Network Innovation Allowance

Annual Summary 19/20

nationalgridESO

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Welcome

As the Electricity System Operator for Great Britain, we are responsible for operating the electricity network safely and efficiently, balancing electricity supply and demand second by second. Our position at the heart of the energy system means we are playing a central role in overcoming the challenges facing the industry and our customers. We believe innovation is critical to help us meet these challenges, allowing us to explore new technologies and approaches that will play a role in shaping the energy system of the future.

Foreword

Throughout 2019/20 we have delivered a diverse innovation portfolio that supports ESO's role in keeping electricity supplies safe, reliable and efficient whilst pushing the boundaries to enable a net zero energy future. Our innovation projects continue to explore how we work in ground-breaking areas such as blockchain and machine learning, as well as state-of-the-art technologies such as Virtual Synchronous Machines.

We undertook our most extensive stakeholder consultation exercise to date in 2019/20 to shape our Innovation Strategy for the final year of RIIO-1, our current price control period. Engaging our stakeholders, internally and externally, has resulted in refreshed priorities for the year ahead, ensuring our portfolio remains balanced and focused on the issues our stakeholders are facing.

We continued to collaborate with industry, hosting a successful Open Innovation Event in November 2019 which attracted 87 idea submissions and resulted in £2m of funding granted across 7 new projects. We also continued working closely with the Electricity Innovation Managers and Gas Innovation Governance Group, alongside the Energy Networks Association (ENA), to develop a Benefit Measurement Framework. This framework will enable network companies to adopt a standardised method to measure and communicate our innovation activities.

For 2020/21, we want to drive innovation that will help us to operate the electricity system of the future, and play our part in delivering a system that supports the Government's net-zero target. We will be working closely with our stakeholders to undertake a detailed review of our Innovation Strategy, to make sure we align with ESO's 2025 ambitions and RIIO-2 Business Plan, as well as the network industry innovation strategies.

As we develop our plans for RIIO-2, innovation remains at the heart of what we do. We are committed to driving real change in our business, delivering value to customers, and enabling a net zero energy future.

Fintan Slye
Director, Electricity System Operator

Contents

2019/20 portfolio overview

Innovation, and the new tools and technologies it generates, is playing an important role in building the ESO of the future.

Three years ago, we reconsidered how we innovate and produced the first Innovation Strategy. This has allowed us to adapt our activities, so we can meet the challenges of a changing energy industry head-on. We're innovating in a more targeted way, using funding more efficiently, and making sure the potential benefits for customers and consumers are maximised.

Projects

Portfolio overview / 05

FUTURE

Portfolio Overview /
Continued

Technology Readiness Levels

We have a broad range of projects in our portfolio and we regularly look to rebalance them. They include activities to develop, demonstrate or research new technologies and processes, which we measure against Ofgem's TRL. This is a scale that measures the maturity of evolving technologies.

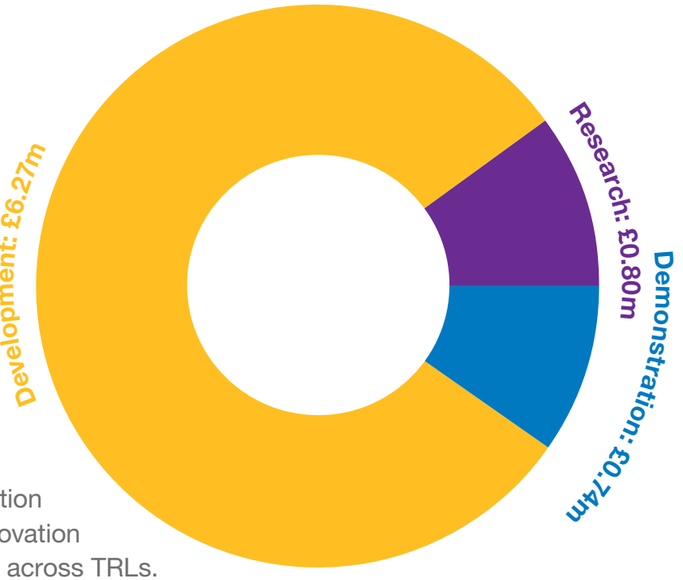
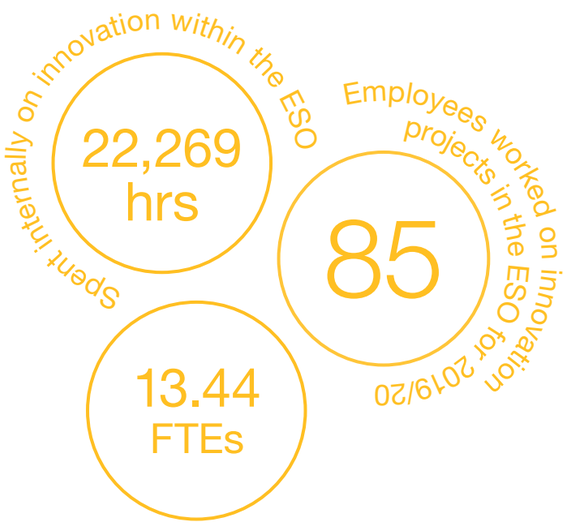


Figure 1 - Proportion of committed innovation spend in 2019/20 across TRLs.

People

We are building a culture of innovation today that will support the business into the future, engaging colleagues throughout the ESO to share their ideas, challenges and expertise to deliver a robust innovation portfolio. Our Business Partnering approach aims to break down silos and ensure that the whole business is equipped with the opportunity, skills and support to innovate.



Our findings are published annually on the ESO website

Portfolio overview / 06

Performance against our Innovation Strategy

Our innovation strategy sets a clear roadmap for our activities over the coming year and shapes how we work with partners from the energy industry and beyond to harness new technologies, markets and ways of working.

System Stability, our top priority, received the most attention, followed by Whole Electricity System, our second priority, and so on. One significant outlier is that we invested more heavily than anticipated on Digital Transformation projects. Recognising an urgent need to improve the availability and use of data across the industry, we focused efforts on developing projects to address this, which you will also see reflected in our refreshed **innovation priorities for 2020/21**.

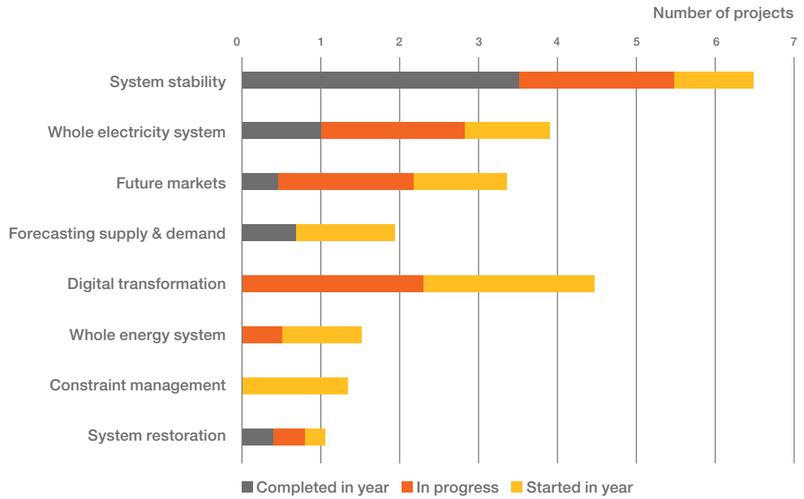


Figure 2 - Proportion of innovation projects live in 2019/20 across our innovation priorities

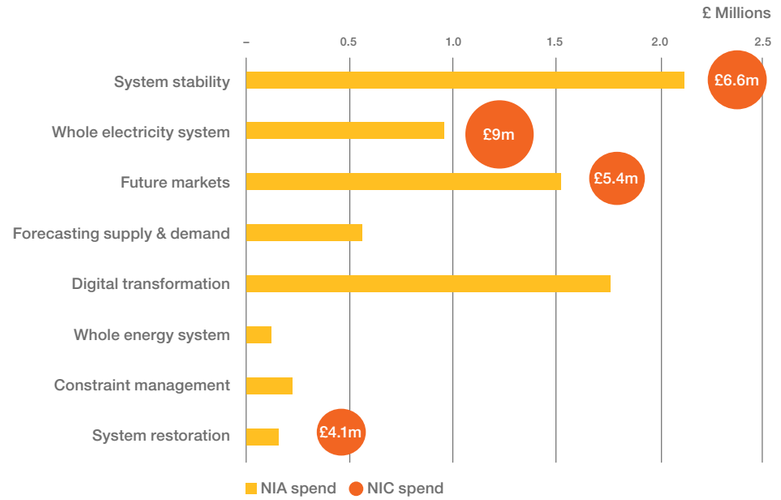


Figure 3 - Committed NIA and NIC spend across live innovation projects in 2019/20 against our innovation priorities.

The graphs above demonstrate how we performed against our priorities, reflecting how we allocated spend and effort according to the strategy that we set out at the beginning of 2019/20. Whilst our projects typically address more than one priority area, Figure's 2 and 3 indicate how our innovation activities address our priorities across the entire portfolio.

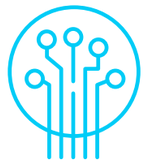
Performance against our Innovation Strategy / 07

Progress against our strategic priorities

We have refreshed our priorities for 2020/21 based on our consultation with stakeholders, and our evolved understanding of the issues from the work we have carried out. The following pages contain case studies illustrating how these priorities are being addressed through innovation projects we are currently delivering with our partners.

1. System Stability
Safe, reliable and secure operation of a zero-carbon electricity system by 2025

2. Whole Energy System
A holistic, integrated view across all energy vectors and sectors that supports efficient and effective system planning, development and operation

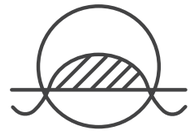


3. Digital Transformation
Efficient digital processes across the energy system; the power of Big Data and associated technologies fully leveraged; new insights created and shared; and new services developed and accessed

4. Future Markets
Competition everywhere, with greater market participation on the supply and demand-side, including all participant types and sizes

5. Forecasting of Supply and Demand
Sophisticated and accurate energy forecasting in both operational and planning timescales

6. Whole Electricity System
Efficient and effective planning and operation across transmission and distribution



7. Constraint Management
Optimised management of networks across T&D with minimal curtailment of renewable generation and at minimum overall cost to consumers

8. System Restoration
Ability to restore GB from total or partial shutdown, with zero carbon sources, by 2025, at minimum cost to consumers

Our findings are published annually on the ESO website

Residential Response

This project is exploring how we can facilitate easier market access for small residential flexibility assets to help us keep the GB electricity system in balance.

The electricity system is in a constant state of change and we need to maintain a balance at all times. To do this, we need to control many different factors including the frequency, which we do by boosting or reducing supply or demand to maintain the required level.

In the past, we have turned coal and gas-fired power stations up and down, but with more and more power now coming from renewable resources like wind turbines and solar panels, this is more challenging to do.

The demand side can provide lots of the flexibility we need to maintain frequency levels. However, for small residential assets, it can be prohibitively expensive to qualify and access ESO markets. This project has been established to see how we can lower these barriers to entry, including the cost of the meter required to add a generator to the system (its around £3,000), how we bring new generators on board and how they are managed once they have signed up.

Case study / Residential Response

Results:

> We have identified and tested many different solutions to simplify the process of bringing small-scale assets onto the system.

These include improvements to the way we test the assets, and how residential portfilios are contracted so it's more streamlined and cost-effective for everyone.

We are also looking at how we make sure we have access to the power and frequency data we need without homeowners buying a costly meter. Areas of study so far include a cloud-based solution for clusters of sites and the use of lower cost meters, either with modifications or statistics to show the expected margin of error.

Benefits:

> This project will give us access to more non-traditional energy providers and with that, more flexibility in the way we balance system frequency in the future.

The larger pool of residential providers created will also improve competition in the market and make it more cost-effective for consumers.

Adam Sims
Power Responsive Manager
Project Lead

NIA Reference	NIA_NGSO0025
Project Name	Residential Response
Suppliers	Element Energy, Intelligent Energy Technology, Upside Energy, Moixa Technology, Lightsource Labs
Registered Value	£275,000
Start TRL	4
End TRL	6

Our findings are published annually on the ESO website

Case Study / Residential Response 10

Demonstration of Virtual Synchronous Machine control of a battery system

VSM – or Virtual Synchronous Machine – technology has the potential to provide stability to the GB electricity system of the future, by enabling us to control frequency and voltage fluctuations without relying on traditional fossil-fuelled power stations.

Currently, we need coal and gas power stations to stabilise the grid, as they are synchronous generators and can give us inertia, to help balance frequency levels, and provide reactive power to stabilise voltage when required.

Renewable power generators use converter-based technology, which doesn't have the same mechanical properties as these fossil-fuelled power stations. So, if we are to bring more low carbon energy suppliers online in the future and phase out the use of fossil fuels, we need to be able to artificially recreate the stabilising properties of the synchronous generators.

The emerging field of VSM technology has the potential to assist us in overcoming this barrier – in particular the development of VSM-controlled batteries, which could deliver a completely new way for renewable energy suppliers to control their power generation and in turn, help us manage frequency and voltage changes.

This project set out to investigate and test the capabilities of VSM battery technology. The information collected will be used to develop a detailed specification for developers, to help them design VSM-controlled batteries that will benefit us as the operator, renewable power suppliers and help increase the provision of green energy to consumers.

Our findings are published annually on the ESO website

Case Study / Demonstration of Virtual Synchronous Machine control of a battery system 11

Case study /
Demonstration of Virtual Synchronous Machine control of a battery system

Digital Transformation

Results:

We created and tested a ‘virtual’ VSM battery using a computer-generated simulation. The model showed us whether the battery could mimic the behaviours of a synchronous generator under different test scenarios and if it could help balance changes in frequency and voltage in the grid.

VSM control software was then trialled on a wind turbine battery connected to a test grid in Cumbernauld, Scotland.

> **90% of the tests were completed between December 2019 and March 2020.**

We will now interpret the data collected and use it to inform and refine our VSM battery specification.

Benefits:

VSM technology could play a major role in helping us operate the network with more renewable power generators. This project has advanced our knowledge of VSM technology.

> **VSM technology could accelerate our transition to operating a zero-carbon electricity system by 2025**

by 2025 by allowing us to bring more low carbon generators onto the network and lowering costs to end users. The project has also delivered a new test framework which we can apply to other new grid support solutions to speed up future innovations.

Djaved Rostom
Power System Engineer
Project Lead

NIA Reference	NIA_NGSO0026
Project Name	Demonstration of Virtual Synchronous Machine control of a battery system
Suppliers	Belectric GmbH, PNDC (University of Strathclyde)
Registered Value	£275,000
Start TRL	4
End TRL	6

Our findings are published annually on the ESO website

Case Study / Demonstration of Virtual Synchronous Machine control of a battery system 12

Testing Coordinated DSO-ESO Procurement and Dispatch

This world-first project is looking at how we could establish a co-ordinated approach between the ESO and DNOs when procuring balancing services from local energy providers.

The creation of a Local Energy Market (LEM) for Cornwall is a multimillion pound project led by Centrica to give homes, businesses and DER in the area the power to sell energy through a virtual marketplace and get paid to reduce or delay their consumption, to help give the ESO the flexibility required to balance the network.

Part of the project looks at how services can be procured by distribution network operators (DNOs) and ESO through the virtual marketplace. DNOs are increasingly proactive in the way they manage their network, and each are trialling ways to procure flexibility from distributed energy resources (DER) as an alternative to building new capacity. ESO also procures services from DER – such as reactive and black start responses – so there is potential for conflict, as well as opportunities for co-ordination.

We established this project in partnership with Centrica to test whether using an online auction marketplace for the procurement of flexible services could work with two buyers (the ESO and Western Power Distribution) to deliver cost and operational efficiencies for all.

Case Study / Testing Coordinated DSO-ESO Procurement and Dispatch 13

Case study /
Testing Coordinated DSO-ESO Procurement and Dispatch

Whole Electricity System

Results:

From September 2019 to March 2020 we ran a live trial with Centrica and Western Power Distribution

using a shared online platform to procure the flexible services we required. Local energy providers and consumers offered their services on the platform and the best bid would be matched to the buyer by auction.

The trial was a success and we have taken away significant learnings about the effect on prices when we procure services by auction, over different time windows and when working alongside DNOs to make sure efforts aren't duplicated or conflicting locally.

Benefits:

The Cornwall LEM project has shown how flexibility providers can access multiple flexibility markets through a single market platform.

It will provide significant insight to the ESO's whole system approach with DNOs.

The project was successful in creating and trialing a short term, flexibility marketplace using closed-gate, pay as clear auctions, that generates a single clearing price at each participating node on the network, thus providing local pricing signals.

Adrian Sellar
Power Responsive Officer
Project Lead

NIA Reference	NIA_NGSO0027
Project Name	Testing Coordinated DSO-ESO Procurement and Dispatch
Suppliers	REstore FlexPond (Centrica)
Registered Value	£275,000
Start TRL	4
End TRL	6

Our findings are published annually on the ESO website

Case Study / Testing Coordinated DSO-ESO Procurement and Dispatch 14

Advanced Modelling for Network Planning under Uncertainty

This project will help us improve the robustness of our analysis across a range of future scenarios. This helps TOs decide what reinforcement projects they should prioritise and invest in over the next year.

Every year, we complete a Network Options Assessment (NOA) to evaluate the impact of different investment projects and to make recommendations on which ones should be progressed the following year.

Our NOA calculations are based on detailed risk/reward analysis of each proposed project considered across four possible future scenarios. These scenarios determine how the future network will develop to meet the changes in the energy landscape, and how different levels of government and consumer engagement will affect the outcomes. Our findings are published annually on the ESO website.

As well as giving their approval on the methodology behind this work, OFGEM also give us feedback. They recently asked us to review our existing decision-making approach to make sure it is effective when planning against an uncertain future.

This project was established to independently validate the economic and technical aspects of our NOA methodology, compare our process to those used in other countries and to explore the potential for new analysis tools.

Case Study / Advanced Modelling for Network Planning under Uncertainty 15

Case study /
Advanced Modelling for Network Planning under Uncertainty

Digital Transformation

Results:

We commissioned the University of Melbourne, Australia – as our independent partner – to produce a detailed assessment of the economic aspect of our methodology and how we manage uncertainty.

> **A report of the findings – due this year – compares the ESO to eight other countries including USA, China and Australia, and shows that our analysis stands out as the most thorough and efficient of all approaches considered.**

The report makes recommendations for some improvements to our process, and we are now developing the tools to be able to trial these later this year.

Next, we will move on to the technical review of our methodology and we expect the first report on this subject to be available soon.

Benefits:

This project has given us external validation that our uncertainty planning methodology is world-leading and makes sure

we are delivering a safe and reliable electricity system both now and in the future

in the most cost-effective way possible to lower bills for our end users.

Thomas Petty
Economics Engineer
Project Lead

NIA Reference	NIA_NGSO0028
Project Name	Study of Advanced Modelling for Network Planning Under Uncertainty
Suppliers	University of Melbourne
Registered Value	£180,000
Start TRL	3
End TRL	4

Our findings are published annually on the ESO website WWW

Case Study / Advanced Modelling for Network Planning under Uncertainty 16

Mapping the Impacts and Visualization of Risks of extreme weather on system operation (MIVOR)

This project explores the impact that climate change could have on the electricity system in the future, and the possible risks we need to plan for to make sure we maintain a safe and reliable system for consumers.

Over the last decade, we have seen more frequent occurrences of extreme weather events due to climate change – including severe flooding, heatwaves and droughts – and it is likely that they will occur more often in the future.

To make sure we can continue to operate a safe, reliable and efficient electricity system, we need to understand what impact climate change will have on our operations and what we can do proactively to minimise the risks.

Working in partnership with the University of Bath, this project will investigate how extreme weather events could affect the electricity system, including the impact of changes in demand and the risks to power generators and the transmission network.

The project will create a detailed model, broken down into 25km grid squares, to give us local risk assessments for the whole of Great Britain for the next 30 years.

Our findings are published annually on the ESO website

Case Study / MIVOR 17

Case study / MIVOR

Digital Transformation

Results:

The project is currently in the exploration phase, where we are collecting data about climate change-related hazards and identifying gaps in our knowledge. The project is also developing models of the system and interaction with weather parameters.

The next stage will be to explore in more depth our three main areas of concern. These are – changes in demand, for example where sustained hot or cold weather could cause peak loads we are not used to; potential changes to energy generation, for instance if water shortages could affect the output of hydropower stations or thermal power stations, which use water for cooling; and the effect of extreme weather on the transmission network, such as where intense storms or flooding could damage power lines and infrastructure.

Benefits:

At the end of the project, we will have a greater understanding of the risk that climate change poses to the electricity system,

and a detailed model of the possible challenges we are facing over the next 30 years to help us continue to operate a safe and reliable electricity system.

Jonathon Barcroft
Power System Engineer
Project Lead

NIA Reference	NIA_NGSO0023
Project Name	Mapping the Impacts and Visualization of Risks of extreme weather on system operation (MIVOR)
Suppliers	University of Bath
Registered Value	£245,000
Start TRL	3
End TRL	5

Our findings are published annually on the ESO website

Case Study / MIVOR 18

Impact of Long-duration Energy Storage Systems on GB Transmission Planning

This project is exploring possible long-duration storage solutions to help us manage transmission constraints, often caused by excess electricity produced by renewable power generators. The project will also investigate whether these solutions could also provide us with extra services to help manage the network more effectively in the future.

The transmission network can only transmit a certain amount of energy at any one time and when that capacity is reached, we need to reduce the supply of electricity coming onto that part of the grid. In certain regions, particularly in Scotland, there are often periods of excess generation from renewable sources.

With more renewable power generators coming on to the system, we need to find new ways of managing the constraints to the transmission system. One possible solution is to absorb any extra power produced and store it for later use, and that's what this feasibility study was established to do.

Our findings are published annually on the ESO website

Case Study / Impact of Long-duration Energy Storage Systems on GB Transmission Planning 19

Case study /
Impact of Long-duration Energy Storage Systems on GB Transmission Planning

Results:

Phase one of the project has investigated different types of long-term storage solutions which include lithium ion, cavern hydrogen, zinc air, electrochemical loads and vanadium flow. Each technology is being analysed to see how much power it can store (MW) and for how long (MWh), the cost to install and run versus how much it could save the ESO in constraint costs, and where it could be sited geographically to be of most benefit to the system.

With the feasibility studies almost complete, the project is moving onto the second phase to evaluate how the storage solutions could also provide additional support services, such as frequency response and reactive power, to help us maintain system stability.

Benefits:

This project could help us reduce our transmission constraint costs, resulting in lower bills for consumers

and advance our understanding of how long-term storage solutions can assist us in running the transmission network more efficiently with a greater number of low and zero carbon energy providers.

Sean Williams
Economics Engineer
Project Lead

NIA Reference	NIA_NGSO0030
Project Name	Impact of Long-duration Energy Storage Systems on GB Transmission Planning
Suppliers	Form Energy
Registered Value	£90,000
Start TRL	2
End TRL	3

Our findings are published annually on the ESO website WWW

Case Study / Impact of Long-duration Energy Storage Systems on GB Transmission Planning 20

Applications of convex optimisation to enhance National Grid’s NOA process

This project is working on the delivery of a year-round voltage analysis tool to help us make more informed investment decisions about the assets we’ll need in place to manage and maintain voltage levels once we are operating a zero-carbon electricity system.

To transmit power around the country, we need to maintain the system’s voltage at a steady level. Throughout the year, voltage can fluctuate depending on changes in background generation and demand as well as availability of network assets, so we control these changes by putting more reactive power into the system or by absorbing it, to reduce the excess.

Voltage management has been a big focus for us in recent years, and this has increased in importance as more renewable energy generators have come on board. As a result, we need to assess more snapshots of voltage use across the year to identify the reactive power requirements for both low voltage and high voltage scenarios.

This project set out to create a new tool which could help us accurately study more snapshots throughout the day, all year round. The data collected from the analysis will be used to identify where we need to invest in new assets to help resolve our reactive power challenge.

Our findings are published annually on the ESO website

Case study /
Applications of convex optimisation to enhance National Grid's NOA process

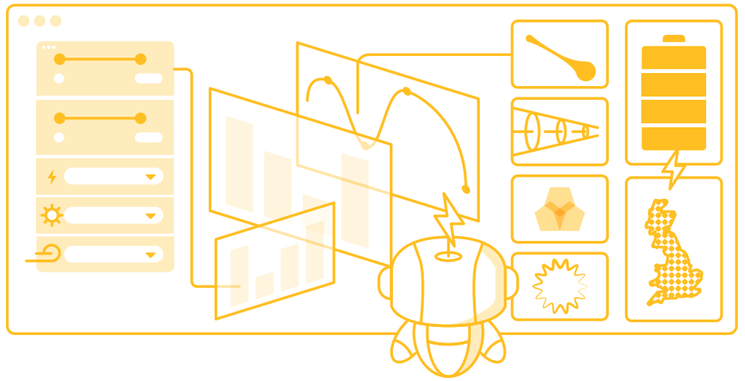
System Stability

Results:

Working in partnership with the University of Strathclyde, we started the project with an analytical review of the most cutting-edge technology and voltage management models available and shortlisted the three strongest solutions for further study.

We've completed a detailed comparison of these three models including analysing their accuracy and computation time – as we need to study more snapshots quickly and accurately – and the potential for clustering data, to give us the same information but in less snapshots.

> The next phase of this project is to develop and test a new voltage assessment tool concept based on the learnings from our research.



Benefits:

The assessment tool created by this project will make sure we make good investment decisions to reduce our voltage management costs and facilitate the operation of a secure and reliable network as we move towards a zero-carbon electricity system.

Mostafa Nick
Power System Engineer
Project Lead

NIA Reference	NIA_NGSO0029
Project Name	Applications of convex optimisation to enhance National Grid's NOA process
Suppliers	University of Strathclyde
Registered Value	£300,000
Start TRL	3
End TRL	5

Our findings are published annually on the ESO website

Case Study / Applications of convex optimisation to enhance National Grid's NOA process 22

Frequency Response Auction Trial

This project is trialling closer-to-real-time procurement of frequency response services to open the market up to more players, thus aiming to reduce costs through increased competition.

The frequency of the GB electricity system needs to be maintained at 50Hz (plus or minus 1%) but sudden changes in generation or demand can make this frequency go up and down. That's why we work with different energy providers and consumers, who can quickly reduce or increase their energy generation or demand, to help us keep the frequency steady.

These frequency response services are currently procured by monthly tender but this approach excludes some providers, particularly renewables, who can't predict their ability to deliver these services over longer-term periods.

This project was established to trial the procurement of frequency response services on a weekly basis, using an online auction platform to be more inclusive of all service providers. The project also seeks to address how we can make sure pricing is consistent, transparent and competitive by adopting a 'pay as bid' approach.

The frequency response auction trial lays the foundations for us to achieve our wider ambition of procuring balancing services a day ahead by 2023.

Case Study / Frequency Response Auction Trial 23

Case study /
Frequency Response Auction Trial

Results:

The live trial of the frequency response auction began in September 2019 with five participants. Initially, the trial operated a manual system, but this was later superseded by an online platform, provided and run by EPEX SPOT.

> **The trial now has 16 participants and continues to attract diverse market interest.**

A survey carried out in May showed that providers using the platform were satisfied with the simplicity of the procurement process, the technology used and agreed it was a competitive route to market.

Benefits:

This project is helping us increase the participation of new technologies in the delivery of frequency response services and make sure a more diverse and competitive market for procurement, while reducing operational costs, resulting in lower bills for consumers.

> **The project also sets the groundwork for a move to day-ahead procurement in the future, which will drive even greater market competition.**

Faye Relton
Ancillary Services Development Manager
Project Lead

NIA Reference	NIA_NGSO0017
Project Name	Frequency Response Auction Trial
Suppliers	EPEX SPOT
Registered Value	£1,142,000
Start TRL	3
End TRL	7

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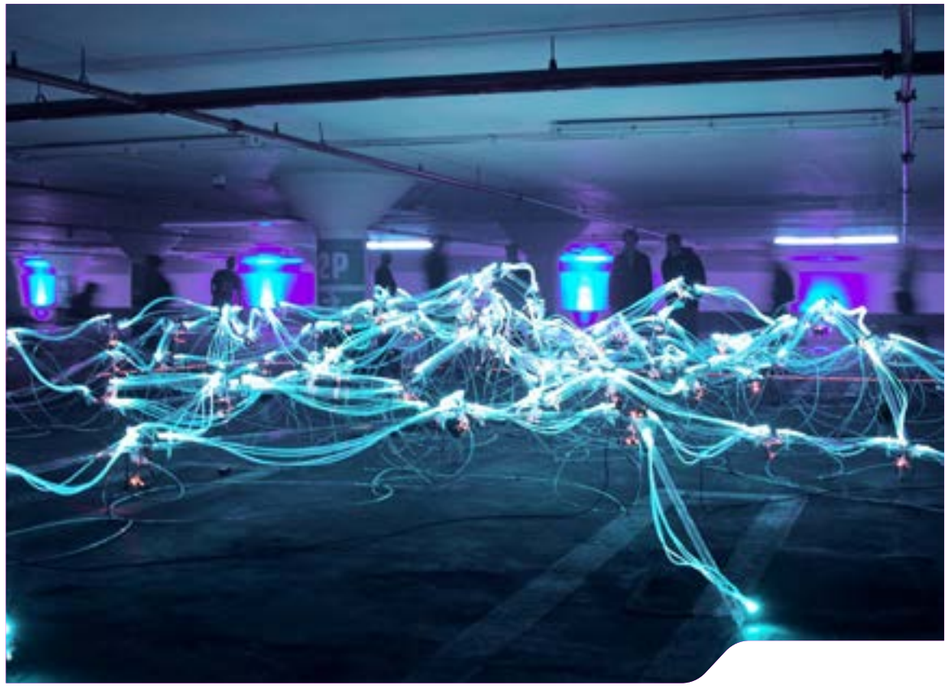
Case Study / Frequency Response Auction Trial 24



RecorDER

The RecorDER project will prove whether it's possible to create a register of all of GB's electricity generation and flexibility assets using blockchain technology.

Every year, we hold Open Innovation Days to encourage people from outside ESO to bring forward ideas and new ways of working. For our 2018 event, specialist energy tech company Electron brought an idea to create a blockchain-based platform which would provide a universal recording of all flexibility assets on the GB network. There are multiple players in the energy industry (ESO, DNOs, aggregators etc) and currently we all have our own asset databases. These asset databases don't record asset information in the same way and some data sets may be more up to date that others.

The RecorDER project – run in partnership with Electron, UK Power Networks and SP Energy Networks – seeks to prove the concept that a whole electricity system register for generation and flexibility assets is possible using blockchain technology. The digital asset register would include information about the location and capability of assets, and details of what services they currently provide and to who.

This 'one version of the truth' will not be a central database, but it will serve as a universal view of all of GB's assets which can be accessed and updated by multiple parties.

Case study / RecorDER

Whole Electricity System

Results:

Over the past 18-months, we have researched and studied the possibilities and practicalities of a digital asset register and creating it using blockchain technology. The digital asset register has never been used before by the UK's transmission or distribution network operators as a platform to host network data.

We also explored how the register would be governed and the legal implications of sharing information across multiple partners, as well as any flaws which could be exploited for market gain.

Electron has led on the modelling of the architecture required for the asset register platform and has run a pilot on two sets of data.

Benefits:

We have proved the concept of a digital asset register, and shown it has many benefits.

It would give us a transparent view of all of GB's energy assets, making it easier to plan and operate the system and identify where additional assets needs to be procured. This will help us run the system more efficiently to improve safety and reliability, and reduce transmission costs and the cost to consumers.

Adrian Sellar
Power Responsive Officer
Project Lead

NIA Reference	NIA_NGSO0018
Project Name	RecorDER
Suppliers	Electron
Registered Value	£753,000
Start TRL	3
End TRL	6

Our findings are published annually on the ESO website

Case Study / RecorDER 26

Short-term system inertia forecast

This project explores whether we can create an accurate inertia forecast for the day ahead, to help us plan our frequency response more efficiently and cost-effectively.

The shifting energy landscape is creating a number of unique issues for the GB electricity system, as we move towards more cleaner, greener sources of energy generation. One of these challenges is how we replace the inertia that fossil-fuelled power stations provide to help us manage daily peaks and troughs in demand.

Traditional power generators channel heat from burning gas or coal into turbines which rotate at a certain frequency to give us a constant, reliable supply of electricity. These turbines can also continue spinning, even when the heat driving them stops – this is inertia. Renewable power generators don't have the same mechanical set up, so the amount of electricity they provide can drop quickly, without notice.

While we explore ways to artificially create inertia to provide future system stability, this project was established to look at the problem from another angle – how we can use a data-driven approach to manage the inertia conundrum by forecasting it a day ahead and proactively planning how to balance the system.

By knowing our inertia needs in advance, we can better manage rate of change of frequency (stability), reduce our operational costs and spot potential issues earlier.

Case Study / Short-term system inertia forecast 27

Case study /
Short-term system inertia forecast

Results:

After much progress on our preliminary analysis based on the historical data the project focused on extracting more detailed information about the system's use of inertia using Balancing Mechanism Units and Embedded Balancing Mechanism Units computer-modelled solutions.

> We are working in partnership with Imperial College London to develop Machine Learning-based algorithms for multi-temporal inertia forecasts in a rolling-basis.

We will then test and validate the proof of concept for accurate inertia forecast to explore whether we could apply the advanced simulation models to quantify the benefits of a data driven approach to inertia forecasting.

Benefits:

This project will increase our system security, reduce the costs associated with managing ROCOF and help us to better respond to frequency changes in the system to deliver a more stable, cost-effective electricity system to consumers.

Yuting Dai
Ancillary Service Implementation Manager
Project Lead

NIA Reference	NIA_NGSO0020
Project Name	Short-term System Inertia Forecast
Suppliers	Imperial College London
Registered Value	£300,000
Start TRL	3
End TRL	6

Our findings are published annually on the ESO website

Case Study / Short-term system inertia forecast 28

Power Potential

This world-first project is investigating whether we can use more small-scale renewable energy generators to establish a new reactive power market to help us safely operate the GB electricity system, while also generating extra capacity on the network.

Distributed Energy Resources (DER) like wind turbines and solar panels have an increasingly important role to play in the energy system, but it's unclear how they can deliver some of the key services we need to balance the grid – such as providing reactive power to help us with dynamic voltage control in the event of a fault, or by providing voltage regulation to release network capacity when needed.

The Power Potential project has been established to explore how renewable generators connected to the distribution network can be used to support the operation of the transmission network.

The project is focused on South East England as a test region. Currently, transmission and distribution networks in this area are at the limit of capacity for both importing and exporting power from the rest of the transmission system. One solution to this problem would be to build additional infrastructure but the Power Potential project is exploring smarter alternative options using distributed energy resources (DER) that could be used as a blueprint for other regions.

The Power Potential project will also deliver a control system solution to instruct the participating DER.

Case Study / Power Potential 29

Case study / Power Potential

System Stability

Results:

Working in partnership with UK Power Networks, the Power Potential project has brought forward the use of new DER technology which could provide reactive power,

such as storage batteries and new solar panels to help balance the grid at night. While on-site commissioning has been delayed by COVID-19, it is expected that live trials of the control system for DER will begin in the Autumn.

Benefits:

This project will demonstrate if small power generators can cost-effectively provide some of the key stabilising services we need to safely and reliably operate the network. It will also demonstrate how transmission and distribution network providers work together to find joined-up solutions to the energy challenges we face, while creating new opportunities for smaller energy businesses and increasing competition in the market to lower transmission charges for the consumer.

Biljana Stojkovska
Project Lead for Power Potential

NIC Reference
NGET_UKPN_TDI2.0

Project Name
Power Potential

Partners
UK Power Networks

Project Budget
£9,560,113

Link
Project Webpage

Our findings are published annually on the ESO website

Case Study / Power Potential 30

Distributed ReStart

Distributed ReStart is a ground-breaking project exploring whether smaller, renewable energy resources can be used to restore power to the GB electricity system following a blackout.

In the very unlikely event of a partial or total blackout, we need to restore electricity to consumers as soon as possible. Currently, we do this by using fossil-fuelled power stations as they are able to self-start and provide the electricity needed to get the transmission system back online.

But the energy landscape is changing and we are now moving towards a national electricity system with fewer fossil-fuelled power stations and more distributed energy resources (DERs), so we need to find alternative, more cost-effective solutions to black start the network.

This project has been established to explore and test new ideas, focusing on how smaller, renewable generators can be co-ordinated to deliver the black start function. This kind of joined up approach with DERs has never been done before, and the innovative ‘bottom up’ solution we are developing will not only provide a future plan for GB, but also a blueprint for other system operators around the world.

Case study / Distributed ReStart

Whole Electricity System

Results:

At the halfway point in this three-year project, we are finalising our design work and procuring equipment ready to begin live trials later in the year on three ‘power island’ case studies in Scotland and North Wales.

> **The key to making the system work lies in automation, which will reduce costs, enhance efficiency and reliability.**

Contracts have been awarded to design an automated control system with the capability to co-ordinate a DER-based response, with the first reports due in the summer, which will lead to system build and test in a ‘live’ environment.

We are making good progress on the design of an end-to-end black start process to address how different stakeholders work together and to establish a resilient communications infrastructure between the ESO, DNOs and DERs.

Our commercial-focused work stream is exploring the need for code and license changes, and how best to navigate the complex procurement process to make sure the final solution is cost-effective for consumers.

To anticipate any challenges and make sure we are on the right track, we are engaging industry stakeholders and academics with our developing plans and ideas.

Benefits:

By using a larger number of renewable energy generators to provide Black Start services, we can open up a new market for DER providers which will increase competition and diversity in the market.

> **This will reduce our operational costs, and therefore lower bills for our customers.**

Pete Chandler
Project Lead for Distributed ReStart

NIC Reference	NIC_ESOEN01
Project Name	Distributed Restart (Black Start DER)
Partners	SP Energy Networks
Project Budget	£11,690,880
Link	**Project Webpage**

Our findings are published annually on the ESO website

Case Study / Distributed ReStart 32

Phoenix - System Security and Synchronous Compensators

This project is focused on the design and roll out of an innovative Hybrid Synchronous Condenser to alleviate some of the major system issues we are encountering as a result of the closure of fossil-fuelled power stations.

The closure of gas and coal power stations is having a big impact on the GB electricity system. As synchronous generators, they provide us with a number of services to help keep the network stable and operating at its optimum, and as more of these generators go offline, we are left with the challenge of counterbalancing reduced inertia, lower short circuit levels and limited voltage control.

We must therefore find an alternative solution to operate the electricity system safely and reliably with more green energy providers.

This project was set up to develop a technological solution to the problem – a Hybrid Synchronous Condenser (HSC), which combines a synchronous generator and static compensator. This project seeks to design and test a workable HSC model and consider how it could be rolled out.

Case Study / Phoenix - System Security and Synchronous Compensators 33

Our findings are published annually on the ESO website

Case study /
Phoenix - System Security and Synchronous Compensators

System Stability

Results:

> A prototype HSC is in the progress of being installed at the Neilston substation near Glasgow, ready to begin live trials during 2020.

Once energised, we will collect data on the HSC's real-world performance, ready to report our learnings at the end of the project in 2021.

We have also been working with University of Strathclyde and Technical University of Denmark on studies to map the system benefits of HSC, the impact of variables (i.e. different sizes and locations) and what we can learn from other TOs who have rolled out similar solutions.

Our cross-industry working group has continued to work on the commercial considerations of the project and how to bring the HSC to market, should trials be successful.

Benefits:

> This project will deliver a technological solution to enable us to operate a stable and secure electricity system

with more renewable providers, helping us meet our 2025 zero-carbon target. It will also improve the safety and reliability of the system by resolving some system issues caused by the changing energy landscape.

Lilian MacLeod
Data and Modelling Manager
Project Lead

NIC Reference	SPTEN03
Project Name	Phoenix - System Security and Synchronous Compensators
Partners	SP Energy Networks
Project Budget	£19,897,000
Link	**Project Webpage**

Our findings are published annually on the ESO website

Case Study / Phoenix - System Security and Synchronous Compensators 34

Working together to drive innovation

Collaboration is at the heart of ESO Innovation and is critical to driving the transformation towards a more sustainable and decarbonised future.

We have continued working closely with the Electricity Innovation Managers and Gas Innovation Governance Group, alongside the Energy Networks Association (ENA), on a number of key projects. Highlights this year include the publication of our second joint **Electricity Networks Innovation Strategy**, published in March 2020 alongside the **Gas Network Innovation Strategy**. We have also made significant progress developing the Benefit Measurement Framework. This framework will enable network companies to adopt a standardised method to measure and communicate our innovation activities.

We actively participated in a wide range of external events, such as the Low Carbon Network Innovation (LCNI) Conference. The LCNI event was organised in partnership with the electricity networks and the ENA and was attended by over 1,000 delegates. A packed agenda of workshops and discussions took place over the two-day event focused on empowering new energy innovators.

We also recognise engaging our counterparts globally can unlock new opportunities for innovation that support our customers and the transition to a low-carbon energy future. We share our insights and experience with system operators from 36 countries across Europe through the European Network of Transmission System Operators' Research and Development Committee (ENTSO-E RDIC).

Our findings are published annually on the ESO website

Working together to drive innovation / 35

Working together to drive innovation /
Continued

We have continued to build an extensive network of partners in the last year delivering ESO innovation projects with academia, DNOs, original equipment manufacturers, infrastructure partners, technology companies and SMEs. 25% of the project partners we worked with for the first time in 2019/20.

We recognise that being open to ideas from across the industry and academia will make sure we build projects with the potential to transform the energy system and deliver the greatest benefits. 38% of ideas that developed into projects came from outside organisations in 19/20.

We increased our project collaborations with Small and Medium Enterprises (SMEs) to access fresh thinking and more agile ways of working. In the last 12 months, 48% of our partners were SMEs and 26% had less than 10 employees.

Our findings are published annually on the ESO website

Working together to drive innovation / 36

Working together to drive innovation / Continued

In the past 12 months, we've worked with new and existing partners to develop ground-breaking projects, to shape our innovation strategy for 20/21 and to identify exciting opportunities for the future, including:

Collaborating across the Industry

We have engaged with more than 130 organisations across a range of activities in the last year. This extends from refreshing our innovation strategy through to hosting our Open Innovation Event. Our third successful Open Innovation Event took place in November 2019 which attracted 87 idea submissions and resulted in £2m of funding granted across 7 new projects.

Spatial GB Clean Heat Pathway Model

We're working closely with National Grid Gas Transmission to tackle one of the major challenges to being carbon free by 2050, the decarbonisation of heat. The project will develop a first-of-a-kind, prototype bottom-up model for forecasting decarbonised heat demand and supply across domestic and non-domestic buildings in GB to 2050 to determine plausible local decarbonisation pathways. The project is engaging key stakeholders through an industry advisory group and is currently building the model to begin validation testing.

4D Heat

Developed during our Open Innovation Event, this project will explore the potential of using surplus wind power to heat houses. We have teamed up with Scottish and Southern Electricity Networks (SSEN) to investigate the feasibility of smartly controlling electric heating to make sure less wind power is curtailed and heat off-gas grid areas in northern Scotland where there are large numbers of electrified residential heating. If successful, this project will the set the groundwork for follow-up initiatives, as the UK as a whole increasingly focuses on the challenges of decarbonising the heat sector.

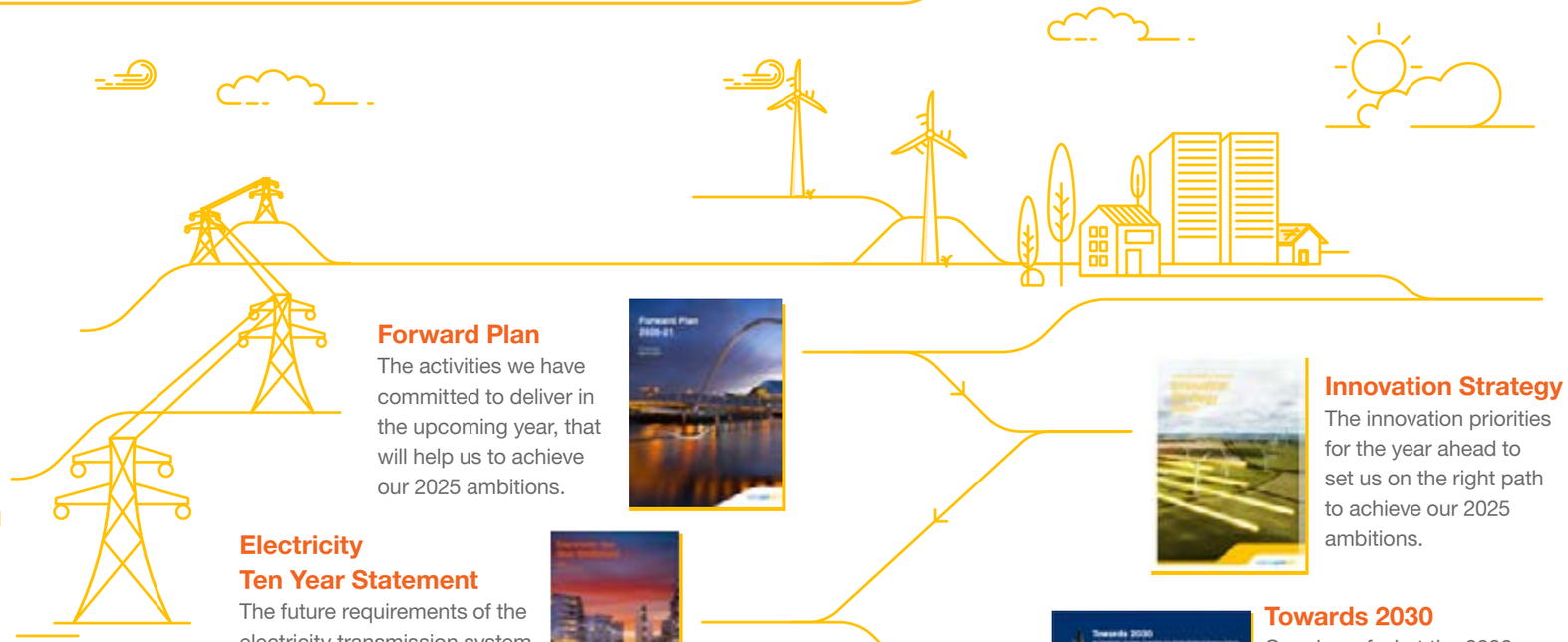
Working together to drive innovation / 37

Our findings are published annually on the ESO website WWW

Facilitating the Energy System of the Future

The ESO sits at the heart of the energy landscape, which is changing at an ever-increasing pace. As we transition to a zero-carbon power system, the increased adoption of cleaner energy approaches such as small-scale renewables, storage and demand-side participation, is making the system more challenging to operate. The ESO is rising to the challenge by having a clear vision of how we, and the industry, must change to build the energy system of the future.

Innovation is playing a central role in helping the ESO achieve this vision by identifying the market and technical solutions needed for system operation in 2025 and beyond. Our Annual Summary reflects on our performance each year in supporting this vision and goes hand-in-hand with a suite of ESO publications which provide an evolving and consistent voice in the development of GB's electricity network.



Forward Plan

The activities we have committed to deliver in the upcoming year, that will help us to achieve our 2025 ambitions.

Innovation Strategy

The innovation priorities for the year ahead to set us on the right path to achieve our 2025 ambitions.

Electricity Ten Year Statement

The future requirements of the electricity transmission system over the next 10 years, based on the FES analysis.

Towards 2030

Our view of what the 2030 energy landscape looks like, our four ambitions for 2025, and the areas where we will priortise our focus to help deliver the energy future.

FES: Bridging the Gap

The immediate actions for policymakers and industry to meet the UK net zero by 2050 decarbonisation target.

Future Energy Scenarios (FES)

A range of plausible and credible scenarios for what the future of energy could look like from today out to 2050.

Our findings are published annually on the ESO website

Facilitating the Energy System of the Future / 38

Project List

Project Reference	Project Name	Status	Supplier
NIA_NGET0188	**WI-POD- Wind turbine control Interaction with Power Oscillation Damping control approaches**	Completed	University of Warwick
NIA_NGET0193	**Project DESERT (hybrid battery and solar enhanced frequency control)**	Completed	Belectric Solar
NIA_NGGT0154	**Spatial GB Clean Heat Pathway Model**	In Progress	Element Energy
NIA_NGSO0004	**Virtual Synchronous Machine (VSM) Demonstrator**	In Progress	University of Nottingham, TTPI
NIA_NGSO0007	**Investigation & Modelling of Fast Frequency Phenomena (“F2P”)**	In Progress	Brunel University
NIA_NGSO0008	**Solar PV Monitoring Phase 3**	In Progress	Sheffield Solar (University of Sheffield)
NIA_NGSO0015	**Optimisation of weather data to improve energy forecasting**	In Progress	The Smith Institute
NIA_NGSO0017	**Frequency Response Auction Trial**	In Progress	EPEX SPOT
NIA_NGSO0018	**RecorDER**	In Progress	Electron
NIA_NGSO0019	**Hybrid Grid Forming Converter**	Completed	University of Strathclyde
NIA_NGSO0020	**Short-term System Inertia Forecast**	In Progress	Imperial College London

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Our findings are published annually on the ESO website

Project List /
Continued

Project Reference	Project Name	Status	Supplier
NIA_NGSO0021	**Development of GB electric vehicle charging profiles**	Completed	Element Energy
NIA_NGSO0022	**Black Start Capabilities from Non-Traditional Technologies**	Completed	TNEI
NIA_NGSO0023	**Mapping the Impacts and Visualization of Risks of extreme weather on system operation (MIVOR)**	In Progress	University of Bath
NIA_NGSO0024	**Enhancing Energy Flexibility from Wastewater Catchments through a Whole System Approach**	In Progress	United Utilities, Open Energi
NIA_NGSO0025	**Residential Response**	In Progress	Element Energy, Upside Energy, Intelligent Energy Technology, Moixa Technology, Lightsource Labs
NIA_NGSO0026	**Demonstration of Virtual Synchronous Machine control of a battery system**	In Progress	Belectric GmbH, PNDC (University of Strathclyde)
NIA_NGSO0027	**Testing Coordinated DSO-ESO Procurement and Dispatch**	In Progress	REstore FlexPond
NIA_NGSO0028	**Advanced Modelling for Network Planning Under Uncertainty**	In Progress	University of Melbourne
NIA_NGSO0029	**Applications of convex optimisation to enhance National Grid's NOA process**	In Progress	University of Strathclyde
NIA_NGSO0030	**Impact of Long-duration Energy Storage Systems on GB Transmission Planning**	In Progress	Form Energy

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Our findings are published annually on the ESO website

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.

You can also find out more about our areas of focus for 2019/20 and how we work in the documents below.

Innovation Strategy 2019/20

Our innovation priorities for the year ahead to set us on the right path to achieve our 2025 ambitions.

Innovating with the System Operator

Provides more information on our processes, how we lead innovation projects and support third party ones.

Carolina Tortora
Head of Innovation Strategy

Cian McLeavey-Reville
Manager Strategy & Stakeholder

Joshua Visser
Manager Pipeline Development

Geoff Down
Manager Portfolio Delivery

Alison Dineley
Senior Innovation Analyst

Our findings are published annually on the ESO website

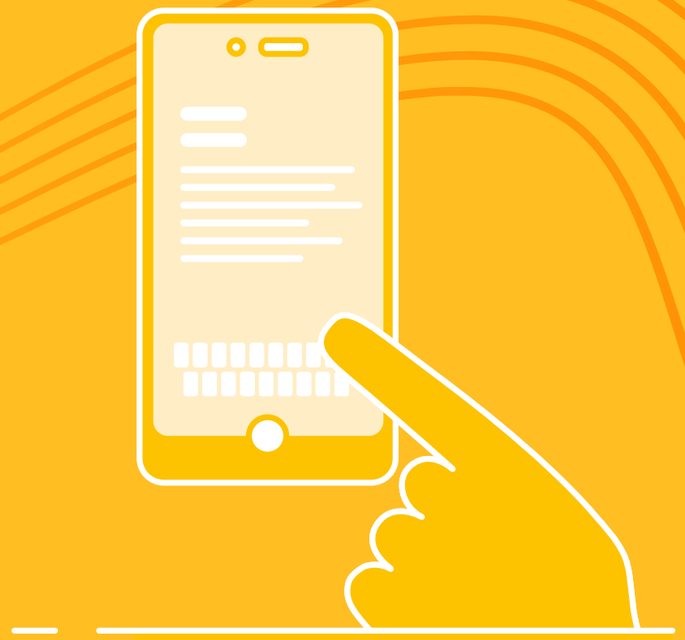
Meet the team / 41

Get in touch

Visit our website or contact us to learn more about the new ESO innovation process, our priorities, and the NIA and NIC funding available.

Contact the team: box.SO.innovation@nationalgrid.com

Visit our website: nationalgrideso.com/innovation



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