Electricity System Operator

Innovation Strategy

2022/23

nationalgridESO

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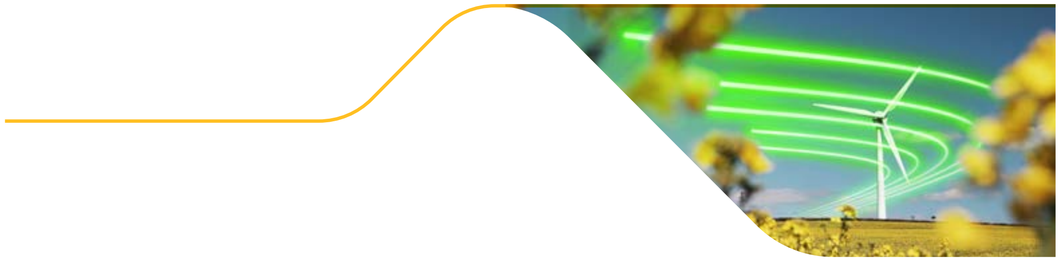

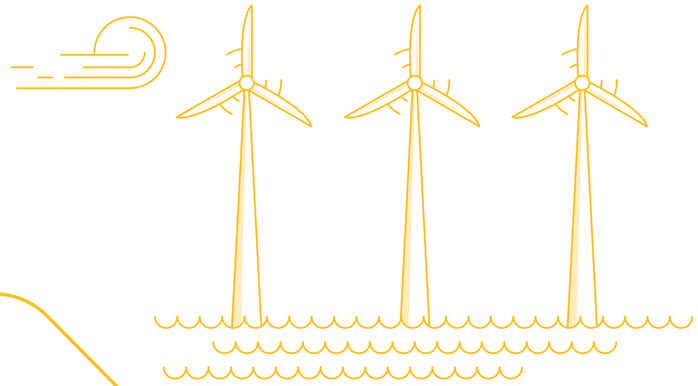

Introduction

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.

We're also helping to tackle one of the biggest challenges facing society: how to create a sustainable, low-carbon electricity system for the future that will help the UK meet its net zero commitments. Innovation plays a vital role in this effort, which is why we're working with partners from 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 (2022/23).

Foreword

2021/22 was our first year under the new RIIO-2 price control. Our increased ambition for the regulatory period, not only in supporting the decarbonisation of the electricity system but in driving costs down for end consumers, has required ESO to intensify its efforts to drive innovation for the system. This has meant securing an increase in the amount of NIA funding the ESO has access to, and a larger team in the ESO to help accelerate new types of programmes and partnerships with which to help find, build and deliver new innovation projects. Just like everyone else, our growing team has risen to the continued challenge of working remotely, needing to find new ways to remain connected and engage effectively with our stakeholders. Building innovation projects collaboratively has been more difficult over video calls and emails, but we have continued to rapidly grow our portfolio of projects and programmes (such as the Virtual Energy System) which aim to drive the change required, while delivering large benefits to consumers and the wider system.

I like to take the time in these forewords to take a step back from the detail of the day to day running of the innovation portfolio to look at the more high-level trends affecting our industry, and to try and understand what it means for the future of innovation and the electricity system. It was in this past year that the UK Government published its Net Zero Strategy: Build Back Greener policy, including the target to "fully decarbonise our power system by 2035", but it is safe to say the whole industry, ESO as its heart, has been busy pushing the decarbonisation agenda for a few years now. If you look at our evolving portfolio, you'll notice that ESO has spent much of these past years conducting studies looking at what to expect from a zero carbon future.

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Introduction

We first tried understanding what that world would look like; then focussed on identifying the problems that would arise from these scenarios, where the issues would be, how much they would potentially cost us. More recently, we started looking at and testing some of the possible solutions, trying to find the most efficient and the most cost effective options, walking that delicate balance between securing the safety and service levels of the grid, while driving costs down for consumers. What we've gathered from much of these past projects is that unfortunately when it comes to a decarbonised grid, there isn't a silver bullet that would solve it all. Our strategic priorities, which have historically been a collection of concerns and areas of investment, have evolved into macro interlinking themes which are not so much looking for a solution, but instead have started to act as catalysers for fundamental changes to the way the system operates. Our recent Net Zero Market Reform proposal is an example of how we have stopped looking at solving problems but have instead started redesigning the future and changing the way we think.

In this context ESO Innovation also had to change the way it approaches innovation, and we realised that merely pursuing individual projects, targeting a single technology or issue, was just not going to be enough. Looking at our current portfolio we now find an emerging number of Innovation Programmes: collections of projects looking at addressing macroscopic themes, and technology is not always the only answer. We also find that leading the development and delivery of these programmes, in the context of our new and improved role in the decarbonisation of the grid, is an ineffective way to do innovation; instead, we must inspire and empower the system to deliver those changes, to each lead and deliver their part of the solution. Only by working together can we truly hope to succeed in our objective and our hopes.

The Virtual Energy System, the energy systems digital twin, is a perfect example of this new way of doing innovation: it isn't an ESO project, we are instead hoping to catalyse an industry wide effort to develop the tool of the future grid by allowing each of us to deliver our own component. Our Sandbox Programme is another example of this, it is merely a platform where we wish to test drive the various services and solutions as proposed and developed by our industry partners. Our Centre of Excellence for Machine Learning, Data Science and Analytics is looking to address the issue around how to fill the skill gap in our industry by working together with academia and the private sector to try and attract top talent in our mission to decarbonise the energy system.

These are just some of the incredible major Innovation Programmes that we can kick off, thanks to having access to an increased NIA funding pot from Ofgem.

As reality of the energy transition becomes increasingly urgent, and the pace of change needed becomes quicker, innovation is even more important to make sure we can adapt to solve the current and emerging challenges we face.

Anna Carolina Tortora

Head of Digital Transformation and Innovation Strategy

Highlights of the year

There are many highlights from this year, but to name a few:

- April 2021 saw the start of the ESO's new (RIIO-2) price control period, this resulted in an increase in Network Innovation Allowance (NIA) available for the ESO. A new Strategic Innovation Fund (SIF) was also launched to help industry address key challenges of the energy system through large-scale, collaborative projects (replacing NIC funding).
- The UK committed to decarbonise the electricity system by 2035. This brings forward by 15 years the government's commitment to a fully decarbonised power system by 2050, originally set out in the Energy White Paper, and builds on the Prime Minister's 10 Point Plan for a Green Industrial Revolution to secure a future clean electricity supply for the UK.
- The Virtual Energy System was launched by the ESO, with the ambition of becoming an industry-led programme to help drive the coordinated digitalisation of the GB energy system. This interconnected network of digital twins will allow better simulation, planning and operational decisions to be made for the benefit of all energy system stakeholders.
- ESO launched the Carbon Intensity Dashboard alongside COP26 (where National Grid was a principal partner). This dashboard shows the live electricity mix in Great Britain and the estimated carbon emissions from power sources, the carbon impact of ESO balancing actions, as well as historic carbon intensity of the system.

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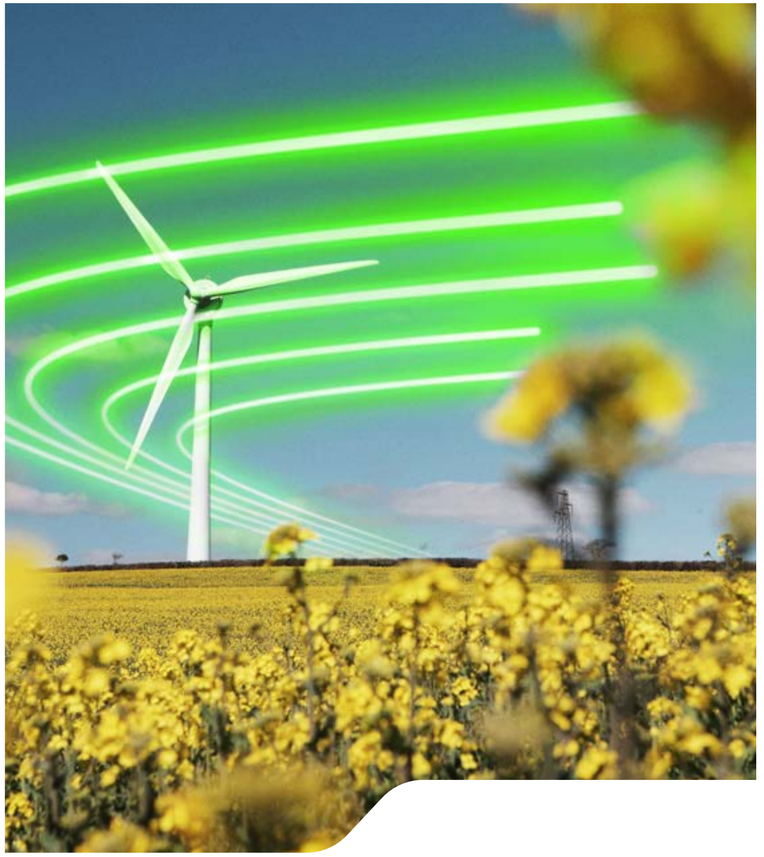
Drivers of Change

The four megatrends of Decarbonisation, Decentralisation, Digitalisation and Democratisation continue to drive change on the GB energy system. The ESO's Future Energy Scenarios (FES) work helps us to understand the potential impact of these changes by 2050. The UK government's clear target for the UK to be "powered entirely by clean energy" by 2035 makes the ambition clear and highlights the already significant progress of renewables and the closing down of large coal generators. Security of supply issues in the wake of the Ukraine crisis, could prompt an even more rapid move to renewable, low carbon sources of energy. How this energy transition is done in an effective way, while maintaining the reliability of the GB electricity system is a key challenge and opportunity for the ESO.

The ESO's **Bridging the Gap** work, which builds upon FES and identifies the tangible "what needs to happen now" actions, looks specifically at the 2035 Net Zero target and how this will be achieved. A key focus is the increasing need to empower consumers and unlock greater flexibility from energy resources within their homes and electric vehicles. This requires transparency and aligned incentives, as well as a better understanding of the characteristics of this potential resource and how it can be used reliably. With the correct technologies, markets and regulatory frameworks in place, this consumer flexibility could help drive faster decarbonisation and lower energy costs for all.

The question of how GB can deliver net zero through a 'whole system' approach to energy is also a key driver (and focus area for Bridging the Gap work). Understanding the interactions between the Electricity and Gas networks, as well as other sectors such as heat, transport and the end consumer is vital to allowing the greater efficiencies in operational and planning decisions necessary for achieving net zero targets.



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Drivers of Change

The UK government has published clear policy and proposals for how the power system is to achieve net zero carbon by 2035. Decarbonising the heat and transport sectors is going to require a complete revolution in technology, markets and consumer behaviour. The knock-on impact on the power system is going to be huge.

As exponentially more assets connect to networks and participate in energy markets, there will be increasing complexity and uncertainty in supply and demand forecasts. Better quality and more peripheral data will be required to optimise balancing actions in future. While open data and digitalisation are key to achieving whole system thinking and delivering net zero.

As energy resources become more decentralised (e.g. embedded solar and batteries), Distribution Networks will need to become DSOs (Distribution System Operators). We need to fundamentally rethink the various roles and responsibilities in the market and remove any barriers to ensure this transition continues.

Better access to information and technology will allow communities and consumers to be much more actively engaged in energy system operation. This important trend means we must continue putting the consumer at the heart of our innovation activities, not just ensuring delivery of robust consumer benefits from projects, but how we can facilitate better consumer participation in the energy markets.

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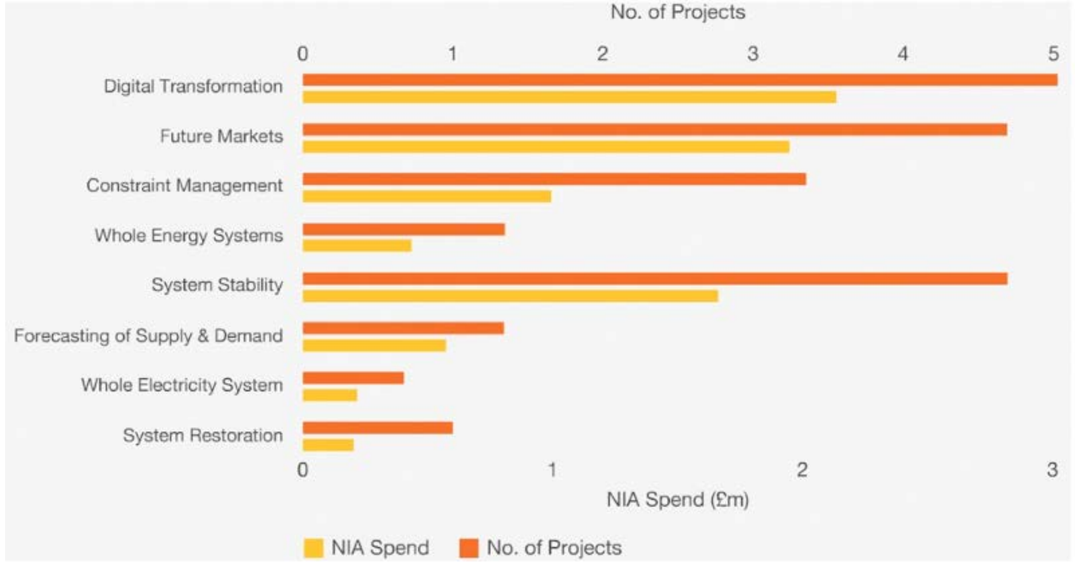
Portfolio Analysis

The first year of RIIO-2 (the 12 months between April 2021 and March 2022) saw the ESO commit more NIA funding towards innovation projects than in any year prior. The increase in NIA from Ofgem and a larger innovation team have allowed the ESO to engage with even more partners and initiate larger, more impactful projects than would have otherwise been possible.

The ESO had 22 live innovation projects last year, 12 of which were started during the year, 10 being carried over from the previous year. This includes two legacy NIC projects and two new SIF projects. Three of our projects last year were led by other networks and we provided many more projects with letters of support, data and expert resources from across the ESO. This is just the beginning, as we ramp up our activity and continue to grow the innovation portfolio into 2023 and beyond.

Most of our projects address two priority areas, as a primary or secondary link. This graph (Figure 1) indicates the level of effort (indicated by Number of projects) and funding (NIA spend) we have allocated against each priority. Our top priorities of Digital Transformation and Future Markets received the most direct attention. The significant outlier is that we focused much more on System Stability than we anticipated, due to this being linked as a secondary priority on many projects last year. We plan to rebalance our portfolio according to the new list of priorities (next page) over the coming year.

Figure 1.



Performance against Innovation Strategy: No. of projects linked to the 8 innovation priority areas (includes projects completed in year, in progress, or started in year) and NIA spend per each of the 8 priorities.

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2022 Priorities

This table summaries our strategic innovation priorities for 2022/23, where you can expect to see us concentrating our innovation focus this year. A more detailed rationale for this prioritisation is given in the following pages, where we dive a bit deeper into each priority, as well as illustrating some of the work done last year with case studies.

Key:

- Increase in priority
- Decrease in priority
- Priority level unchanged
- Complete
- Added this year

Order	22/23 Priority	21/22 Priority	Rationale
1	 **Zero Carbon Transition**	⊕	New Priority: focused on how the ESO will be ready to tackle issues such as the potential effect of climate change, and how to enable and encourage the operation of a decarbonised energy system. It will capture projects to improve how we monitor/track carbon in ENCC (Electricity National Control Centre) operations and markets etc., make sure the system is resilient enough to deal with the effects of climate change, and increase the ESO's expertise and capacity to help deliver a zero carbon power system.
2	 **Digital & Data Transformation**	↓	Remains a top priority as a key enabler of the energy system transition, and supporting solutions for the other priority challenges. Addition of 'Data' to ensure this priority reflects the type and quantity of new information being shared, as well as the process to digitalise how we operate.
3	 **Future Markets**	↓	Remains a top priority as a key enabler for unlocking greater competition and flexibility in the system.
4	 **Constraint Management**	↓	Still a key challenge for the ESO, more opportunities remain for innovation projects to help address this challenge.
5	 **System Stability**	—	Remains a priority based on feedback from the business, and as indicated by the significant level of innovation activity towards this last year.
6	 **Whole Energy System**	↓	A lot of research and insight have already been gained, the development and testing of new ways to optimise between vectors will remain a focus.
7	 **Whole Electricity system**	—	More progress has been made on integration between ESO and DSO operations (e.g. through ENA (Energy Networks Association) workgroups and RDP (Regional Development Plans).
-	 **Forecasting of Supply and Demand**	✓	Many prior innovation projects have addressed this issue, and next steps are focused on improving source data (part of BAU activities).
-	 **System Restoration**	✓	This priority will be paused while we await further implementation of the Distributed ReStart project and outputs of the new ESRS (Electricity System Restoration Standard) work. This will help us better understand how innovation can contribute to solving this challenge in future.

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Priority 1: Zero Carbon Transition

The need to rapidly decarbonise our power system is only becoming greater. The UK targets to achieve this by 2035 have made this an even clearer priority for the ESO and energy industry.

While this net zero ambition already underpins all ESO activities, we believe faster progress in some areas can be made through innovation. We have set this as our new top Innovation Priority for 2022/23.

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.

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Priority 1: Zero Carbon Transition

Challenges

As we press ahead with the transition to an energy system with lower levels of carbon emissions, it becomes increasingly difficult to remove the final, harder-to-decarbonise aspects of the system which are carbon-intensive. There needs to be fundamental changes to the way the system is planned and operated to ensure zero carbon is possible. Progress must be rapid to achieve this by the 2035 target.

We must develop better ways to operate the system under zero carbon conditions while maintaining a secure, resilient energy system for consumers. Currently it is gas ‘peaking plants’ that provide the majority of generation for balancing actions in the ENCC (Electricity National Control Centre).

There is currently no standard way, agreed by all industry participants, to calculate carbon intensity of generators. This makes it harder to assess and track carbon intensity on the system at any point in time. This will be critical to understanding what emissions are on the system, finding improvements in operations and planning to avoid these in future or replacing them with zero carbon (or lower carbon) sources.

Opportunities

- Learn how best to assess, track and predict carbon intensity to understand what improvements are needed to network infrastructure and ESO operations to continue minimising this in future.
- Predict how much reserve capacity is required to ensure security of supply from renewable sources and understand how long-duration storage can help support intermittent generators to allow the system to run with a higher penetration of renewables.
- Create new market mechanisms that account for carbon intensity of participants to optimise our future system, e.g., for lowest cost and least carbon intensity.
- Understand the long-term effects of climate change on the GB energy system and how to prepare – including how the transition to renewable generation and the electrification of transport and heat will change the energy landscape for all stakeholders.

Innovation Strategy / Priority 1: Zero Carbon Transition 12

Priority 2: Digital & Data Transformation

Challenges

The energy sector is becoming more integrated, and the number of new players is rapidly increasing. To drive digitalisation and a whole system approach we need greater transparency and open access to make data more accessible and easily understood. As the electricity networks become more reliant on data and aging technologies, the risk of cyber-attacks and the need for a faster response to them also becomes greater.

Consumers will make choices and change their behaviour today and in the future. This will influence decarbonisation pathways and the options for efficient, whole system operation. They'll also be looking to the energy industry for data, insights and simple systems they can use to support their decision making.

Flexibility is a key component for delivering value for consumers in a net zero economy. Cost effectiveness will require large volumes of open data to both extract the most value and create confidence that the system can rely on this flexibility, to overcome the peaks and troughs created by a renewables-dominated generation mix.

Digital & Data Transformation underpins the success of 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. We know that our stakeholders are relying on us to lead the way, which is why this continues to be our top priority in 2022/23.

Opportunities

- Help the industry build a network of individual digital twins, of both the power system, as well as markets. We call this the Virtual Energy System.
- Give teams access to better quality data and models to produce useful insights about the system as its characteristics continue to get increasingly complex.
- Work towards faster decision-making to match our more complex, faster-moving electricity system using AI and machine learning.
- Understand how these techniques can process the large amounts of data required to make the most economic, efficient and effective decisions, in sufficient time – from long-term network planning, to running new markets, to real-time operations in the Control Room.

Innovation Strategy / Priority 2: Digital & Data Transformation 13

Case study: Virtual Energy System - Common Framework

Determining the key socio-technical factors that need to be considered for the Virtual Energy System to succeed.

Digital & Data Transformation

The Project

As part of the Virtual Energy System (VirtualES) programme the Common Framework aims to define the standards and principles required to combine and evaluate data from digital twins across the energy system. This will enable better informed decisions on managing the increasingly complex and uncertain system dynamics as we continue the transition to green energy.

The four factors of the energy transition - decarbonisation, digitalisation, decentralisation and democratisation - are resulting in a more complex system. The Common Framework will set out the technical standards and engagement principles that stakeholders can follow to collaborate and build an interoperable VirtualES. This integration will deliver new insights in how to improve investments, operation and participation, which will drive increased benefits to the consumer.

Stakeholders from across the ever-changing energy landscape have been contributing to an NIA feasibility study and will in future share digital twins of their assets to help create the Virtual Energy System, which will integrate disparate models into the calculations. Stakeholders involved will include transmission and distribution networks, generators and technology companies.

Meet the Project Lead

Name: Jonathan Barcroft

About: I am a data scientist working in the ESO Lab. My primary role is short term energy forecasting. I use artificial intelligence and machine learning to predict trends and find new techniques that ESO can use to model uncertainties like climate change.

> *There are few industries where by reducing carbon intensity we can reduce the emissions of other industries, businesses and homes across the whole country. The rapid pace of change in energy presents lots of opportunities to apply new technologies and approaches to solving problems."*

Innovation Strategy / Case study: Virtual Energy System - Common Framework 14

Case study: Virtual Energy System - Common Framework

Determining the key socio-technical factors that need to be considered for the Virtual Energy System to succeed.

Digital & Data Transformation

The Challenge

Great Britain's electricity system has evolved over 100 years and the complexity of implementing digitalisation cannot be underestimated. Components of the system are represented as individual models and data sources which are not interoperable, or shared openly. This means the models and data can't easily be combined to provide a representation of the whole interconnected system.

Inevitably, the inability to conduct a comprehensive system-wide analysis means that both investment and operational decisions may be limited by the data available. Therefore, the creation of a Common Framework will help overcome this by setting out the principles, guidance and standards to which disparate stakeholder models need to adhere to in order to better collaborate and share data.

By integrating their models, better data driven insights would be available, allowing better informed decisions on day-to-day operation and energy transition planning. The Virtual ES will offer an opportunity to make these decisions more effective, by helping reduce uncertainties and highlighting any interdependencies between different stakeholders on the system.

Innovation Strategy / Case study: Virtual Energy System - Common Framework 15

Case study: Virtual Energy System - Common Framework

Determining the key socio-technical factors that need to be considered for the Virtual Energy System to succeed.

Digital & Data Transformation

Potential Benefits

There is also a transparency benefit as more information would be shared with the consumer and wider industry to make better informed decisions. The integration of different model scenarios will help improve reliability, security and support cost-efficiency savings.

The creation of new business models will lead to new methods of balancing power flows. It will also enable the system to be built in a way that can deliver value to users and consumers over the long term. The results of the feasibility study will enable National Grid ESO to deliver financial benefits by feeding the new insights into the control centre, markets, networks and strategy teams.

Project Information

NIA Reference	Project Name	Status
NIA2_NGESO0014	Virtual Energy System – Common Framework	In progress

Suppliers

Arup are leading a consortium with Energy Systems Catapult and Icebreaker One

Registered Value	Start TRL	End TRL
£350,000	2	3

Innovation Strategy / Case study: Virtual Energy System - Common Framework 16

Priority 3: Future Markets

Designing markets that are fit for purpose underpins the ESO ambitions of 'competition everywhere' and zero carbon operation. But stakeholder feedback continues to show us that current market designs – not just ESO but the wider energy and capacity markets we interact with – aren't always optimal for net zero. 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.

Challenges

Everything is changing. From the technologies and stakeholders that generate and use electricity to the characteristics of the transmission system to the number and makeup of market participants and the business models of the companies that distribute electricity.

All of these changes have a deep impact on how markets function. As we strive for net zero, we need to understand and test the differentmarket reforms that will impact this change.

Smart technologies mean many consumers won't just passively use power – they will become active players of the system too. It's important we identify how best to facilitate their participation in markets because increasing engagement with their energy network is critical to achieving GB's net zero ambitions.

Opportunities

- Learn how to remove barriers to new and existing markets for smaller participants and new technology types.
- Identify the potential impact of locational marginal pricing on the network, market, and consumers.
- Investigate how highly distributed, smaller assets can participate in our markets and how we can support this.
- Develop more effective market modelling tools and capabilities which we can use to assess future market designs and interactions.
- Understand potential new consumer markets, their technical characteristics and their entry requirements.

Innovation Strategy / Priority 3: Future Markets 17

Case study: Reactive Power Market Design

Reactive Power is an essential service used by National Grid ESO to control the system voltage level within set limits. This research project has been set-up to ascertain the feasibility of creating a reactive power market.

Future Markets

The Project

The acceleration towards green energy has led to conventional transmission sources of reactive power being replaced by renewable energies such as wind and solar.

A Reactive Market design project – launched in September 2021 – is exploring whether a market could be developed to help the ESO access more reactive power in the right locations. National Grid ESO uses reactive power to control the system voltage level.

The ongoing transition away from the traditional centralised power generation, along with a change in demand patterns, has made controlling voltage more challenging.

Meet the Project Lead

Name: Yuting Dai

About: I'm working as Ancillary Service Implementation Manager in National Grid ESO. The role is mainly to develop and implement the new ancillary services into existing and new markets, to help the ESO to become a better buyer by delivering transformational change into the ESO's ancillary and balancing markets to create the new markets and capabilities required to maximise competition, optimise balancing costs and ultimately reduce the cost to the end consumer.

> *Voltage control has been increasingly challenging due to the change on its supply and system demand sides, which need to be managed in a locational basis. As there is limited experience of using a market-based mechanisms to procure reactive power in GB and worldwide, it's a great opportunity to explore a new market and its benefits through the innovation route. I'm very exciting to work on this project, and really enjoying its way of working with external industry parties to learn, understand and contribute together on this possible future.*

Innovation Strategy / Case Study: Reactive Power Market Design 18

Case study: Reactive Power Market Design

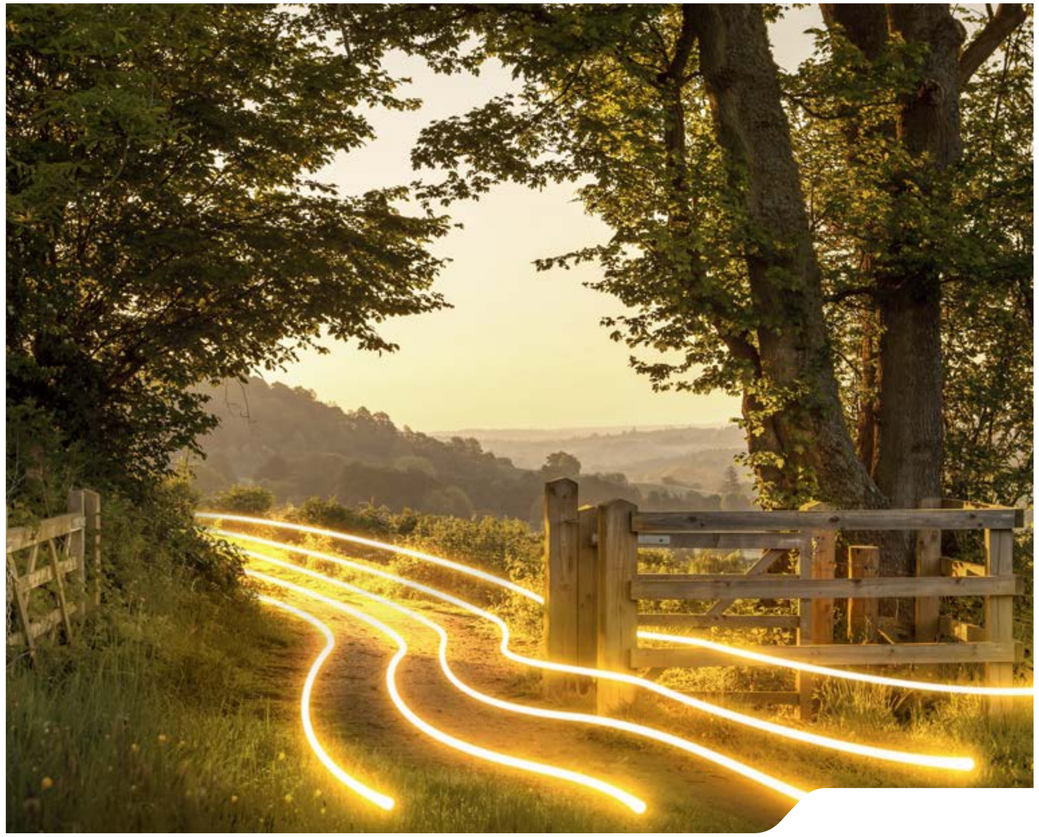
Reactive Power is an essential service used by National Grid ESO to control the system voltage level within set limits. This research project has been set-up to ascertain the feasibility of creating a reactive power market.

Future Markets

The Challenge

There have been challenges due to the complex nature of reactive power. Firstly, in most countries, reactive power is provided under a mandatory approach and is treated as a by-product of energy production, complemented by dedicated TO assets. Using market-based mechanisms to procure reactive power is practically non-existent globally, which means there is limited experience of successful commercial procurement of reactive power on which to draw.

Secondly, the nature of reactive power is that it cannot travel far. This requires location-specific markets; which limits competition, adding complexity to the market design. Developing a transparent method to quantify the locational need for reactive power and the contribution of different providers is crucial to fostering competition and enabling efficient investment decisions.



Innovation Strategy / Case Study: Reactive Power Market Design 19

Case study: Reactive Power Market Design

Reactive Power is an essential service used by National Grid ESO to control the system voltage level within set limits. This research project has been set-up to ascertain the feasibility of creating a reactive power market.

Future Markets

Potential Benefits

Reviewing today's reactive power provision and procurement routes has given us a better view of the limitations. We have explored potential market models to better understand how a market-based solution might perform at meeting our desired objectives.

Technical methodologies are being developed to quantify market-based indicators, which will help deepen understanding of the system requirements and the impact of potential solutions.

Our ultimate goal is to develop a market that will achieve the most cost-effective way of maintaining voltage security, supporting zero carbon operation of the grid by increasing ESO's access to reactive power solutions from existing and new providers. The arrangements are intended to allow effective investments and efficient delivery of reactive power services. With improved transparency, we can encourage investments, incentivise future competition, and eventually boost economic efficiency to deliver value for all end consumers.

Further project details can be found on the ESO website.

Project Information

NIA Reference	Project Name	Status
NIA2_NGESO008	Reactive Power Market Design	In progress

Suppliers
AFRY

Registered Value	Start TRL	End TRL
£600,000	2	4

Innovation Strategy / Case Study: Reactive Power Market Design 20

Priority 4: Constraint Management

The costs to manage transmission system constraints have a large impact on consumers. As GB's offshore wind and interconnection capacity grows, these costs are expected to increase significantly further. 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.

Challenges

The Network Options Assessment (NOA) launched the Constraint Management Pathfinder to reduce the impact constraints have and to maximise the use of renewable generation.

The Future Energy Scenarios (FES) and Electricity Ten Year Statement (ETYS) have shown that changes in the volume and location of electricity generation will lead to significant constraint costs.

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.

Opportunities

- Research long-term energy storage (electrochemical, thermal, or mechanical) and how it could help reduce year-round constraints.
- Investigate whether low-carbon hydrogen production could be sited at advantageous locations to reduce constraints.
- Understand how we can use data and new technologies to increase transfer or provide a fast acting, automated response to a system condition, to increase boundary capacity.

Innovation Strategy / Priority 4: Constraint Management 21

Priority 5: System Stability and 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.

Challenges

Synchronous generation supports the stability of the system. But, as we move towards zero carbon, this generation capacity decreases, and the system becomes less stable. This means faster frequency changes, less voltage and fault ride-through stability which makes it more difficult for both synchronous and non-synchronous generators to operate safely.

Opportunities

- Find better ways to model stability in an increasingly non-synchronous system.
- Identify what tools can be developed to support the system in a decarbonised network.
- Develop new ways to speed up our processes, or automate them, to keep up with a lower inertia system.
- Investigate what kinds of data or metadata could further support system operation and improve how we manage stability into the future.

Innovation Strategy / Priority 5: System Stability and Resilience 22

Case study: Dunkelflaute Modelling

Statistical Characterisation of “Dunkelflaute” events, wind droughts, and extreme cold spells.

System Stability

The Project

The energy landscape has changed significantly with an increasing reliance on renewable energies. This presents new challenges and there is a pressing need to build more flexibility into the system to accommodate this. This process must be accelerated to meet the net zero target for decarbonisation by 2050.

Low wind and low solar periods - known as ‘Dunkelflaute’ conditions - can impact heavily on the management of the GB energy supply (the word translates into ‘dark doldrums’ or ‘dark wind lull’).

A new modelling project is being undertaken to further improve our understanding of Dunkelflaute and to work out when and how often it occurs and for what period of time.

Meet the Project Lead

Name: Rob Nickerson

About: Rob has worked across both gas and electricity since joining National Grid ten years ago. He initially joined the Gas Transmission business where he worked on network planning and design, in particular studying the changes required to the compressor fleet following the industrial emissions directive. From there Rob moved in to longer term gas demand analysis as part of the FES before transitioning to electricity and his current role as Electricity Market Modelling Manager. As part of this role, Rob is responsible for the electricity supply components of our future energy scenarios. His team undertakes analysis to understand the future generation and interconnector capacities expected, and how they will operate within a pan-European market.

Innovation Strategy / Case study: Dunkelflaute Modelling 23

Case study: Dunkelflaute Modelling

Statistical Characterisation of “Dunkelflaute” events, wind droughts, and extreme cold spells.

System Stability

The Challenge

Gaining a better insight into the Dunkelflaute period and the use of flexible solutions such as interconnection and storage to meet this challenge is vital to the management of GB’s energy needs moving forward.

Predicting events and how they will impact on the demand for energy is no easy task. By evaluating historic weather data, a valuable insight into potential future weather patterns may be established. However, the likely impact of climate change going forward has to be factored in.

Forecasting the future likelihood of Dunkelflaute occurring at a time of peak electricity capacity, usually occurring in the winter months when demand is high, is a key part of the research, and how the peak electricity demand patterns may evolve due to the electrification of heat.

Innovation Strategy / Case study: Dunkelflaute Modelling 24

Case study: Dunkelflaute Modelling

Statistical Characterisation of “Dunkelflaute” events, wind droughts, and extreme cold spells.

System Stability

Potential Benefits

A key benefit of the research will be to enhance the conversation about Dunkelflaute, by working with meteorological experts to put measurements into place which would enable evidence-based decisions on managing the demand for energy when wind and solar power is at low levels for a substantial period of time.

Project Information

NIA Reference	Project Name	Status
TBC	Dunkelflaute Modelling	In Development

Suppliers

Delft University is currently proposed to deliver this project

Registered Value	Start TRL	End TRL
TBC	2	4

Innovation Strategy / Case study: Dunkelflaute Modelling 25

Priority 6: 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.

Challenges

The heating and transport sectors are decarbonising. While the electricity system is increasingly reliant on gas for flexibility. This gives us a crucial opportunity look at the energy system as a whole. By considering energy vectors (electricity and multiple gas types) and sectors (heat, power, transport and industry) alongside each other, we can improve efficiency and support decarbonisation.

Opportunities

- Improve how we model the whole energy system (across all sectors) and incorporate this into our work with FES, NOA, and Early Competition.
- Support further impact assessments and feasibility studies.
- Investigate hydrogen's impact and see how Hydrogen electrolysers could benefit the system.
- Identify and explore flexibility services that could be created for the electricity network – as other sectors, like transport and heating, decarbonise.

Innovation Strategy / Priority 6: Whole Energy System 26

Priority 7: Whole Electricity System

Whole Electricity System focuses on how products, markets, and best practice can be aligned across transmission and distribution. This is an area which continues to see significant investment and collaborative efforts from the ESO, Transmission Operators (TOs) and Distribution Network Operators (DNOs).

Challenges

More energy resources are connecting to distribution networks (rather than the transmission network). This turns them into active networks and transforms the role of Distribution Network Operators. Many of these new resources can provide valuable services to us - increasing competition in our markets and in the markets of emerging Distribution System Operators (DSOs).

Opportunities

- Solve issues that affect both transmission and distribution networks and unlock additional network capacity through joint innovation projects.
- Develop methods for how we build more complex, whole system models, which use data from both ESO and DSO.

Innovation Strategy / Priority 7: Whole Energy System 27

Case study: COMMANDER

Coordinated Operational Methodology for Managing and Accessing Network Distributed Energy Resources (COMMANDER)

Whole Electricity System

The Project

National Grid ESO's role is to make sure that the energy supply always meets demand on a second-by-second basis and, to do this, must coordinate more closely with the activities of DSOs (Distribution System Operators) and other external partners in future. An 18 month long project is now underway to look at ways of improving current systems processes whilst developing a roadmap of scenarios for a new approach to coordinating the operations of the ESO (Electrical System Operator) and DSOs.

This will include clearly defining their roles and responsibilities and the potential coordination options for accessing and managing the services of DERs (Distributed Energy Resource) connected to the distribution networks.

Meet the Project Lead

Name: Matthew Rivett

About: I am an Engineering Manager responsible for the delivery of our in-flight Regional Development Programmes. My primary role is overseeing a multi-disciplinary team to deliver the systems, tools and processes required to ensure the ESO can deliver on its net zero ambitions.
I also work closely with our IT colleagues and our external partners to build new functionality utilising an Agile delivery approach.

> *I am proud to be part of a highly motivated and dedicated team that sits at the heart of the changing energy system. We have some big challenges to overcome, but the opportunity to fundamentally change the way we do things will benefit many future generations.*

Innovation Strategy / Case study COMMANDER 28

Case study: COMMANDER

Coordinated Operational Methodology for Managing and Accessing Network Distributed Energy Resources (COMMANDER)

Whole Electricity System

The Challenge

The transitioning energy landscape has seen a move away from large, centralised generators, to lots of smaller distributed generation and flexible energy resources across Great Britain. The complexity of managing the system has increased with the addition of intermittent renewable energy - such as small wind farms and solar panels, which now provide large contributions to the overall energy mix.

A precursor innovation project took place last year looking at the increasing interaction of active network management schemes and service providers and assessed how the ESO and DSOs could further coordinate to enable more efficient service provision.

Innovation Strategy / Case study COMMANDER 29

Case study: COMMANDER

Coordinated Operational Methodology for Managing and Accessing Network Distributed Energy Resources (COMMANDER)

Whole Electricity System

Potential Benefits

The existing Regional Development Programmes (RDP) will deliver whole system benefits utilising a ‘trial by doing’ approach. However, this project will seek to accelerate work to understand how these concepts can be scaled through future RDP functionality across a broader range of ESO and DSO activities.

By working with various external partners, National Grid ESO will identify a series of tangible options that could be deployed across various BAU (business as usual) processes and activities to further enhance coordination and the overall efficient operation of the whole electricity system.

Project Information

NIA Reference	Project Name	Status
TBC	Coordinated Operational Methodology for Managing and Accessing Network Distributed Energy Resources (COMMANDER)	In Development

Suppliers

WPD (Western Power Distribution) and WSP are currently proposed to deliver this project

Registered Value	Start TRL	End TRL
TBC	2	5

Innovation Strategy / Case study COMMANDER 30

Virtual Energy System

The journey to net zero and a carbon free future has already begun, and the way we generate, manage and consume energy is changing for the better. Continuing to innovate and adapt the energy system will require a range of new tools and a reimagining of how the entire industry can come together to deliver lasting impact.

That is why we're launching an ambitious, industry-wide mission to digitise our energy system. This world first, real-time replica of our entire energy landscape will work in parallel to our physical system, affording a virtual environment through which we can share data and model and test scenarios to make our decision-making more robust.

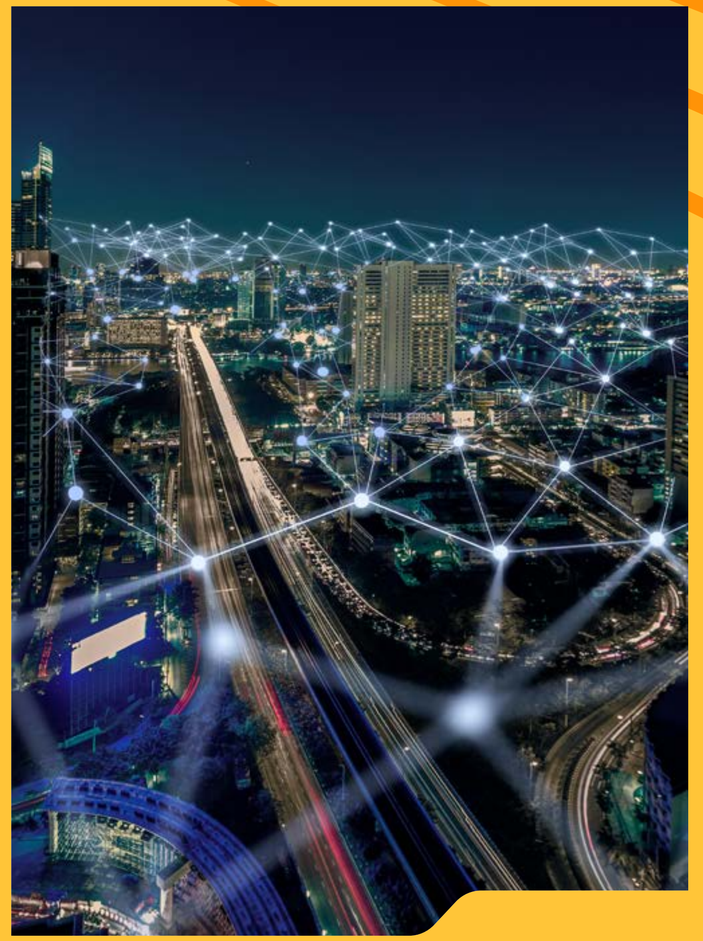
The next step on this journey is to work together to find a way to take these digital twins forward, in unison. A way in which we can connect these digital assets and encourage future development across the entire energy spectrum. This is reflected through our three workstreams:

1) **Stakeholder Engagement - We need to come together, as an industry, to turn this vision into a reality. We are calling on every element of the GB energy industry to lend its support, expertise and investment.**

2) **The Common Framework - It will set out the technical standards and engagement principles which stakeholders can follow to collaborate and build an interoperable digital twin.**

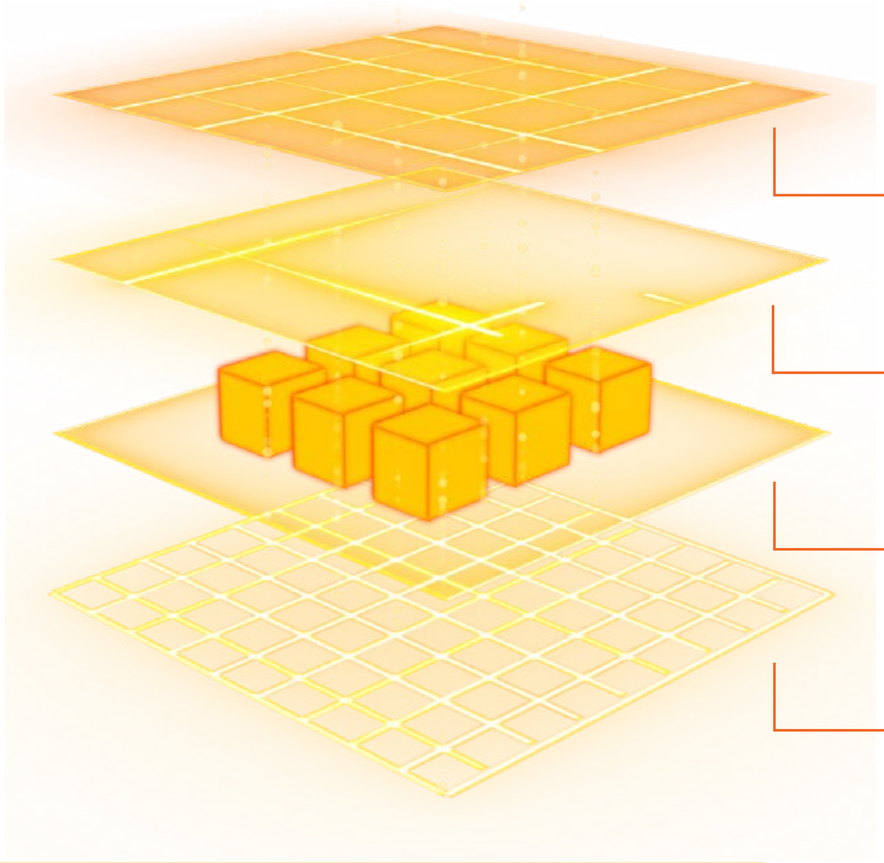
3) **Use Cases - To inform the capabilities and considerations of how interconnected digital twins could provide substantial benefits for consumers and the whole energy system.**

We're continuing to reach out to industry to collaborate, learn and we have already begun to facilitate opportunities for feedback and engagement. Keep up to date on all of the latest developments and engagement opportunities on our website and by signing up to our mailing list.



Innovation Strategy / Virtual Energy System 31

Virtual Energy System



Virtual Energy System

Powered by National Grid ESO

Building a digital replica of GB's energy system

We are building a digital view of our entire energy landscape, providing a virtual environment to share data, model and predict scenarios that support the decarbonisation of our energy industry.

4 **The data becomes more layered, creating valuable insight to help guide and govern our transition to net zero and how we generate, manage and consume energy.**

3 **Each digital twin will contribute to and access real-time data on the status and operation of other elements of the system.**

2 **Populated by digital twins – replicas of physical components of our energy system.**

1 **An open framework, with agreed access, operations and security protocols.**

Innovation Strategy / Virtual Energy System 32

How to get involved in Innovation

There are several ways to get involved or find out more about collaborating on innovation projects.

Co-create with us

We're eager to hear your thoughts and ideas about finding new ways to adapt to the changes in the energy system. We welcome your proposals throughout the year, you can find out more about our process and how to submit a proposal on our website.

We also run annual Open Innovation Events which give industry and academia an opportunity to fast-track the development of innovation projects with experts within the ESO. They start with an open call for ideas which focus on our strategic priorities. The best ideas are then taken forward to a two-day event where respondents have a chance to work with ESO experts, to develop their initial concepts into full project proposals and pitch their ideas to a panel of experts. These events are announced widely via social media and our mailing list.

Funding

We provide funding for projects which link to at least one strategic innovation priority, through Ofgem's Network Innovation Allowance (NIA), a set amount each Energy Network receives as part of their price control allowance. The focus is on earlier stage research and development, or small-scale demonstration projects.

Ofgem has also introduced the Strategic Innovation Fund (SIF) to support the transition to net zero, while delivering net benefits to energy consumers. This will support large-scale transformational research and development projects. Ofgem (working with UKRI) will set the strategic direction through Innovation Challenges.

If a project proposal has the potential to address our innovation priorities, we are also keen to support third party bids for grant funding.

Industry Events

Members of the Innovation team take part in industry events throughout the year including the flagship Energy Networks Innovation Conference (ENIC) which will be held again in September 2022. You can hear more about our ground breaking projects, speak to us in person about your ideas and see how the ESO is committed to collaborating on Innovation.

Feedback

We frequently go out to industry to get feedback on our publications, strategy, and events but we welcome comments at any point throughout the year. Please get in touch with us via email if you have any ideas you would like to share.

Further Reading

You can see how we tackled our previous innovation priorities and some of our remarkable projects in our NIA Annual Summary 2020-2021 (published in July each year).

Innovation Strategy / How to get involved in Innovation 33

Meet the team

We're always on the look-out for new ideas and opportunities to partner on innovation projects. If you'd like to find out more about the way our innovation process works, the ESO Innovation team would be happy to speak to you and share details of our current innovation portfolio.

Learn more about how to Get Involved.

Anna Carolina Tortora, Head of Digital Transformation and Innovation Strategy

About: I have the coolest job in the world. My job is to learn new things, imagine possible scenarios, and then finance solutions.

> Climate change is the challenge of the age and being a part of the solution truly drives me. I have a toddler son and like all parents I must live with the responsibility of knowing the kind of planet my generation is going to leave behind and the fact that he won't be able to experience it as I did. Unlike other parents however I can do something big about it. Every action I take, every meeting, every email, every hour spent reviewing a paper allows me to give a piece of myself to my son's future.

Joshua Visser, Innovation Manager

About: My role is to ensure our ESO innovation activities have a strategic focus, aligned with existing strategies from the ESO, industry and government, which address priority challenges the ESO can help solve to deliver the energy transition. I am working on ways to help us engage more closely with our innovation partners and stakeholders to ensure we collaborate better and are seen to be innovative as an organisation.

> There are so many new technologies and solutions in development, or ready to be rolled-out to mass market, which will help us achieve our net zero ambitions. It is exciting to play a part in helping these innovations become a reality, and finding answers to the challenges we will face in shaping the future energy system.

Innovation Strategy / Meet the team 34

Meet the team

Isla Martin-Abel, Stakeholder Engagement Lead

About: I support the Innovation team to build and manage positive working relationships with our stakeholders. I develop communications and engagement plans to ensure we are proactively anticipating our stakeholders' requirements; manage our presence at industry events; and provide guidance to ensure we are aligned with the rest of the ESO.

> Through Innovation you are given a glimpse into the future of energy. It's exciting to see and inspiring to be involved and work with so many likeminded individuals committed to reaching our net zero goal.

Arwen Seymour, Team Assistant

About: My role is to organise the wider Innovation Team by ensuring everything is completed on time and to quality. I support the team with a variety of administrative duties including, coordinating team meetings and calendars, taking actions, arranging the logistics and invites for Innovations events, helping to manage internal / external comms to stakeholders, ensuring the teams' stakeholder engagement information is kept updated; and being responsible for risk and data compliance.

> I've been very passionate about tackling climate change for a long time now, mainly by reducing my own carbon footprint. I feel privileged to be working for National Grid ESO, to be able to support, contribute and be an active part of the journey towards net zero is a great honour!

Rhiannon Calado, Innovation and Digital Transformation Manager

About: My role is to bring innovative projects to life and define the digital transformation journey that is crucial in achieving net zero.

It's amazing to be able to actively contribute to solving one of the most current and relevant challenges the world is facing, and Innovation allows us to close the gap of where we are and where we need to be in the future.

> The fact I get to do it together with so many brilliant partners from various backgrounds only makes it more exciting!

Innovation Strategy / Meet the team 35

Meet the team

Geoff Down, Innovation Manager

About: I look after the innovation portfolio – helping the business to innovate through research, development and demonstration projects.

> The types of innovation projects we are doing as we progress to net zero are changing which is reflected in the priority areas detailed in our Innovation Strategy. Net zero isn't just about how we use electricity, it's a part of everything we do in our lives whether its transport or heat, being a part of that journey and helping deliver this for future generations is amazing.

Justina Zvirblyte, Innovation Analyst

About: I support the delivery of the Virtual Energy System (VirtualES) programme - an ambitious, industry-wide mission to digitise our energy system. I ensure that activities across multiple projects within the programme are coordinated and monitored.

> For me the most thrilling is to see new technologies, business models and even new market designs being developed – all this innovation required to solve the net zero challenge. I feel lucky to be working at National Grid ESO as I get to contribute to this exciting work!

Alison Dineley - Senior Innovation Analyst

About: My role is to support the delivery of our innovation portfolio and ensure the ESO delivers its innovation regulatory requirements, including the NIA Annual Summary publication.

> Having a background in sustainability, being part of the innovation team at the ESO couldn't be a better fit. The ESO has a key role to play in tackling climate change by transitioning GB's electricity system to net zero. Delivering innovation projects to support this transition and achieve our zero carbon ambition is a privilege.

Innovation Strategy / Meet the team 36

Meet the team

Alexander Hurley, Innovation Business Manager

About: As an Innovation Business Partner, I work with the various ESO Networks teams to understand their key strategic challenges, and to help launch and facilitate the delivery of innovation projects to tackle those challenges.

> I am extremely passionate about transitioning to a low carbon future and I am grateful to play a part working for National Grid ESO. I have always enjoyed solving problems and many of the challenges we are facing require a collaborative industry approach, with the development of new business models and technologies, not before seen on this scale.

Caroline Rose-Newport, Innovation Business Partner

About: I support teams within our Markets department solve some of their challenges and problems through innovation. I help them to identify gaps, develop new project ideas and support project delivery.

> We all use energy every day. How we generate, supply and manage it will impact the planet for generations to come. There is some exciting technology out there now giving us possibilities to reach net zero-carbon in ways that weren't even imagined a generation ago. We all need to do more to tackle climate change I love that I can now play a (small) part in making that change happen.

James Kelloway, Energy Intelligence Manager

About: As Energy Intelligence Manager I run the ESO Lab which allows me to work with top tier data scientists across the world who use brand-new, cutting-edge digital techniques to make sure that GB's electricity grid can operate with net zero carbon capability by 2025. This enables me to engage with partners to drive forward the tech needed for the next generation of power grid.

> Climate change is one of the biggest challenges that humans have ever faced. We're the first generation to fully understand the impact that we've had on our climate and the last that can do something about it.

Innovation Strategy / Meet the team 37

Meet the team

Lyndon Ruff, Lead Data Scientist (Machine Learning), Data Science Manager

About: I lead a team of machine learning engineers that apply machine learning and deep learning to solve energy problems on the electricity grid, from renewable generation forecasting to national demand forecasting, I also get to build these machine learning models myself which is a passion of mine. What excites me most is the fact I'm able to significantly contribute to operating a carbon free National Grid by 2025, whether that is directly applying my machine learning knowledge or helping find the world class projects and people that can deliver us to where we need to be.

Jonathan Barcroft, Senior Data Scientist/ Power System Engineer

About: I am a data scientist working in the ESO Lab. My primary role is short term energy forecasting. I use artificial intelligence and machine learning to predict trends and find new techniques that ESO can use to model uncertainties like climate change.

> There are few industries where by reducing carbon intensity we can reduce the emissions of other industries, businesses and homes across the whole country. The rapid pace of change in energy presents lots of opportunities to apply new technologies and approaches to solving problems.

Joshua Brooke, Data Scientist

About: My job is to write code to help run the grid at net zero. The energy transition is the most difficult and interesting challenge facing us in our lifetime, being part of solving that problem is the most rewarding things you can do!

Innovation Strategy / Meet the team 38

Meet the team

Nina Klein - Innovation Manager – Virtual Energy System Use Cases

About: As a secondee to the ESO Innovation team I provide technical advice and project management for the Virtual Energy System programme, with a focus on developing Use Cases. My specialist area is smart systems and flexibility, including Electric Vehicles. I previously worked as an Energy Engineer at BEIS, providing independent technical advice to Ministers and policy makers on technologies to decarbonise the energy system.

> To meet our carbon targets, we need transition the industry at a literally unprecedented scale and pace.
> I'm really grateful for the opportunity to be on secondment at ESO and contribute to this great work!

Innovation Strategy / Meet the team 39

Get in touch

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