations, evolving our control room processes. These are just a couple of examples of the AI and ML-based tools and programs currently in our portfolio.

It's important to note that all digital technologies come with a few caveats: they are only as good as the data they are built upon. As such they need to be carefully developed, trained and vetted before being integrated into our system solutions. To truly act as a whole system innovation enabler, we must unlock the AI potential for the whole industry by ensuring we have the infrastructure to share data consistently and safely.

Through our Powering Wales Renewably (PWR) project we're working with the Welsh government to create a digital twin of the Welsh transmission and distribution system. Combining this with other data sets will provide a digital common interface to accelerate the integration of renewable generation and decarbonised demand into the electricity system. Our role is not just to innovate for ourselves, but also to bring everyone along on this journey, ensuring that the entire industry's innovation is enabled. The more we collaborate with the industry and share data, the more powerful AI tools will become.

We're committed to being GB's energy industry's innovation champions, leading by example, identifying and taking on the big challenges the system faces. We are actively looking for emerging technologies, not just to solve today's challenges, but also to find new opportunities to revolutionise our current operations. Achieving our goal of a zero-carbon grid by 2035 requires a significant transformation, including a shift in culture, policy, markets and technology. We are changing our mindset and bringing our innovation influence to both the wider industry and consumers. I want this strategy to be a call to arms to our current partners, to new innovators, to start-ups and new industries. We are here to enable the change you are trying to make in the world. Let's work together.

Anna Carolina Tortora

Head of Innovation Strategy and Digital Transformation

Portfolio Analysis

To monitor our progress, we track alignment of the innovation portfolio against priorities for the previous year. This graph (Figure 1) shows the level of effort (indicated by Number of projects) and funding (Sanctioned value for NIA and SIF projects live in 2023/24).

Network Innovation Allowance (NIA)[1]

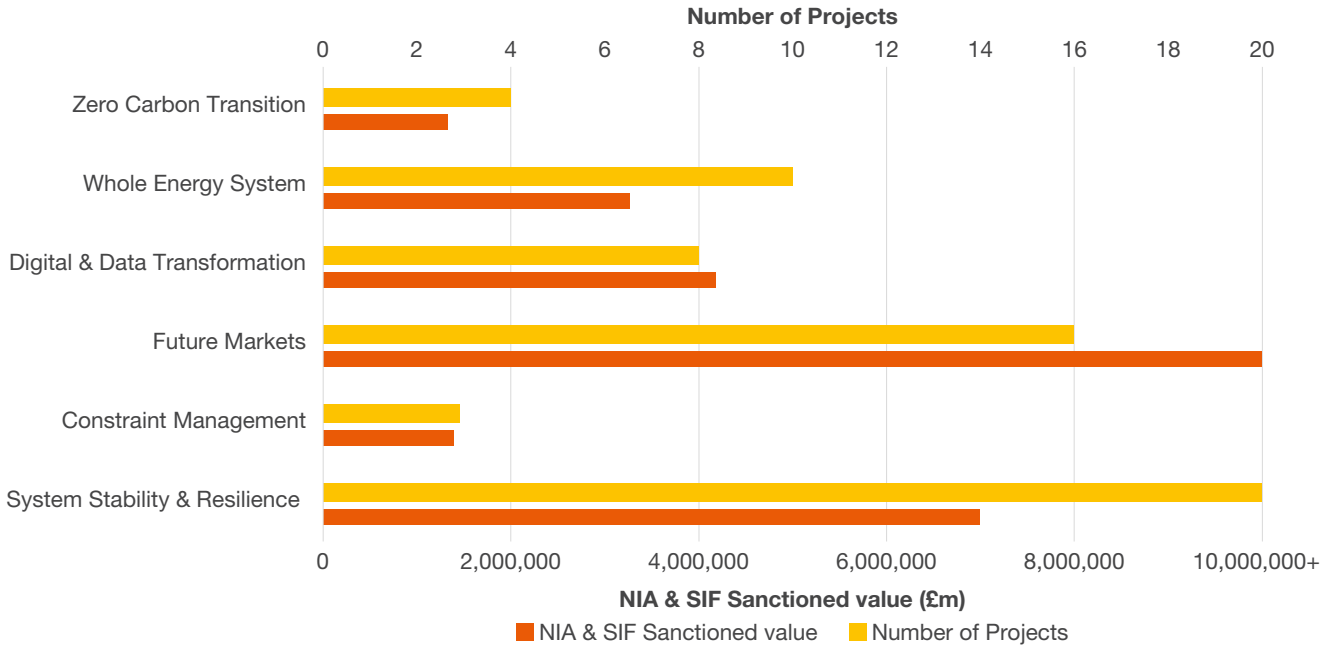
- 21 NIA projects started last year (April 2023 – March 2024)
- 27 NIA projects continued from the previous year (projects started April 2022 – March 2023)

Strategic Innovation Fund (SIF)[2]

SIF projects started and live last year (April 2023 - March 2024), where ESO is lead:

- 4 Discovery projects –
  - 2 – Discovery Round Two
  - 2 – Discovery Round Three
- 2 Alpha projects
- 1 Beta projects

Figure 1. Portfolio Analysis: Number of projects linked to the 6 priority areas and sanctioned value for NIA and SIF projects live last year linked to the 6 priority areas.



1 ofgem.gov.uk/energy-policy-and-regulation/policy-and-regulatory-programmes/network-price-controls-2021-2028-riio-2/riio-2-network-innovation-funding/network-innovation-allowance-riio-2

2 ofgem.gov.uk/energy-policy-and-regulation/policy-and-regulatory-programmes/network-price-controls-2021-2028-riio-2/network-price-controls-2021-2028-riio-2-riio-2-network-innovation-funding/strategic-innovation-fund-sif

Portfolio Analysis

We have realigned our portfolio based on how our innovation priorities have evolved since last year, the graph reflects this. In this realignment, we have mapped projects to just one innovation priority (based on the primary challenge the project addresses). This will help us better track our progress against each innovation priority.

Driving the zero-carbon transition

We received feedback that this priority needed to be more focused, to clearly communicate the type of projects we are looking to develop in this area. To address this, we have modified the priority and mapped projects live in 2023/24 to specific areas e.g. Better forecasting for integration of renewables, Reducing balancing costs and Improved Carbon Monitoring. As a result, there may be less projects in this area than expected. However, all of our projects contribute to the zero-carbon transition.

Whole Energy System

The number of projects in this area has increased as we transition to National Energy System Operator.

Digital, AI and Data

The number of projects in this area may be lower than expected, this is because a large number of the projects previously mapped to this priority have been realigned to others e.g. System Stability & Resilience. Digital, AI and Data is an enabler for the other innovation priorities, with projects always having a Digital, AI and Data element, however projects have been mapped to the innovation priority that covers the primary challenge they are addressing.

Future Markets

The number of projects in this area has steadily increased as we continue to drive competition across industry and explore how markets should evolve.

Constraint Management

Similar to last year, the number of projects in this area may be lower than expected. This is due to the main activity addressing this priority being done following the **Constraint Management Pathfinders**,[3] innovation projects support this where possible.

System Stability & Resilience

The number of projects in this area is higher due to realignment e.g. some projects previously mapped to Digital & Data Transformation have been realigned to this innovation priority as they address challenges covered by this innovation priority and Digital & Data is an enabler. The number of projects in this area may also have increased as we look to better understand how and why the system may be impacted by different factors and how to mitigate against them e.g. more extreme weather events.

3 nationalgrideso.com/industry-information/balancing-services/pathfinders/noa-constraint-management-pathfinder

2024/25 Innovation Priorities

Below are our strategic innovation priorities for 2024/25, where you can expect to see us concentrating our innovation focus this year.

The following pages provide an overview of each innovation priority, including:

- Introduction to the innovation priority
- Key opportunities that we need to explore
- Relevant ESO publications and example projects

How to use our Innovation Strategy

The Key opportunities in the innovation priority pages are areas where we want to develop new projects or build on existing work. It isn't intended to be a complete list but helps to give an idea of the opportunities we want to explore within the innovation priorities.
We have also listed some completed projects and those in development so you can see examples of what has been done so far.

Driving the zero-carbon transition

We must enable new research and technology, developing and testing the solutions necessary to ensure the zero-carbon transition is delivered by the ESO and wider energy system in a timely, responsible way, for the benefit of all consumers.

Whole Energy System

As our energy system changes, we will take a leading role and deliver a holistic approach. With our unique position in the industry, we'll invest significant effort to encourage collaboration and find efficiencies, particularly within hydrogen, transport, heating and smart technologies.

Digital, AI and Data

Digital, AI and Data underpins the success of the ESO tackling almost all of its ambitions while leading the energy transition. The scale of the challenge, both internally and across the industry, is great.

Future Markets

Designing markets that are fit for purpose underpins the ESO ambitions of 'competition everywhere' and zero-carbon operation. We need to understand the long-term options for market design, and work with our customers and stakeholders to find the best whole-system solutions.

Constraint Management

Building new transmission and distribution network capacity to meet peak flows on the system is not always the lowest cost solution for consumers, or the best for the environment, so we need to test a variety of innovative market-led solutions and technologies in this area.

System Stability & Resilience

Significant progress has been made on System Stability across the ESO, but there is still more to be done. As we transform to a zero-carbon electricity system, it will remain a key area of investment.

Driving the zero-carbon transition

Watch our Zero Carbon Transition video

About the priority

As we continue to move to an energy system with lower levels of carbon emissions, it remains difficult to remove the final, harder-to-decarbonise aspects of the system.

To ensure zero-carbon operation is possible, while maintaining a secure system, it is crucial that we explore better forecasting of supply and demand to enable increased integration of renewables and reduction in balancing costs. This will require collaboration across the energy industry, through data sharing and application of technologies such as Artificial Intelligence and Machine Learning.

In a similar way, collaboration is required to more accurately monitor carbon across the energy system to inform decisions on optimal routes to net zero.

Key opportunites

Success for this innovation priority is:

- The electricity system is capable of operating 100% zero-carbon 24/7, while maintaining reliability at the lowest cost to consumers.

To achieve this, we need to explore opportunities and build on existing work in the following areas:

- Exploring better forecasting of supply and demand to allow for increased integration of renewables
- Exploring how to reduce balancing costs while the electricity system decarbonises
- Enabling better carbon monitoring across the system
- Exploring the opportunities for microgrid management (at a system operator level) and decentralised dispatch

Driving the zero-carbon transition

Watch our Zero Carbon Transition video

Relevant publications

Future Energy Scenarios[4]

Operability Strategy Report[5]

Balancing Costs Strategy[6]

Where we are today

Example innovation projects in this area

*Year of completion

*2021	Control REACT[7] Understanding the cost impacts of forecast errors and demonstrating how probabilistic forecasts can lead to more efficient decision making.
2022	Peak Demand Forecasting[8] Studying the latest advancements in peak demand forecasting, both in GB and globally, in addition to quantitatively assessing the drivers of peak electricity demand.
2023	Probabilistic Machine Learning for Dynamic Reserve Setting[9] Setting reserve levels dynamically, day ahead, using artificial intelligence and machine learning.
2024	Carbon Intensity Modelling[10] Developing our understanding of how operating carbon emitting plants in different ways impacts the carbon intensity released, improving the representation of progress to net zero, and enabling future options for carbon optimisation. Balancing Costs Forecasting[11] Improving existing short term forecasts by applying machine learning and cutting-edge forecasting methods. Solar PV Nowcasting[12] Exploring whether if we had more accurate predictions for solar electricity generation then we could reduce the amount of “spinning reserve” required.

4 nationalgrideso.com/future-energy/future-energy-scenarios-fes
5 nationalgrideso.com/document/299926/download
6 nationalgrideso.com/document/288236/download
7 smarter.energynetworks.org/projects/nia_ngso0032
8 smarter.energynetworks.org/projects/nia2_ngeso019
9 smarter.energynetworks.org/projects/nia2_ngeso003
10 smarter.energynetworks.org/projects/nia2_ngeso027
11 smarter.energynetworks.org/projects/nia2_ngeso022
12 https://smarter.energynetworks.org/projects/nia2_ngeso002

Whole Energy System

Watch our Whole Energy System video

About the priority

As National Energy System Operator (NESO), we will have responsibilities across the electricity, gas and hydrogen systems. Therefore, it is crucial that we leverage our unique position to understand how multiple energy vectors can be co-optimised to enable the decarbonisation of different sectors (heat, power, transport and industry) while maintaining a secure and resilient energy system.

We will take a holistic view to find synergies and dependencies across the whole energy system and ensure collaboration in finding the optimal routes toward net zero.

Key opportunites

Success for this innovation priority is:

- Strategic coordination, whole energy system thinking and collaboration across all sectors to optimise the cost and speed of reaching net zero.

To achieve this, we need to explore opportunities and build on existing work in the following areas:

- Exploring more efficient approaches to Whole Energy Planning & Modelling
- Facilitating collaboration across the energy system (sharing of knowledge, insights, best practice)
- Enabling more Distributed Energy Resources
- Enabling decarbonisation of heat
- Enabling electrification of transport
- Understanding the role of hydrogen

Whole Energy System

Watch our Whole Energy System video

Relevant publications

Future Energy Scenarios[13]

Beyond 2030[14]

Where we are today

Example innovation projects in this area

*Year of completion

*2020	4D Heat[15] Exploring whether controlling electrified residential heating in Scotland can be used to reduce the curtailment of renewable generation, without adversely impacting the distribution network.
2021	Decarbonisation of Heat – Integrated Market Study[16] Focusing on the Decarbonisation of Heat, specifically heat demand, technology, markets, networks, and policy implications.
2022	Gas and Electricity Transmission Infrastructure Outlook[17] Providing a vision of the UK's future gas and electricity transmission systems that will deliver net-zero energy to industry, transport, heat and power in collaboration with ET and GT.
2022	The Role for Hydrogen as an Electricity System Asset[18] Understanding how the development of hydrogen markets will interact with the electricity system, and how targeted hydrogen investment can more effectively support the electricity system.
2023	Distributed Energy Resources (DER) Visibility[19] Understanding the data sources available on DERs and how they can be aggregated to better plan and provide increased flexibility. This is to address the challenge of limited visibility and data pertaining to Distributed Energy Resources (DERs) (e.g., power outputs, utilisation, locations) or forecasts for when new DERs will be connected.
	Powering Wales Renewably: Discovery[20] Taking a whole electricity system approach to deliver an innovative digital twin of the network (the first to include both transmission and distribution in Wales).

13 nationalgrideso.com/future-energy/future-energy-scenarios-fes
14 nationalgrideso.com/future-energy/beyond-2030
15 smarter.energynetworks.org/projects/nia_ngso0033
16 smarter.energynetworks.org/projects/nia2_ngeso007
17 smarter.energynetworks.org/projects/nia_nggt0184
18 smarter.energynetworks.org/projects/nia2_ngeso010
19 smarter.energynetworks.org/projects/nia2_ngeso029
20 smarter.energynetworks.org/projects/10060474

Whole Energy System

Watch our Whole Energy System video

2023	Role and value of electrolysers in low-carbon GB energy system[21] Analysing the benefits of linking electricity and hydrogen vectors from a whole system perspective to determine the optimum capacity, location, technologies, and system benefits of electrolysers under different future development scenarios.
	Whole Energy System Network Planning Review[22] Undertaking research into what the options are for performing whole energy network planning across multiple energy vectors (e.g. electricity, gas, hydrogen, CCUS).
2024	Coordinated Operational Methodology for Managing and Accessing Network Distributed Energy Resources (COMMANDER)[23] Conducting a techno-economic feasibility assessment, impact assessment and producing a roadmap of the ESO and DSO coordination schemes.
	Powering Wales Renewably: Alpha[24]

2024	System value from V2G peak reduction in future scenarios based on strategic transport and energy demand modelling[25] Developing a strategic transport and energy demand (STED) model using transport demand modelling techniques and a whole-energy simulator to investigate the impacts of V2G on the electricity peak demand across the entire GB system under different credible decarbonisation scenarios.
	Probabilistic Pathways for Energy System Planning[26] Developing an enhanced end-to-end network planning methodology for the whole energy system. We will explore applying advanced computational techniques, such as artificial intelligence and probabilistic modelling, to capture risk and uncertainty within future energy pathways, enable rapid iterative network needs analyses, risk-based network options assessments, and deliver optimised planning decisions.

21 smarter.energynetworks.org/projects/nia2_nget0002
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23 smarter.energynetworks.org/projects/nia2_ngeso012
24 smarter.energynetworks.org/projects/10078792
25 smarter.energynetworks.org/projects/nia2_nget0017
26 smarter.energynetworks.org/projects/10104062-1

Digital, AI and Data

Watch our Digital, AI and Data video

About the priority

As the net zero transition continues, our energy system becomes more decentralised and complex, with the number of new and diverse participants increasing (including communities and consumers). It is crucial that the drive towards digitalisation continues to allow faster, more informed decision making, automation of processes, better user experiences and it enables the transformation to a fully integrated, whole energy system that is cyber-secure.

As we become a Digital Leader, we will drive collaborative digitalisation across the system by improving data standards and access for all participants. We will continue to enable the digital transformation of our own operations by leveraging the power of Artificial Intelligence and Machine Learning and other emerging technologies.

Key opportunites

Success for this innovation priority is:

- The ESO is a Digital Leader, operating an energy system where participants can make informed choices through access to data, and transformational technologies have been implemented to ensure greater efficiency and security.

To achieve this, we need to explore opportunities and build on existing work in the following areas:

- Exploring how we can better enable data interoperability and automation (including using AI to improve data quality and standards)
- Understanding how transformational technology can help to create the Control Room of the future
- Developing detailed Use Cases and project proposals for trialling Generative AI for more efficient operations
- Progressing our understanding of energy Use Cases for Quantum Computing in simulation and optimisation

Digital, AI and Data

Watch our Digital, AI and Data video

Relevant publications

The ESO Digitalisation Strategy & Action Plan[27]

Where we are today

Example innovation projects in this area

*Year of completion

*2022	**Advance Dispatch Optimisation**[28] Assessing the feasibility of developing an advanced dispatch optimisation tool for the Balancing Mechanism (BM).
	Virtual Energy System (Discovery)[29] This Discovery phase project supports the common framework workstream and will be used to understand what standards should be set out with participants to facilitate collaboration and compatibility. The common framework will provide a 'blueprint' so multiple parties can develop a wide range of digital twins which are interoperable and can interact using open data.
*2022	**A Common Framework for Virtual Energy System**[30] This feasibility study explores the scope and content for a Common Framework, investigates how it can be informed by current best practice, and recommends possible delivery approaches.
2023	**Common Framework Demonstrator**[31] This project will provide a greater understanding of the requirements from the common framework to support the overall Virtual ES. This will be achieved through a small-scale demonstration of the priority key factors applied to a tangible use case centred on whole-system flexibility, and through development of best practice guidance for building a common framework.
	AI Centre of Excellence[32] Unifying and growing a collective AI workforce in the energy industry to decarbonise the whole system through digitalisation by creating a collaborative space where people can apply their skills to help meet net zero targets, discover, learn and contribute positively towards improving society and saving our planet.

27 nationalgrideso.com/document/299416/download
28 smarter.energynetworks.org/projects/nia2_ngeso0013
29 smarter.energynetworks.org/projects/10026595
30 smarter.energynetworks.org/projects/nia2_ngeso0014
31 smarter.energynetworks.org/projects/nia2_ngeso028
32 nationalgrideso.com/news/future-eso-and-artificial-intelligence

Digital, AI and Data

Watch our Digital, AI and Data video

2024	**Model-driven Strategy for Balancing Optimisation**[33] Developing an Underpinning Balancing Model (UBM) and map existing manual processes to analytical equations aligned with the UBM.
	Virtual Energy System - Common Socio-technical Framework Development[34] This project continues the development of the tangible demonstrator for the common framework, with the long term aim to develop a proof of concept and detailed design of the technical architecture and governance processes required, bringing together the related programmes: National Digital Twin Programme and Digital Spine.
	Course-correction Dispatch Instructor[35] Delivering a proof-of-concept decision-support tool to the ENCC, aiming to release operators of manual tasks and enabling them to focus on validating results and ensuring timely decisions are made, to address the increasing number of units to dispatch across multiple services.
	Generative AI Discovery[36] Exploring high impact use cases appropriate for Generative AI deployment. Open Data initiatives will then be used to lab test three priority Use Cases.
	Network Security in a Quantum Future[37] Investigating the quantum threat to the energy system's cybersecurity, developing a novel assessment framework and a prioritised mitigation approach.

33 smarter.energynetworks.org/projects/nia2_ngeso041
34 smarter.energynetworks.org/projects/nia2_ngeso065
35 smarter.energynetworks.org/projects/nia2_ngeso032
36 smarter.energynetworks.org/projects/nia2_ngeso064
37 smarter.energynetworks.org/projects/10103996-2

Future Markets

Watch our Future Markets video

About the priority

We will design and test market reforms to reduce consumer costs whilst facilitating the net zero transition. We will do this with coherence of markets and will remove barriers to enable diversity of market actors.

We will continue to explore how all consumers can become active participants in the system and benefit from potential cost savings.

Key opportunites

Success for this innovation priority is:

- Market arrangements enable the net zero transition, at the lowest cost to consumers, with a diverse range of market participants.

To achieve this, we need to explore opportunities and build on existing work in the following areas:

- Exploring market design and testing potential market reform to enable the net zero transition
- Exploring how to prioritise the optimal market arrangements to reach net zero, where the largest number of participants experience benefits
- Enabling a diverse range of actors to access and participate in markets (e.g. diversity of technology types and revenue streams)
- Understanding demand behaviour better and how to incentivise decisions to support the net zero transition
- Exploring the role of interconnectors in our future energy system

Future Markets

Watch our Future Markets video

Relevant publications

Markets Roadmap[38]

Operability Strategy Report[39]

Balancing Costs Strategy[40]

Where we are today

Example innovation projects in this area

*Year of completion

***2022**

Mass Market Flexibility[41]
Exploring the opportunities for households providing a reliable support to the network through aggregated energy flexibility and developing a baseline methodology with recommendations for adoption.

CrowdFlex: Discovery[42]
Exploring how the energy industry would like to see domestic flexibility resources play an active role in energy markets and services.

2023

CrowdFlex: Alpha[43]
Delivering an innovative specification for consumer demand and flexibility models and developing a plan for conducting randomised control trial to study and gather data covering different aspects of demand-side services.

2023

Consumer Building Blocks[44]
Developing a set of consumer archetypes covering gas, electricity and hydrogen to benefit the further development of future energy scenarios across the whole system.

Enduring Cross-Border Balancing[45]
Exploring the possibilities and implications associated with the introduction of a new balancing market in GB, able to interact with EU balancing markets.

Future of Interconnectors[46]
Researching and modelling of different net zero scenarios to investigate the role that interconnectors could play in the net zero electricity system, including understanding the impact of nodal pricing on the operation of interconnectors.

38 nationalgrideso.com/research-and-publications/markets-roadmap
39 nationalgrideso.com/document/299926/download
40 nationalgrideso.com/document/288236/download
41 smarter.energynetworks.org/projects/nia2_ngeso001
42 smarter.energynetworks.org/projects/10027180
43 smarter.energynetworks.org/projects/10037410
44 smarter.energynetworks.org/projects/nia2_ngeso026
45 smarter.energynetworks.org/projects/nia2_ngeso030
46 smarter.energynetworks.org/projects/nia2_ngeso015

Future Markets

Watch our Future Markets video

2023

InterCast[47]
To forecast the hourly electricity price in each country, the ESO have acquired future market price data for the peak and baseload periods from external data sources. This is transformed to hourly prices using a technique based on similar historical days. This project seeks to produce an improved method of converting future market prices data into a forecast of hourly electricity prices.

Reactive Power Market Design[48]
Exploring if a reactive power market could be developed to help ESO access more reactive power in the right location, create market access for more providers, incentivise more efficient new technologies and lower the overall spend on reactive power control.

Revamp Interconnector Ramping Arrangements (RIRA)[49]
With the further increases to cross border capacity, current ramping arrangements need to change to ensure security of supply. The ESO seeks a cost benefit analysis (CBA) review of possible solutions to help solve this issue.

REVEAL[50]
Designing a single enduring environment to test services, improving our time to market and allowing us to prototype/quickly assess services.

Service Provider Capability Mapping[51]
Generating guidance on how to design future markets to better account for changing asset types.

Stability Market Design[52]
Considering current stability arrangements and investigating the best option for an end-to-end stability market.

2024

Alternative Metering (Baselines)[53]
Investigating analysis techniques and developing an algorithm to validate Response delivery from a large number of these assets which are unable to use conventional metering solutions.

Exploring the Economic Benefits of Co-optimising Procurement of Energy, Response and Reserve[54]
There have been no quantitative studies to date that explore the theoretical historic and future efficiency savings when energy, reserve and response are co-optimised within GB. The outcome of this project will help inform the wider debate on future market reforms.

Demand Flexibility Service Evaluation[55]
Capturing and analysing data from the Demand Flexibility Service to understand how consumers, as well as commercial and industrial users, interacted with the service and provide recommendations for increased participation.

QWID FLEXER[56]
Developing a rigorous, repeatable, transparent method for quantifying the need for within-day flexibility. This will include identifying relevant data sources and how to process them, assumptions, treatments of averages and extremes, calculations and interpretation of results.

2026

CrowdFlex: Beta[57]
Developing probabilistic modelling of domestic demand and flexibility to improve forecasting of baseline domestic demand and flexibility, as well as conducting large-scale consumer trials to enable the model development.

47 smarter.energynetworks.org/projects/nia2_ngeso058
48 smarter.energynetworks.org/projects/nia2_ngeso008
49 smarter.energynetworks.org/projects/nia2_nges042
50 smarter.energynetworks.org/projects/nia2_ngeso024
51 smarter.energynetworks.org/projects/nia2_ngeso031
52 smarter.energynetworks.org/projects/nia2_ngeso005
53 smarter.energynetworks.org/projects/nia2_ngeso057
54 smarter.energynetworks.org/projects/nia2_ngeso053
55 smarter.energynetworks.org/projects/nia2_ngeso043
56 smarter.energynetworks.org/projects/nia2_ngeso055
57 smarter.energynetworks.org/projects/10070764

Constraint Management

Watch our Constraint Management video

About the priority

Changes in the volume and location of electricity generation will lead to significant constraint costs that continue to impact consumers. One of the key areas of congestion is the Anglo-Scottish boundary (B6). The area is limited by a constraint, so sometimes requires renewable generation to be turned down pre-fault. This can lead to higher costs which are then passed onto consumers.

ESO's **Constraint Management Pathfinders**[58] focus on reducing the need for build solutions and seek solutions from new constraint service providers to help with cost reduction.

However, we need to test a variety of innovative, market-led solutions and technologies to identify the most economic solutions to mitigate constraints and reduce costs for consumers. Opportunities also remain to better forecast the occurrence of constraints, including the cost impacts.

Key opportunites

Success for this innovation priority is:

- The costs and occurrence of constraints on the electricity system have been reduced as effectively as possible.

To achieve this, we need to explore opportunities and build on existing work in the following areas:

- Enabling better forecasting of constraints
- Exploring the most economic solutions to mitigate constraints

58 nationalgrideso.com/industry-information/balancing-services/pathfinders/noa-constraint-management-pathfinder

Constraint Management

Watch our Constraint Management video

Relevant publications

Constraint Managment Pathfinders[59]

Where we are today

Example innovation projects in this area

*Year of completion

*2021	Probabilistic Planning for Stability Constraints[60] Exploring, developing and testing cutting-edge automated and probabilistic approaches for modelling of angular stability.
2024	FastOut[61] Developing a tool to provide indicative constraint cost risks caused by equipment outages (RAG status). A Gantt chart like interface would allow users to find the best time slot for an outage.
2024	Hydrogen Production for Thermal Electricity Constraints Management[62] Demonstrating how the large-scale production of green hydrogen can support the management of regional electricity transmission network constraints during times of high output from intermittent renewables generation.
	Forecasting the Risk of Congestion[63] Developing probabilistic forecast of congestion, after the clearing of the day-ahead market, to assess the impact of congestion across the network and predict the probabilistic risk of congestion on specific branches of the power grid.

59 nationalgrideso.com/industry-information/balancing-services/pathfinders/noa-constraint-management-pathfinder
60 smarter.energynetworks.org/projects/nia_ngso0036
61 smarter.energynetworks.org/projects/nia2_ngeso060
62 smarter.energynetworks.org/projects/nia2_ngeso036
63 smarter.energynetworks.org/projects/nia2_ngeso037

System Stability & Resilience

Watch our System Stability & Resilience video

About the priority

As we transform to a zero-carbon electricity system, the system becomes less stable with increasing non-synchronous generation affecting frequency changes, voltage and fault-ride through stability. In parallel, the system faces increasingly challenging operating conditions due to global events - such as COVID-19, invasion of Ukraine and more extreme weather events.

With this constantly changing environment, ESO needs to better understand how and why the system may be impacted by different factors and how to mitigate against them.

Key opportunites

Success for this innovation priority is:

- Operating the electricity system with low inertia, predicting and mitigating issues to maintain system stability and ensuring security of supply.

To achieve this, we need to explore opportunities and build on existing work in the following areas:

- Identifying methods for early oscillation detection and impacts
- Developing tools to increase our operational awareness around inertia
- Improving our capabilities to conduct EMT studies
- Optimising system strength and stability metrics
- Ensuring security in operation
- Exploring potential system impacts and scenarios
- Exploring alternative approaches to outage planning and system restoration
- Exploring how to best manage frequency/stability with an asynchronous system

System Stability & Resilience

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Relevant publications

Winter Outlook[64]

Summer Outlook[65]

Where we are today

Example innovation projects in this area

*Year of completion

*2021	DETECTS[66] Understanding the risks of "sub-synchronous control interactions" better by assessing the behaviour of actual manufacturer-provided converter models.
*2021	Mapping the Impacts and Visualisation of Risks of Extreme Weather on System Operation (MIVOR)[67] Evaluating the impacts of extreme weather events on system operation up to 2050 to produce a map demonstrating the risks, probabilities and consequences of such events at a 25km grid level of GB.
2021	Short-term System Inertia Forecast[68] Providing a proof of concept for an accurate day-ahead and intra-day system inertia forecast with multi-time resolution, that can be potentially used to support the day-ahead frequency response procurement and the real-time system operation.
2022	Resilient Electric Vehicle Charging (REV)[69] Analysing the impact of electric vehicle charging on grid short term frequency and voltage stability, and cascade fault prevention and recovery.

64 nationalgrideso.com/research-and-publications/winter-outlook
65 nationalgrideso.com/research-and-publications/summer-outlook
66 smarter.energynetworks.org/projects/nia_ngso0031
67 smarter.energynetworks.org/projects/nia_ngso0023
68 smarter.energynetworks.org/projects/nia_ngso0020
69 smarter.energynetworks.org/projects/nia2_ngeso006

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2023	**Dispatch Optimiser Transformation**[70] Building on the Advance Dispatch Optimisation project and designing a blueprint for transformation of control room tools and processes to meet the System Operator needs.
	Distributed ReStart – Redhouse Live Trial[71] Exploring how Distributed Energy Resources (DERs) can be used to restore power in the event of a total or partial shutdown of the GB Electricity Network.
	Optimal Outage Planning System[72] Providing added value to the current planning process by providing a solution to the imperative need for better integration of risk estimation into the planning optimization so that the amount of work remains manageable for the NAP process.
	Scenarios for Extreme Events: Discovery[73] Developing a decision-making framework, supported by scenario modelling capabilities to allow evaluation of, and build resilience against, future black swan events.
2024	**Automated Identification of Sub-Synchronous Oscillations (SSO) Events**[74] Exploring, developing and testing a combination of novel frequency domain methodologies and machine learning techniques to identify potential system operating conditions which can lead to Sub-Synchronous Oscillations (SSOs) and implementing an automated control interaction studies framework.

2024	**Co-optimisation of Energy and Frequency-containment Services**[75] Exploring if novel mathematical modelling techniques to achieve cop-optimisation of energy and frequency services can be used to enhance efficiency and security of the operation of the future GB electricity system.
	Data-Driven Online Monitoring and Early Warning for GB System Stability (DOME)[76] Examining whether measuring on-line impedance spectra of a gird can give early warning of emerging oscillations, and beyond that, whether it is possible to identify which aspects of which equipment should be re-tuned to damp those oscillations.
	DETECTS II[77] Enhancing the DETECTS models with further analysis for more scenarios and operating conditions and providing training to the ESO.
	Inertia Measurement Method Optimisation[78] Analysing and verifying data from new commercial inertia monitoring tools and compare to NGESO operational data, establishing different generation and demand scenarios for inertia and Rate of Change of Frequency.
	Real-Time Phasor-EMT Simulations (RealSim)[79] Considering real-time simulation of a region of GB power system in both phasor and EMT modes. The developed real-time models will be used to assess the impact of controllers on transient stability and analyse different contingencies in the system.

70 smarter.energynetworks.org/projects/nia2_ngeso044
71 smarter.energynetworks.org/projects/nia2_ngeso047
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79 smarter.energynetworks.org/projects/nia2_ngeso045

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2024	**Stability Requirements Calculation Toward Net-Zero (STARTZ)**[80] Reviewing the current methods of calculating system stability needs and implement automation and machine learning to calculate system stability needs for the GB network at a granular level.
	Scenarios for Extreme Events: Alpha[81]
	Strength to Connect[82] Exploring appropriate alternatives to short circuit level to measure grid strength in the future GB system, particularly with high penetration or dominance of inverter-based resources.
	Trial on Implementation of Wide Area Monitoring and Control System (WAMCS)[83] Exploring the use of the Phasor Measurement Unit (PMU) based Wide Area Monitoring and Control System (WAMCS) on the GB electricity network. This system has been recognised as a tool to facilitate system operation in low inertia scenarios with high penetration of renewables.
	Practical Transition into Wider EMT GB Modelling[84] Enhancing the GB network's EMT model by improving the models' computational efficiency, which will help investigate more scenarios with stability risks while transitioning into zero carbon operation.
2025	**Enhanced RMS (e-RMS) Models for Stability Assurance**[85] Developing an enhanced RMS (e-RMS) modelling framework that can provide dynamic stability assurance in planning studies and at operation timescale without carrying the cost of being overly conservative.
	MinGFM[86] Investigating new methods and control strategies for when additional energy storage is not needed. In particular, this project will help develop an understanding of the potential for data-driven intelligent control of wind turbines while delivering a techno-economic comparison of various control strategies.

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Key project updates

Join our mailing list to stay updated on the latest Virtual Energy System news and events.

Find out about how the Virtual Energy System Programme[87] and CrowdFlex[88] project have progressed over the past year.

Virtual Energy System

The Virtual Energy System (VirtualES)[89] Programme, launched in 2021 by the ESO, will enable the creation of an ecosystem of connected digital twins of the entire energy system of Great Britain which will operate in synchronisation to the physical system. Facilitating the secure and resilient sharing of data across organisational boundaries, it will provide the ability to model complex real-world scenarios and generate insights to cut carbon emissions and accelerate the transition to net zero.

The programme focuses on:

1. **Stakeholder Engagement:** The energy industry, regulator and government will be impacted by the Virtual Energy System and so must be involved in its development.
2. **Common Framework:** It's vital that there's a framework established setting out technical standards and engagement principles which stakeholders can follow to collaborate and build an interoperable VirtualES.
3. **Value driven development through Use Cases:** The development and build sequence of the VirtualES is organised to respond to real-world needs; its scale and complexity will grow iteratively over time based on requirements of Use Cases it will be called to serve and stakeholders' feedback. We are working with stakeholders to agree which Use Cases to build and how to prioritise them to deliver whole system value.

Key developments over the past year include:

Memorandum of Understanding with the National Digital Twin Programme

In November 2023, the Virtual Energy System Programme and the National Digital Twin Programme, led by the UK Government's Department for Business and Trade, signed a Memorandum of Understanding to collaborate on developing an energy system Data Sharing Infrastructure.

This collaboration furthers the aspirations for sector-wide secure and resilient data sharing outlined by the Energy Digitalisation Taskforce,[90] Ofgem's Future Systems and Network Regulation (FSNR) decision,[91] and the recommendations set out in the Department for Energy Security and Net Zero's recent Transmission Acceleration Action Plan.[92]

The agreement initially focuses on developing an integrated high-level technical design and architecture, which identifies the interfaces between components of the future energy system Data Sharing Infrastructure. It also aims to scope the technical, process, and policy requirements for achieving an integrated minimum viable product that both programmes can use to practically demonstrate the concept of connected digital twins.

87 nationalgrideso.com/future-energy/virtual-energy-system
88 nationalgrideso.com/future-energy/projects/crowdflex
89 nationalgrideso.com/future-energy/virtual-energy-system
90 es.catapult.org.uk/case-study/energy-digitalisation-taskforce
91 ofgem.gov.uk/publications/decision-frameworks-future-systems-and-network-regulation
92 assets.publishing.service.gov.uk/media/65646bd31fd90c0013ac3bd8/transmission-acceleration-action-plan.pdf

Key project updates

> We are excited to sign this Memorandum of Understanding with the National Digital Twin Programme, led by the Department for Business and Trade, to look at the components for developing an energy sector data sharing infrastructure. This collaboration is a significant step for energy digitalisation and the goal of enabling secure and resilient exchange of data across the sector, to support the delivery of a zero-carbon energy system in Great Britain by 2035."
>
> ***Shubhi Rajnish, Chief Information Officer at the ESO***

Published six priority factors for development of the VirtualES

The creation of the VirtualES is a socio-technical challenge, requiring a collaborative and principled approach. The programme has identified 14 socio-technical factors that create a clear path forward to collaboratively build the VirtualES. Extensive research took place over the last year on the six priority factors below, its outcomes were consolidated and published in a series of reports.

1. Raising awareness and fostering culture
2. Engaging stakeholders
3. Creating a Governance framework
4. Aligning models and taxonomies
5. Increasing visibility and enabling sharing
6. Creating an interoperable tech stack

To validate these with industry, VirtualES formed advisory groups. These groups span both gas and electricity vectors with representatives from industry bodies, networks, generators, suppliers, academia, and technology.

Visit the **Virtual Energy System webpage**[93] to view reports on the six priority factors.

93 nationalgrideso.com/future-energy/virtual-energy-system

Key project updates

CrowdFlex

The CrowdFlex[94] project explores consumer demand and domestic flexibility to understand how it can support the coordination of energy consumption, generation and grid management. As more renewable generation comes online, balancing supply and demand becomes increasingly challenging to manage. Domestic flexibility can help create a smart, flexible energy system, enabling consumers to act as a reliable source of flexibility on the network.

CrowdFlex will build interconnected models of consumer demand and flexibility, enabling more accurate forecasting and reliable deployment of domestic flexibility in the control room, helping consumers reduce their energy costs and the energy industry to meet its ambitious decarbonisation goals.

Following CrowdFlex's Alpha phase, which refined options and identified the path for the development of the interconnected models, in July 2023 the project was awarded £20m in funding for the Beta phase, through the Strategic Innovation Fund (SIF), a programme from the UK's independent energy regulator Ofgem, managed in partnership with Innovate UK.

This large-scale demonstrator Beta phase, will utilise data gathered from trials based on two kinds of domestic flexibility services:

- **Utilisation payments:** Consumers will be paid to turn-up or turn-down demand as part of a scheduled service that examines how domestic flexibility can contribute to the management of system constraints.
- **Availability payments:** Consumers will be paid a regular fixed payment to make their assets available (e.g., to plug in their EVs).

As well as the models, data from the trials will also be used to generate consumer understanding and help develop go-to-market strategies for flexibility service providers.

CrowdFlex is being delivered by the ESO with a consortium of partners including Octopus, OVO, Ohme, Centre for Net Zero, Element Energy, Amazon Web Services, National Grid Electricity Distribution, and Scottish and Southern Electricity Networks. The ESO will also be supported by The Smith Institute and the Centre for Sustainable Energy.

> We're excited to be in the beta phase. CrowdFlex will be looking at building interconnected forecasting models of domestic demand and flexibility, and aims to firmly establish consumer flexibility as a reliable grid management resource, helping to reduce energy bills and to transition to a smart, flexible and zero-carbon grid."
>
> ***Sanna Atherton, CrowdFlex Project Lead at the ESO***

> We're proud of the work we have done together with the ESO to push the boundaries of household flexibility. We've been a partner on the landmark CrowdFlex project since the very beginning, and it's brilliant to see that cutting-edge tech and innovation has allowed it to scale further and make an immediate impact.
>
> We now have an unmissable opportunity to use the learnings from this project to continue innovation, and create a greener, cheaper grid of the future. More household flexibility is a win-win for all - boosting grid resilience whilst directly putting pounds back into people's pockets who take part."
>
> ***Kieron Stopforth, Flexibility Lead at Octopus Energy Group***

94 nationalgrideso.com/future-energy/projects/crowdflex

What's coming up

Becoming National Energy System Operator (NESO)

In the summer of 2024, the ESO will become National Energy System Operator (NESO). The new organisation will be founded on the ESO's current activities and capabilities, but we'll also take on new roles with a whole system perspective across energy vectors.

We will deliver additional value for the energy system across these five areas:

- Strategic Planning
- Security of supply
- Resilience
- Market Development
- Net zero energy insights

This whole system approach will help to strengthen energy security, deliver net zero and ensure household bills are affordable in the long-term.

Visit our website[95] to find out more.

Emerging Technology Horizon Scanning

In a rapidly changing energy industry, horizon scanning across all external factors is increasingly important to the ESO's strategy, planning and decision-making. To support our Innovation Strategy and ideation efforts, we will explore the opportunities and threats presented by emerging technologies.

We will achieve this by developing a broad view of relevant emerging technologies, their maturities, timescales and likely impacts on the energy system. Following which, technologies will be prioritised for further investigation in the year ahead.

Find out more in the ESO's Digitalisation Strategy & Action Plan[96] (section 3.7 Accelerator: Future Technology Led).

Our Innovation Annual Summary

We will publish our Innovation Annual Summary this Summer. This will explore our key activities, performance, and project case studies from the past year, and how they are helping to address our innovation priorities (detailed in this report).

Visit our website[97] to view our 2022/23 Innovation Annual Summary.

95 nationalgrideso.com/what-we-do/becoming-national-energy-system-operator-neso
96 nationalgrideso.com/document/299416/download
97 nationalgrideso.com/future-energy/innovation/innovation-annual-summary

How to get involved

Are you interested in collaborating with us on addressing our innovation priorities? There are several ways to collaborate and develop innovation projects with us. We are eager to hear your thoughts and ideas about finding new ways to meet the challenges of transitioning to a zero-carbon future.

You can also learn more about how to get involved[98] on our website.

Stay up to date with ESO Innovation

Visit our website to find out about events we are hosting and attending and view our publications.

Sign up to our mailing list to be notified of future events, news and publications.

98 nationalgrideso.com/future-energy/innovation/get-involved-eso-innovation

How to get involved

Partner with us

Network Innovation Allowance (NIA)

Network Innovation Allowance (NIA) is a set allowance that each network receives to administer as part of their network price control. It is designed for early-stage research and development or small-scale demonstration projects.

Using NIA, we develop and provide funding for projects which link to at least one of our innovation priorities (detailed in this Innovation Strategy). We welcome your project proposals throughout the year.

Fill in our **Big Idea form**[99] to submit your project idea - this will be sent straight to our Innovation team who will assess your idea. Before submitting your Big Idea, we recommend reading our **NIA Project Requirements.**[100]

Strategic Innovation Fund (SIF)

The Strategic Innovation Fund (SIF) is administered by Ofgem with support from Innovate UK (UKRI). It is focused on funding large-scale transformational research and development projects in 3 phases (Discovery, Alpha, Beta). You can read more about the phases and requirements of the fund in the **SIF Governance Document**.[101]

For each Discovery funding round application, Ofgem and UKRI publish challenge areas related to the energy transition to net zero that projects should address. You can keep up to date with the latest challenges and deadlines on **Ofgem's website**.[102]

If you think you have an idea for a large-scale transformational project suitable for SIF funding and the ESO, you can **email us**[103] at any time with your proposal. When challenge areas are published by Ofgem and UKRI, we upload a form to our website for sharing suitable ideas. **Sign up to our mailing list**[104] to be notified when this form is uploaded.

99 nationalgrideso.fra1.qualtrics.com/jfe/form/SV_eqW0lYOt6vW2EaV
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103 innovation@nationalgrideso.com
104 subscribers.nationalgrid.co.uk/h/d/779485208E80014D

How to get involved

Co-create with us

Our Open Innovation Events create a dedicated environment for the ESO to collaborate closely with innovators and stakeholders across the energy sector, working together to address the most pressing energy system challenges we face. The event creates a kind of fast-track innovation process to rapidly develop viable new projects.

1. We invite innovators to submit proposals through an open call, with details of the challenges we are looking to address and the strategic innovation priorities they relate to.
2. The best ideas are then taken forward to a two-day in-person event where the project teams collaborate with subject matter experts from the ESO and other networks to develop their initial concepts into full project proposals.
3. Project proposals are pitched to a panel of industry experts, who provide feedback and recommendations for next steps.

Visit our website[105] to find out about our Open Innovation Event July 2022.

105 nationalgrideso.com/future-energy/innovation/innovation-events-and-publications/open-innovation-event-july-2022

Contact us

General Innovation:
Innovation@
nationalgrideso.com

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