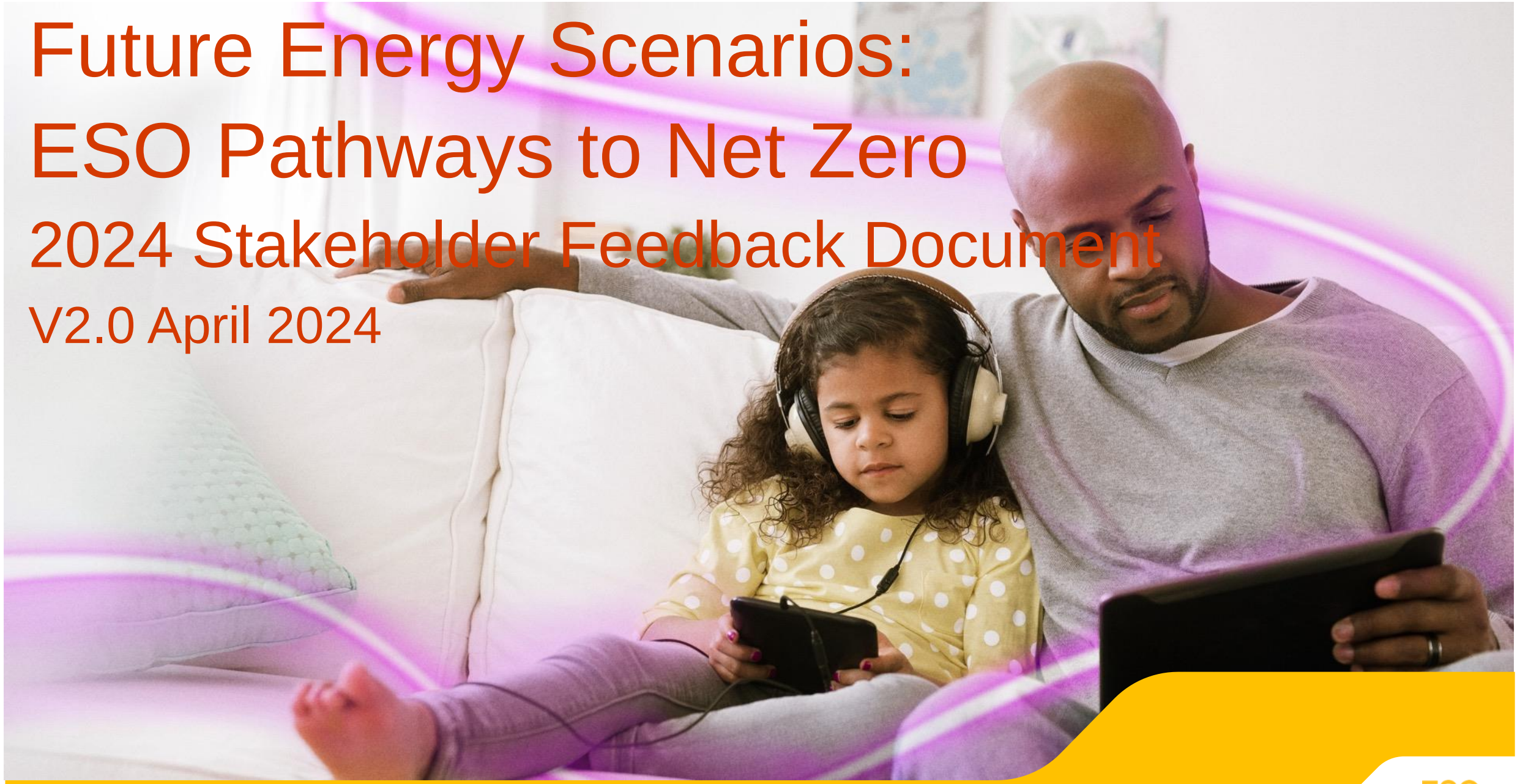
Future Energy Scenarios: ESO Pathways to Net Zero

2024 Stakeholder Feedback Document

V2.0 April 2024



Contents

Welcome and executive summary

Welcome to the 2024 Future Energy Scenarios (FES) Stakeholder Feedback Document, which sets out our framework and pathways for the coming year, together with details of our engagement activities. We have provided summaries of the feedback gathered from all of our engagement activities and set out how we are taking this forward.

We plan to publish our 2024 analysis in the summer and look forward to welcoming stakeholders to our event programme for **Future Energy Scenarios: ESO Pathways to Net Zero**

Changes to FES 2024

We're in a period of significant change for the energy industry as a whole but also for FES. While we will be continuing to produce supply and demand projections for Great Britain, we are moving from a 'scenario' to 'pathway' framework to support changes to the network planning process. Our previous framework explored a wide range of credible outcomes for how the UK could meet net zero. Our new framework seeks to set out credible, strategic pathways for achieving net zero.

Engagement for FES 2024

Our engagement for FES 2024 began at the time of the FES 2023 publication and continues until late spring. Our engagement strategy was set out in advance to ensure a range of methods are employed to give as many stakeholders as possible the chance to be involved and provide their insight. We have detailed our engagement activities on pages 6 – 7, together with the data that sits behind this on pages 8 – 17.

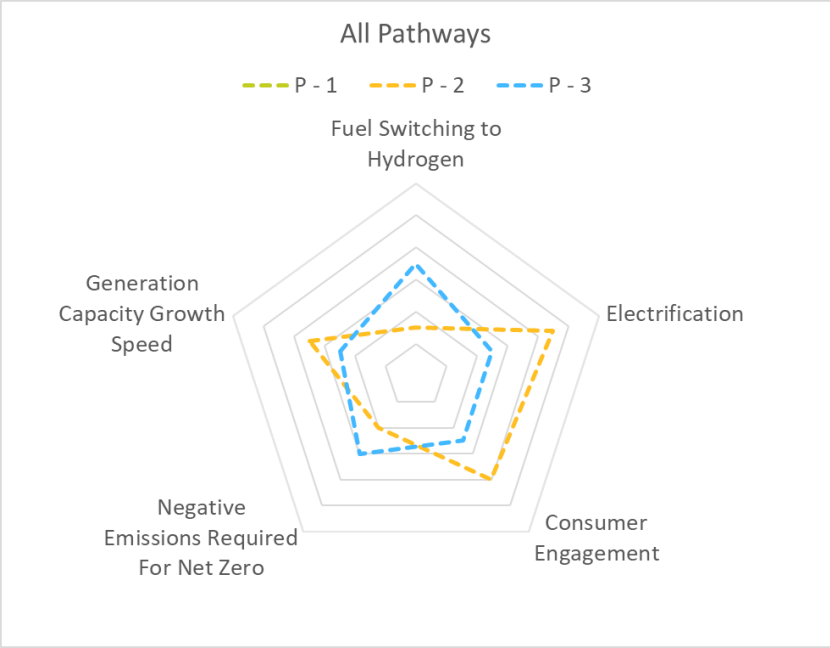
Continual improvement

We are constantly striving to meet and exceed the expectations of our stakeholders. To help us to do this we measure levels of satisfaction and seek feedback at every opportunity. This includes on-the-day satisfaction cards at our in-person events, as well as formal and informal surveys throughout the year. We have provided a summary of these improvements from our engagement and communication on page 19.

FES 2024 framework and pathways

FES 2024 is adopting a new framework to better present the pathways at a glance, and the visualisation is key to showing how the levers and pathways relate to each other. We have tested our draft visualisations with stakeholders during multiple engagement sessions, including our most recent Table Topic Talks event – a summary of the feedback received can be found on page 19 of this document.

Please note that we are also developing a simplified graphic to put up front in the document, with the spider diagram providing additional detail. Pathway names are still in development.



Please note Pathway 1 is not included on the spider diagram, as the levels will be determined through the modelling process. Pathway 2 and Pathway 3 are indicative only and will be developed through stakeholder engagement, research and analysis.

Objective	Pathway 1	Pathway 2	Pathway 3
	To explore a route to net zero under a mixed technology development path.	To explore a route to net zero under a highly electrified development path.	To explore a route to net zero under a hydrogen development path.

Counterfactual		
	To explore a world where not enough progress is made on decarbonisation and net zero 2050 is missed.	A reframing of FES 2023 Falling Short scenario to become a Counterfactual that is deliberately separated from our core pathways. Falling Short represents the slowest credible speed of decarbonisation. It does not meet net zero by 2050.

FES 2024 framework and pathways

Our new framework illustrates a move from reactive to strategic network planning.

Where our previous framework analysed what *could happen* by using scenarios to explore a wide range of credible outcomes for how the UK could meet net zero, our new framework seeks to identify what *should happen* through credible, strategic routes for achieving net zero.

Similarly to the framework visualisation, we continue to engage our stakeholders on the changes to our framework/modelling approach, with feedback found on page 20 of this document.

Scenarios	Pathways
Range of credible outcomes for how the UK **could** meet net zero. Not all scenarios meet net zero	Routes showing strategic direction to net zero. All pathways must meet net zero
Wide range of possible outcomes	Provides a narrower strategic range
Creates scenarios that are cost agnostic	Brings in additional economic modelling
Potential efficiency savings through interactions between electricity and hydrogen networks are highlighted but not assessed	Whole system optimisation fundamental to finding most efficient future energy system across all energy vectors – (in development for future iterations)
Built to emissions and Security of Supply targets (SoS)	Considers whole energy trilemma
Seeks out the edges of credibility to ensure scenario range is wide enough to encompass uncertain future	Explores a narrower range of outcomes to drive more strategic credible routes to net zero
Assumes unconstrained network	Assesses the impact of network constraints

Our engagement

An explanation of the consultation process undertaken

Engagement summary

Engaging with our stakeholders and planning for FES 2024 began in the summer after the publication of FES 2023. We took the opportunity to review the stakeholders with whom we had engaged as part of the FES 2023 planning process and, recognising the importance of continuing to seek out both a broad range of views and fresh perspectives, identified new organisations for FES 2024.

For FES 2024 we have engaged with **2,627** stakeholders across all our events (including the 2023 launch) representing a total of **561** organisations. To ensure we maximise the breadth of stakeholder engagement, we engage with all nine stakeholder categories identified for FES, with organisations across sectors including motor manufacturing, home building associations, universities, energy suppliers, trade bodies and more.

To conduct our engagement, we use a range of methods to ensure we offer all stakeholders the opportunity to get involved and share insight with us. These methods are outlined in our strategy and include online meetings, in-person workshops and consultations, as well as our email and social media platforms. During these events we ask our stakeholders a range of questions: from targeted and specific, to broader open-ended questions, all designed to encourage discussion and foster debate.

We thank all stakeholders who have taken the time to contribute to FES 2024 with their evidence, research and insight.

We have combined the output from all our engagement activities, together with our knowledge and expertise, research, and evidence, to model and produce the pathways for FES 2024.

Our engagement

An explanation of the consultation process undertaken

The list below outlines the key engagement activities we have conducted for FES 2024 so far, ranging from full-day, multi-stakeholder engagement sessions, to strategic bilateral meetings.

- The **FES 2023 launch** saw over 5.3k stakeholders attend or watch our launch events on catch-up. We hosted an in-person event at the Science Museum in London, followed by four webinars looking closely at each of the FES chapters from the main document
- The **FES 2024 Call for Evidence** took place in September, promoted via ESO social media and FES platforms. This online engagement provides new and existing stakeholders the opportunity to contribute to the future of energy
- The **FES 2024 framework workshop** took place during September in London, giving stakeholders early sight of the draft FES 2024 framework and pathways. Feedback received was taken forward to further refine the new framework
- **FES 2024 bilateral meetings** began in August 2023 and will continue until early spring. These 1:1 meetings with key organisations form an important element of the engagement cycle and production of FES
- **FES 2024 Topic Table Talk Day** took place at the end of November in London. This in-person event attracted 80 stakeholders representing a wide range of energy industry organisations
- We have hosted two **Network Forum** meetings during the second half of 2023, the latter one in October

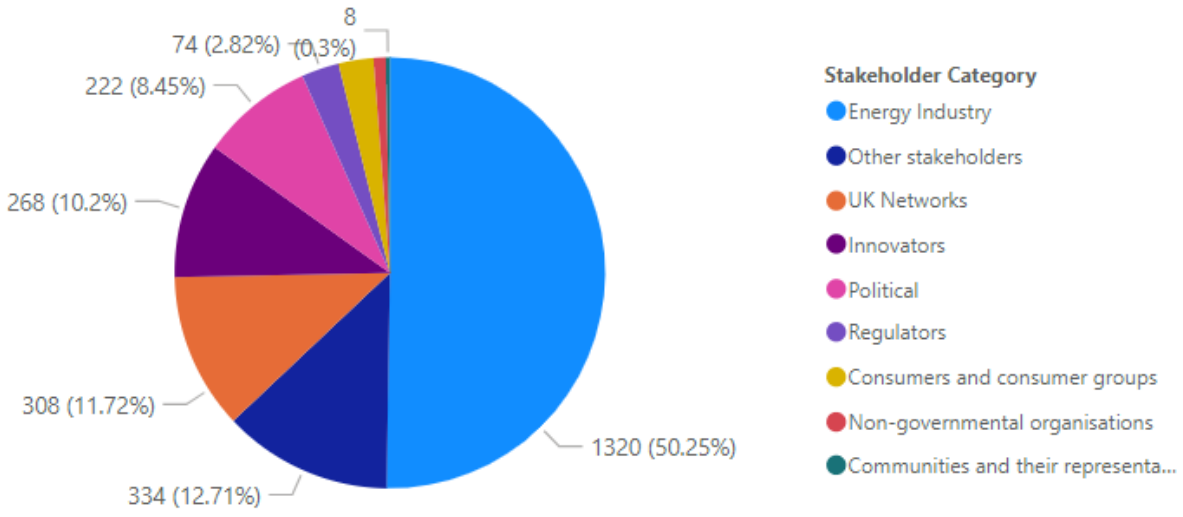
In addition to the significant activities referenced above, the team have attended industry events such as exhibitions, webinars and conferences. We also continue to keep up regular communication with stakeholders and interested parties via the FES newsletter (which is sent to 6.2K recipients) alongside the ESO website and social media platforms.

Our engagement: high-level summary

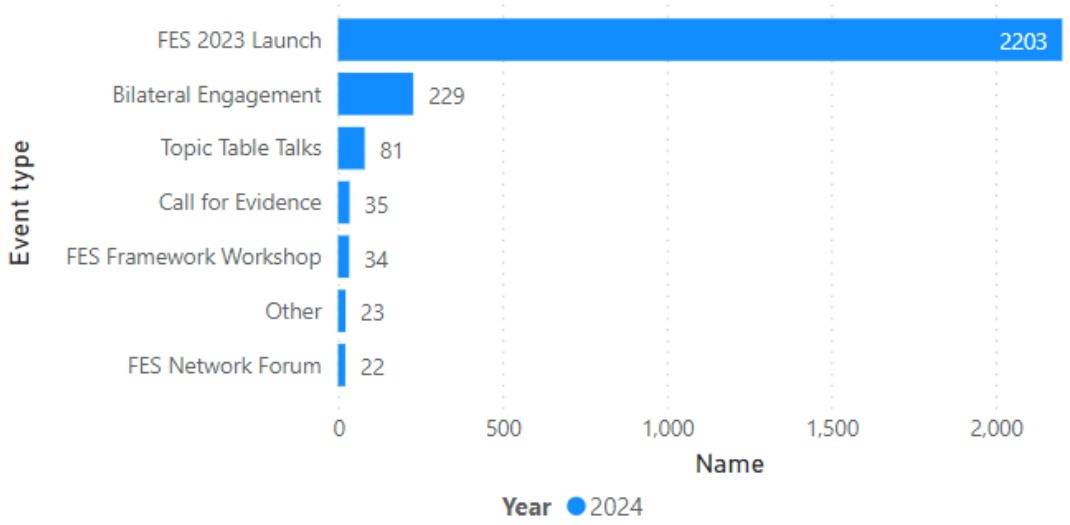
Engagement event:	2023 for FES 2024	2022 for FES 2023	2021 for FES 2022
FES launch event (in-person and webinars)	2,203 stakeholders	1,365 stakeholders	428 stakeholders
FES launch stream and catch-up	3,188 stakeholders	1,984 stakeholders	142 stakeholders
FES framework workshop	34 stakeholders	n/a	n/a
Call for Evidence	35 stakeholders	61 stakeholders	46 stakeholders
Topic Table Talks	81 stakeholders	63 stakeholders	n/a
All other FES engagement	83 organisations	76 organisations	95 organisations

Our engagement: all engagement (July to date)

Stakeholder Category



Yearly Engagement



Our engagement: all engagement

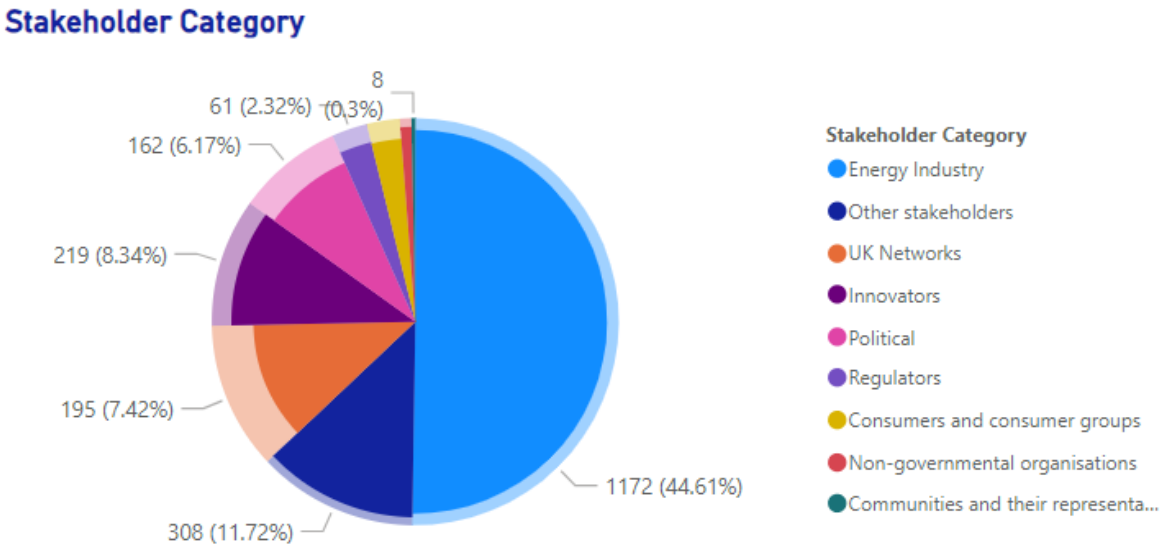
Stakeholder sub-category breakdown

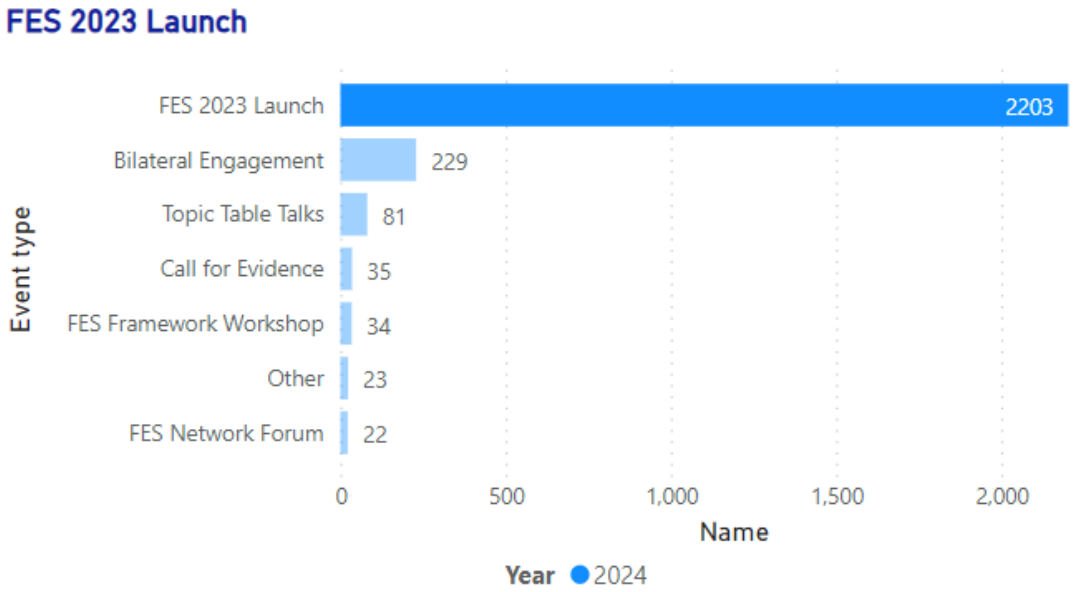
Sub-category	Total
Industry bodies & experts including consultancies and trade bodies	407
Generators (including Big 6)	241
National Grid ESO	221
Gas and electricity transmission companies	193
Manufacturers and technologists	168
UK government bodies	165
Energy suppliers	119
Storage and flexibility	112
Academics, universities and schools	103
Infrastructure providers	96
Distribution network operators	82
Finance and investment community	80

Sub-category	Total
Regulatory bodies	74
Small businesses	66
Large businesses	65
Small renewables	58
Offshore gas companies	45
Gas distribution networks	39
General public/individual responses	39
European TSO	37
Local authorities	37
Consumer groups and charities	30
European and international networks	23
Devolved administrations	20

Sub-category	Total
Interconnectors	17
Other including media	17
Other non-governmental organisations	17
Transmission directly connected demand	14
Small generators	10
Environmental groups	7
Environmentalists	7
Local campaign groups and advocacy groups	6
Other UK networks including water and communications	4
Shippers	3
Terminal operators	3
Impacted local communities and residents	2

Our engagement: FES 2023 Launch (July)



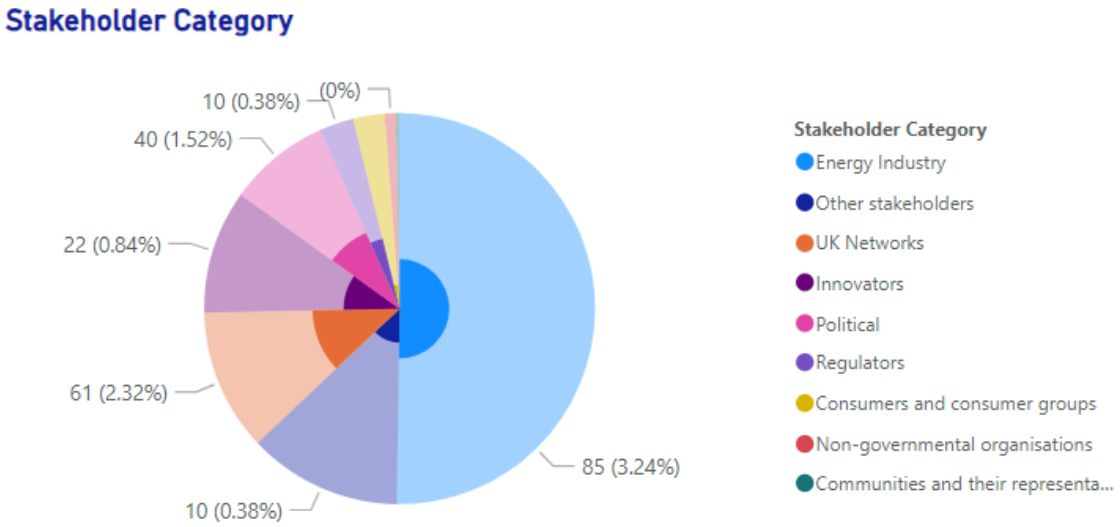


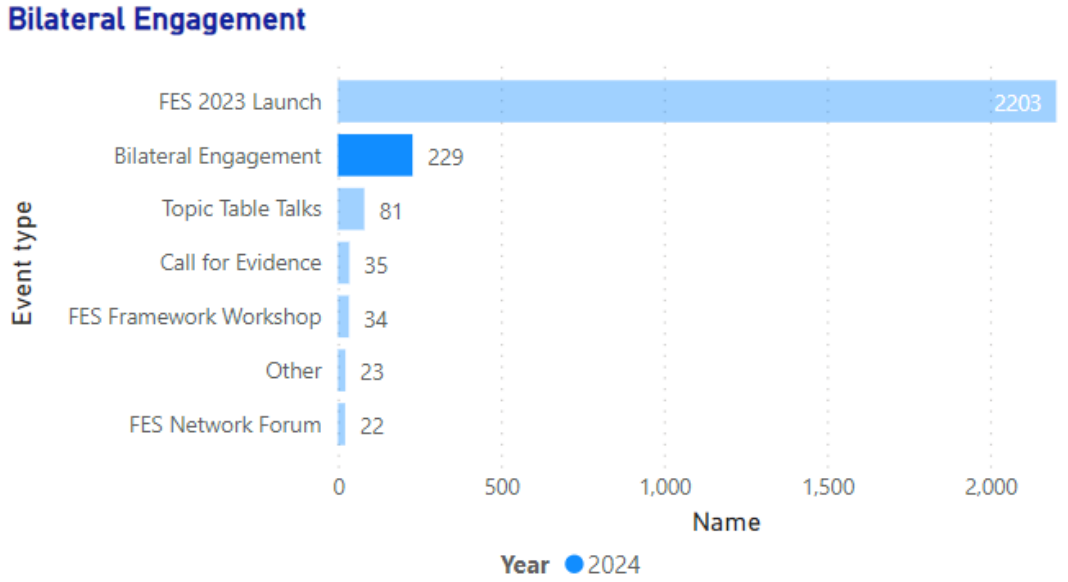
The launch events included question and answer (Q&A) sessions and the chance to network with teams across the ESO. These events led to key discussions and new stakeholder relationships.

The webinars raised over **430** questions which were addressed either directly in sli.do or during the Q&A.

FES 2023 launch via live-stream or catch up:	
Science Museum	2,683
Net zero webinar	143
Flexibility webinar	147
Energy consumer webinar	98
Energy system webinar	117

Our engagement: Bilateral (August to date)

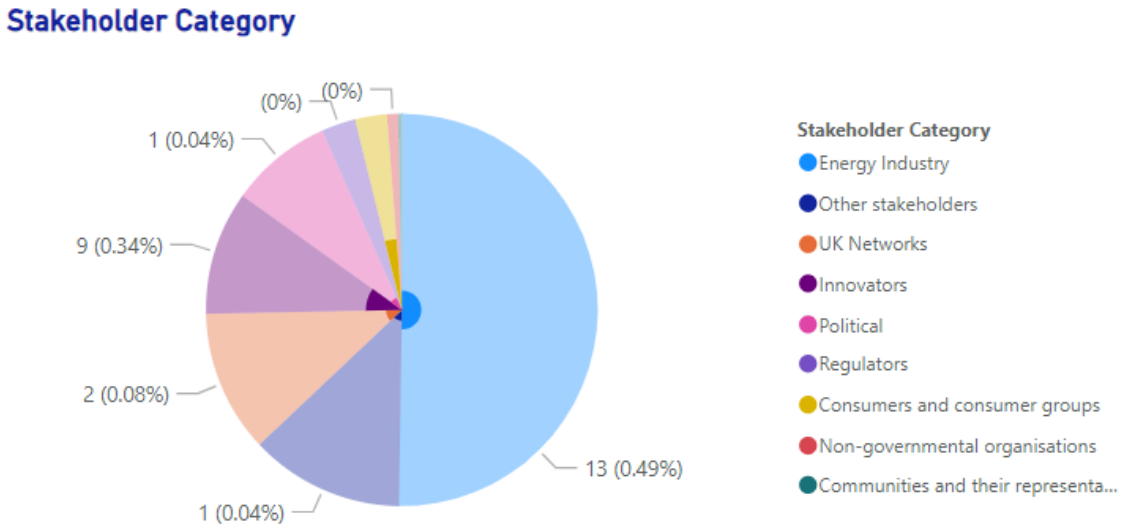


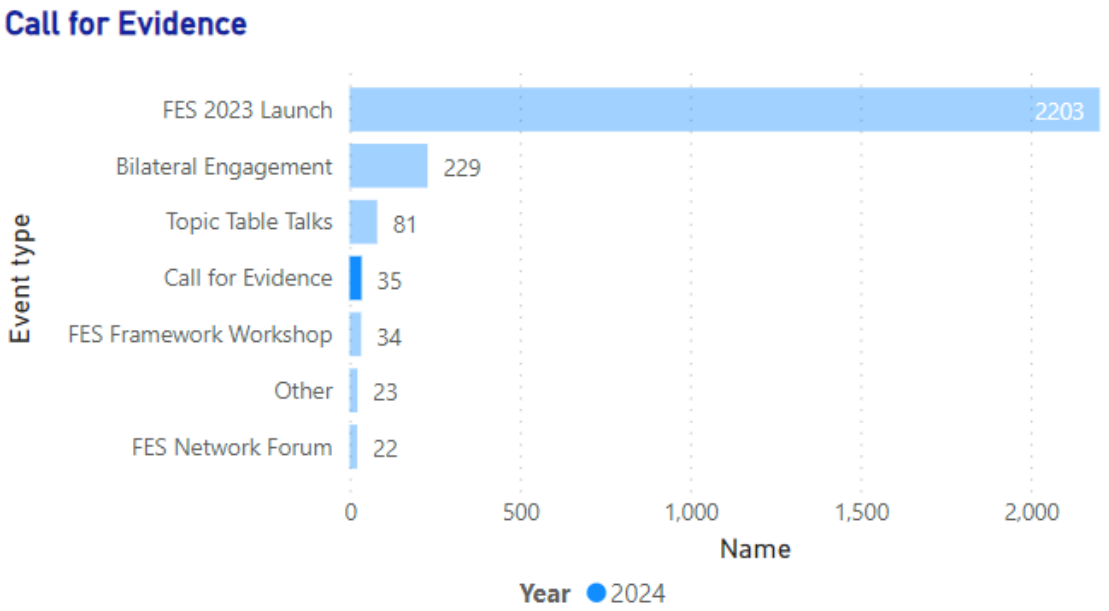


We have met with approximately **50 new organisations for our FES 2024 bilateral engagement** compared to FES 2023.

The team have attended **10** other engagement events and a further **44** bilateral meetings are planned to take place during spring time

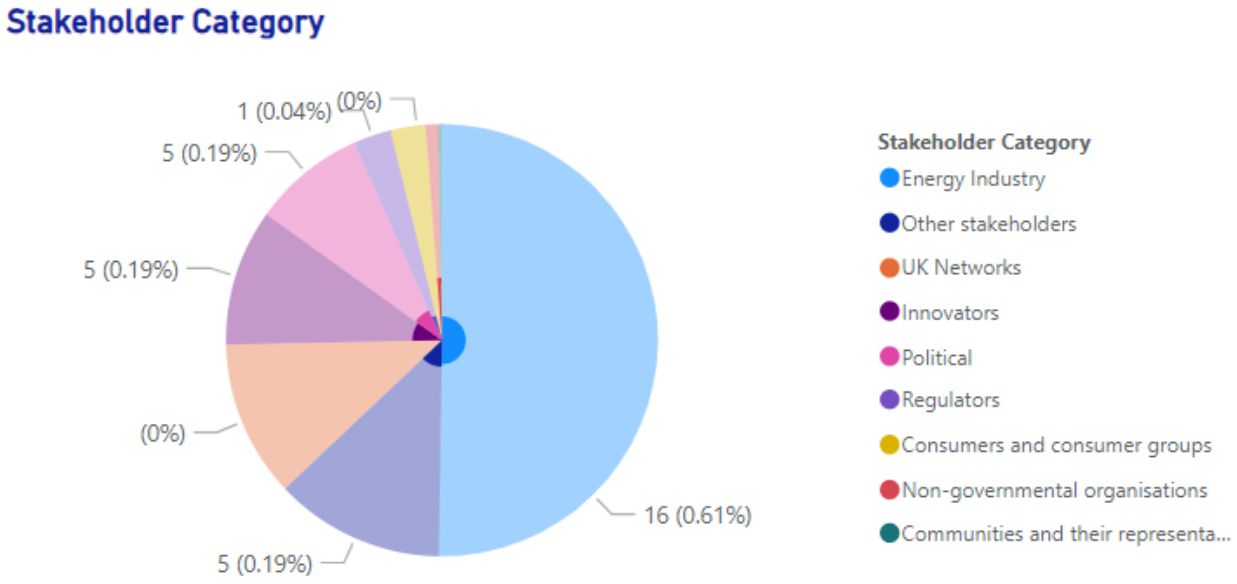
Our engagement: Call for Evidence (September)

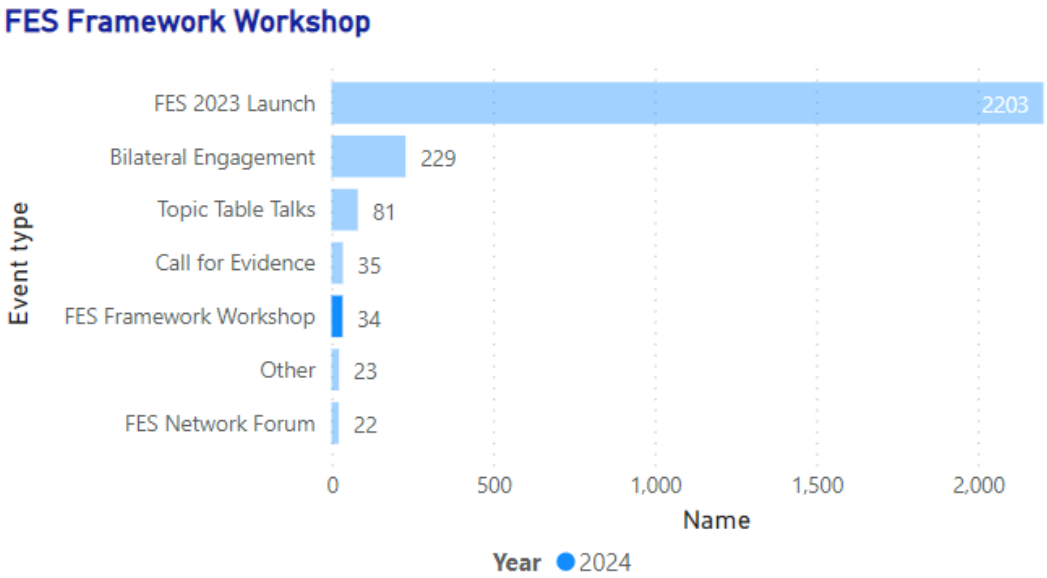




We received 35 responses to our Call for Evidence which is lower than in previous years. We are exploring ways to improve engagement in this form for next year to provide the opportunity for all who wish to contribute.

Our engagement: FES framework workshop (28 September)

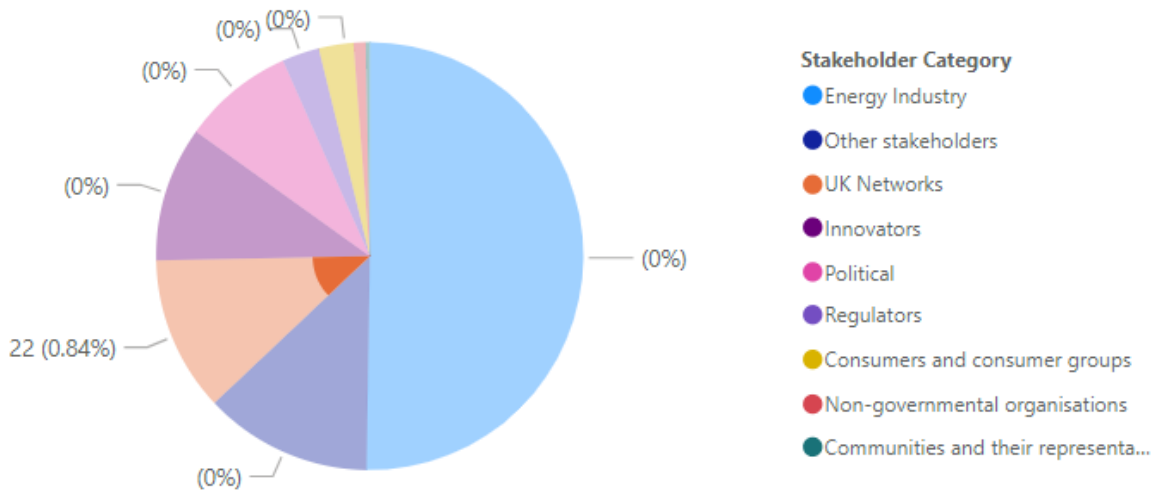




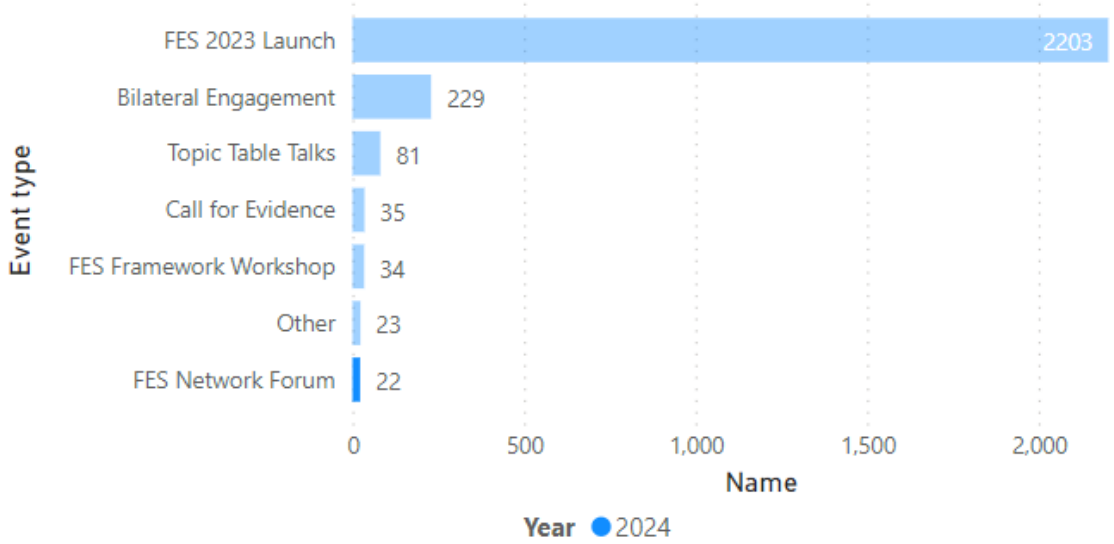
Our framework workshop was held in London on 28 September 2023. We opened the invite to all of our stakeholders through our newsletter and promoted via ESO social media channels.

Our engagement: Network Forum (3 October)

Stakeholder Category



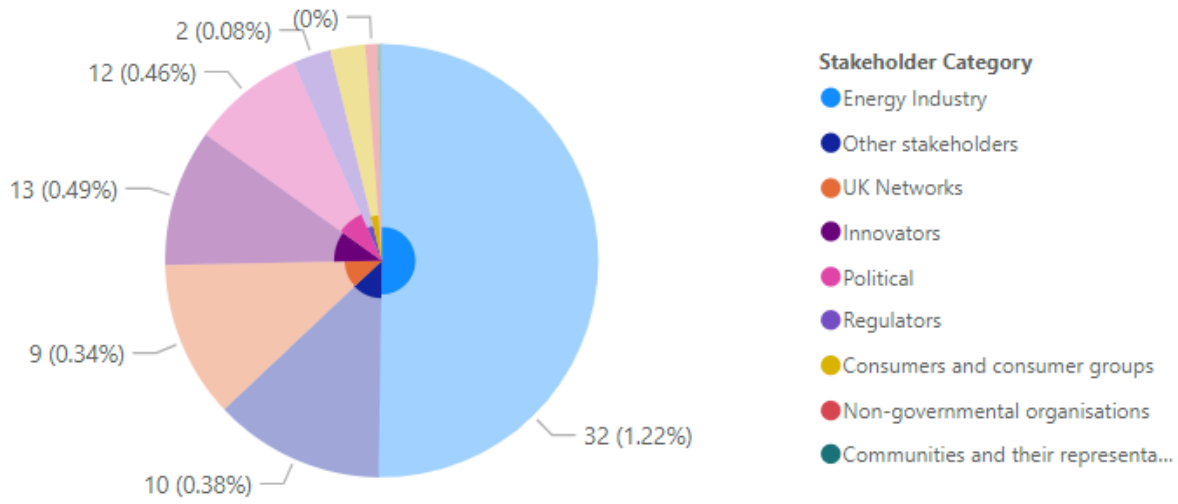
FES Network Forum



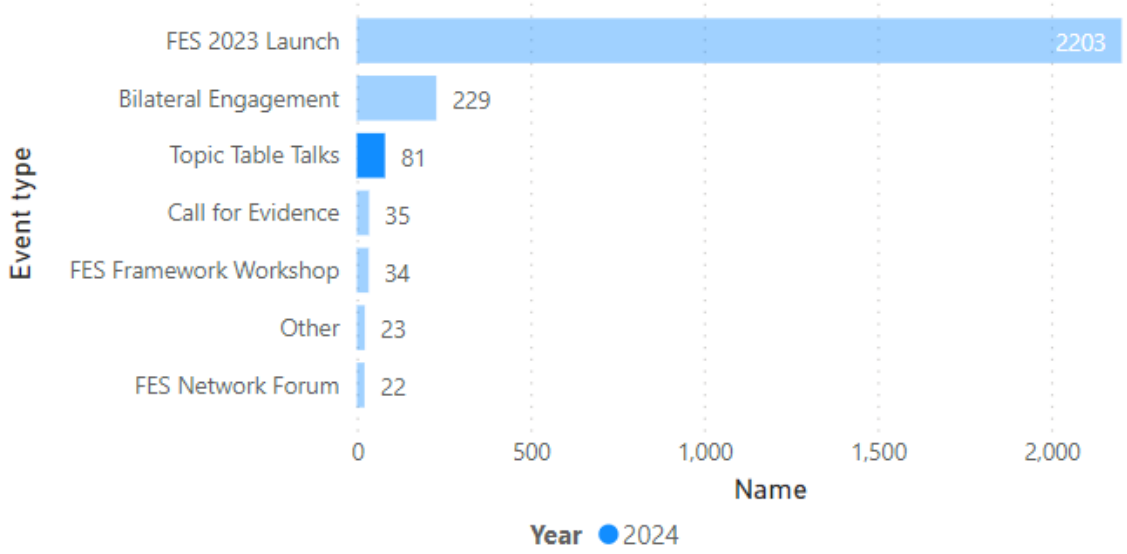
ESO

Our engagement: Topic Table Talks (30 November)

Stakeholder Category



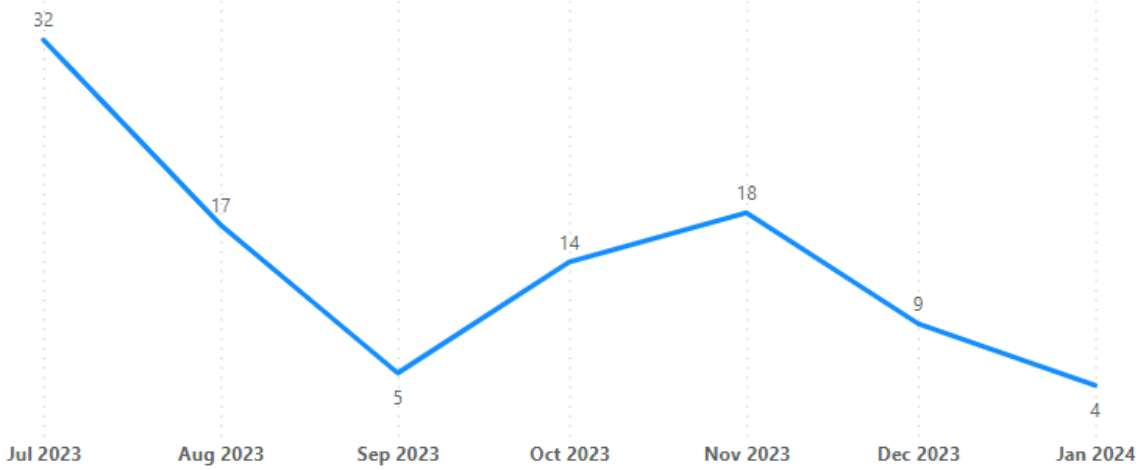
Topic Table Talks



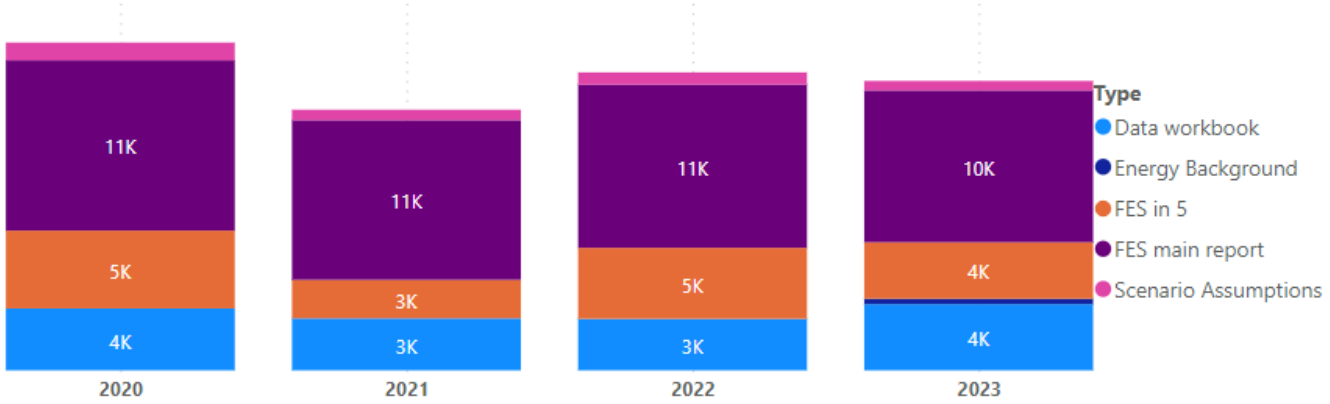
ESO

Stakeholder satisfaction and communication

Queries per month



Document downloads



Event name	FES cycle	Satisfaction	Target
Bilateral engagement	2023	8.68	8.15
Bilateral engagement	2024	8.75	8.15
FES launch	2022	8.23	8.15
FES launch	2023	8.32	8.15
FES framework workshop	2024	8.37	8.15
Topic Table Talks	2023	8.72	8.15
Topic Table Talks	2024	8.37	8.15

	2023	2022	2021	2020
FES website views	49,751	109,618	116,486	62,729
ESO data portal	5,937	5,466	n/a	n/a

Summary of views from interested parties

The following pages summarise the views of our stakeholders and insight gathered during our engagement for FES 2024. These pages outline where, together with our expertise, research and evidence, this insight has been used to model and produce credible pathways for FES 2024.

The views presented in the following summaries are those collected from stakeholders and do not present the views of the ESO.

Where feedback has not been actioned, we have included the rationale. Any areas of uncertainty are also set out within each section.

Thank you to all those who have contributed to FES 2024. We value all feedback, evidence, research and insight that we receive throughout the annual cycle.

Summary of views from interested parties

An explanation of how these responses are being considered in the design of our framework and pathways

Engagement and communication

Summary:

- Stakeholders find our FES year-on-year comparison document very valuable.
- Stakeholder would like a notification when a new version of the FES data workbook is published.
- Some stakeholders expressed views that clearer and more detailed assumptions (particularly at a regional level) would be beneficial.
- Some stakeholders highlighted a desire for enhanced resolution of graphics in the main FES report to improve visibility.
- Linking the FES report to government policy would be helpful.
- An agenda/advance notice of topics in bilateral meetings would add more value to the engagement and ensure relevant contacts are there.
- Using videos to explain the different aspects of modelling and interactions would be good.
- Some stakeholders requested we provide as much notice as possible for in-person events and look to host events and online options for those outside of London.
- Ability to submit questions in advance of the launch programme of events.

How this will or won't be taken forward:

- We will continue to provide a year-on-year comparison document but we anticipate this document may differ from previous versions due to the FES 2024 framework change from scenarios to pathways.
- We will ensure that the website and subsequent newsletters provide notifications for new versions of the data workbook.
- We are exploring different ways of presenting our assumptions and will publish a separate document alongside the main report.
- We will look to enhance the resolution of our images and graphs for on-screen and print versions of the main report and FES in 5 in collaboration with our design agency.
- We provide policy tables within the main report and FES in 5. We are exploring further ways of linking to policy.
- We will ensure an agenda with advance notice of topics and questions will be distributed ahead of each bilateral meeting.
- We are exploring the potential for use of videos for FES 2024 explaining our new FES 2024 framework and modelling approach.
- We will aim to provide a minimum of three months' notice for our in-person events and provide online options if suitable. We will also consider venues outside of London where appropriate, but from our experience, events in London have seen better attendance.
- We will consider the value and best way to allow questions to be submitted in advance for our FES 2024 launch events.

Summary of views from interested parties

An explanation of how these responses are being considered in the design of our framework and pathways

Framework and publications

Summary:

- Stakeholders are generally supportive of the move to pathways and the changes to the FES 2024 framework but wish to see further detail on the pathways as it becomes available.
- Stakeholders welcome the move away from the two-dimensional axes and the additional level of detail over the selected levers shown on the spider diagram.
- Stakeholders are more concerned about the levers and inputs to the pathways and the level of transparency that is presented rather than the framework itself.
- There have been several requests for an additional publication, setting out the new framework.
- Stakeholders were supportive of an updated Falling Short scenario forming the basis for the counterfactual.

How this will or won't be taken forward:

- FES 2024 will move to the new framework as set out on page 4 of this document.
- We will continue to engage with our stakeholders about the levers and inputs to the pathways.
- We will aim to provide additional detail around the levers in our updated assumptions document which will be published alongside FES.
- We will aim to publish a new framework explainer document prior to the publication of the main FES analysis.

Summary of views from interested parties

An explanation of how these responses are being considered in the design of our framework and pathways

Data and modelling

Summary:

- Some stakeholders requested additional information to help them understand the assumptions that underpin the analysis we perform.
- Some stakeholders had specific questions as to what is included in our modelling or not.
- Some stakeholders believed our modelling requires a higher level of temporal granularity and regional disaggregation in the published results.
- Stakeholders were supportive of increasing the economic and behavioural modelling throughout our analysis.
- Stakeholders liked the data workbook and appreciated that this data was made available.
- Some stakeholders found the data workbook hard both to navigate and find what they were looking for.

How this will or won't be taken forward:

- We will ensure that our assumptions document, published alongside the main FES documents, are discoverable and review these for clarity of our assumptions around key levers. Likewise, we will continue to develop the modelling methods document to help stakeholders understand what is included in our modelling.
- We will review our communication of changes in the modelling and ensure it is made clearer.
- As the models are developed, these will include higher temporal and geospatial information and will incorporate appropriate levels of economic modelling. We will consider the most appropriate way to present this in our data workbook.
- We will continue to review and develop how data is shared externally to ensure that it meets the needs of stakeholders.

Key areas of uncertainty:

- Contractual arrangements around third-party data may limit the granularity of what can be shared.
- It is important to balance the sharing of increased resolution of data with the limitations of the current routes and discoverability, noting the comments about the existing data workbook being hard to navigate.

Summary of views from interested parties

An explanation of how these responses are being considered in the design of our framework and pathways

Energy demand: Transport

Summary

- Stakeholders expressed views that in order to achieve ‘Leading the Way’ and ‘Consumer Transformation’, the overall size of the car market and Battery Electric Vehicles (BEV) sales figures in FES 2023 needed to be very strong.
- Despite the Internal Combustion Engine (ICE) vehicle ban date moving back to 2035, there is broad confidence on BEV uptake from stakeholders. The introduction of the Zero Emissions Vehicle (ZEV) mandate adds certainty, year-on-year Electric Vehicle (EV) uptake has been consistently in line with our Five-year Forecast.
- Many stakeholders are sceptical of hydrogen for transport, even for Heavy Goods Vehicles (HGVs).
- The main areas of uncertainty are around levels of smart engagement and Vehicle-to-Grid (V2G). V2G upper range is seen as quite ambitious, but if pathways are now stating what ‘should happen’ there is a case for this to be maintained.
- HGV assumption updates: lifespans and split between <26t and >26t HGVs updated based on new data.

How this will or won’t be taken forward:

- We are moving to a ‘single projection’ for EV car uptake, which follows the ZEV mandate.
- We will lower hydrogen transport demand in non-HGV subsectors, but Pathway 3 (Strategic Hydrogen) continues to see Hydrogen Fuel Cell (HFC) HGVs dominating.
- We will continue to have a range of smart charging and V2G engagement assumptions across the pathways to reflect uncertainty.
- We will aim to explore the impact of lower levels of flexibility engagement in a 'What If' study.

Key areas of uncertainty:

- Levels of V2G engagement.
- Annual passenger vehicle sales – ZEV mandate specifies a % of EV sales that manufacturers must meet, but there can be significant variation in passenger vehicle sales numbers year-to-year. Consistently low sales would affect the speed of decarbonisation of the transport sector by reducing the minimum numbers of EV sales seen.

Summary of views from interested parties

An explanation of how these responses are being considered in the design of our framework and pathways

Energy demand: Industrial and commercial

Summary

- Several large industrial energy users highlighted the significant uncertainty in costs and timings surrounding various decarbonisation routes, including access to hydrogen, Carbon Capture and Storage (CCS) and electrification.
- Electrification of suitable industrial processes was seen by some as a challenge with potentially high cost, but one carrying potentially less technical risk in some areas.
- Individual sectors had differing views of the potential to engage with demand flexibility.

How this will or won't be taken forward:

- We have used feedback from industrial users to guide several of our input assumptions around future underlying demand for particular sectors.
- Industrial hydrogen demand growth within the pathways will be linked to expected production pipeline in industrial clusters in the short to medium term.
- We are developing a new industrial model to better capture fuel switching in difficult to decarbonise sectors.

Key areas of uncertainty:

- Timeline and costs for carbon capture and hydrogen and how these may be shared across organisations within a particular site.
- Access to hydrogen for some difficult to decarbonise, dispersed industries that are located far from potential hydrogen clusters.

Summary of views from interested parties

An explanation of how these responses are being considered in the design of our framework and pathways

Energy demand: Heat and appliances

Summary

- Stakeholders agree that the decarbonisation of heat is a significant challenge and there will be infrastructure challenges with all options.
- A majority of stakeholders thought hydrogen for heat levels in ‘System Transformation’ (FES 2023 and 2022) were too high, including some stakeholders in the hydrogen industry.
- Some stakeholders feel that it is important to have a pathway showing widespread access to hydrogen for heat prior to a decision being made it 2026.
- Most stakeholders thought that if hydrogen was used for heat, it would be most likely around local regional areas, e.g. around industrial clusters. Though some stakeholder felt it could be used more widely.
- Most stakeholders thought that heat pumps would be optimal for most homes.
- Energy efficiency is key for all heating technologies to reduce demands and costs to consumer and should be prioritised.
- Consistent messages from stakeholders on the need for policy and certainty in areas such as zoning, targets, regulation and supply chains.

How this will or won’t be taken forward:

- Maximum uptake of hydrogen for residential heat has reduced across the pathways but pathway 3 will still include widespread access to hydrogen for heat.
- Based on real-world data, heat pump coefficients of performance have been increased, as have capex costs.

Key areas of uncertainty:

- Policy decision on hydrogen for heat (due 2026)
- How district heat will be rolled out.
- The extent to which heat pumps can provide flexibility, and the effect on peak demand in an electrified scenario.

Summary of views from interested parties

An explanation of how these responses are being considered in the design of our framework and pathways

Regional insights

Summary

- There have been some significant changes in how future regional energy systems might operate as part of the Centralised Strategic Network Plan (CSNP), in particular the new regional energy strategic plans and the ongoing publication of local area energy plans. Stakeholders have been strongly supportive of the need for coordination between the various levels of local and network planning but are keen to understand how this will be implemented.
- The new pathways have also been positively received. Several regional network operators identified concerns over how network constraints could or should be modelled within the pathways, how the pathways might be costed and whether they reflected an optimum or likely view of the future.

How this will or won't be taken forward:

- We are looking at how FES forecasts and data might be incorporated as part of the detailed design of the new regional system energy planning role.
- We have committed to a series of Electricity Network Association (ENA) sponsored workshops to look at the impact of the new pathways on regional processes such as the Distributed Future Energy Scenarios (DFES).

Key areas of uncertainty:

- How the link between regional FES, DFES and local area energy plans will work in practice.
- How to capture regional ambitions, progress and targets within a national energy framework like FES.
- Local development of heat and hydrogen networks and how this could be fed into the FES framework.

Summary of views from interested parties

An explanation of how these responses are being considered in the design of our framework and pathways

Whole energy system, gas supply and hydrogen

Summary

- The growth of low-carbon hydrogen supply and demand was a key talking point among stakeholders. While it is seen as a route to decarbonising UK energy, questions were asked over the pace and location of production, as well as who would use it and how.
- There was a consensus that growth would originate from the UK's industrial clusters. While renewable electrolytic hydrogen production was considered the ideal by most, those questioned collectively indicated that initial supply is expected to be dominated by 'blue' hydrogen created from methane. This was to ensure stability and scale of supply while green projects reach increased output levels.
- Beyond direct hydrogen market developments, many felt that methane had a sustained role to play in the UK energy mix, potentially longer than had been indicated in previous forecasts.
- There remained a distinct split in opinion on the topic of biomass use, particularly when it comes to their application in the area of 'negative emissions'. Stakeholders noted negative emission technologies such as Bio-Energy with Carbon Capture and Storage (BECCS) are likely to be needed for meeting net zero. However many felt this should be only be used as the last technology to be deployed to offset hard to decarbonise sectors such as aviation and agriculture.

How this will or won't be taken forward:

- We will incorporate the views on the scale and pace of hydrogen development into the FES pathways.
- We aim to explore the impact to net zero and carbon budgets of a slow move away from natural gas for residential heating in a what if study.

Key areas of uncertainty:

- Outstanding policy decision of hydrogen for heat.
- The potential for 'negative emission' classifications to be modified, impacting on net zero plans.

Summary of views from interested parties

An explanation of how these responses are being considered in the design of our framework and pathways

Electricity supply and modelling: Interconnection and transmission connected generation

Summary

- There are conflicting views on the development of interconnector capacities and what level these may peak or be optimal. Stakeholders indicated that future development may have a greater focus on offshore hybrid assets and promotion of offshore wind/North Sea energy islands/grid than bilateral importing and exporting of electricity.
- There are a range of views about the amount of tidal and offshore wind power included, as well as concerns regarding future wind projects in light of the recent Contract for Difference (CfD) results and inflationary impacts on project costs. Those same results led other stakeholders to suggest significantly more tidal power should be included. We also received strong representation on the amount of nuclear power; some indicating that significantly more should be included over other forms of generation.

How this will or won't be taken forward:

- We will update capacity forecasts to reflect the latest information we have received on Offshore Hybrid Assets (OHA).
- We will ensure that the outputs of network modelling from the transitional Centralised Strategic Network Plan (tCSNP), which considers economic benefits, including the interconnector capacity assumptions are considered.
- Further assess how the nuclear ambition for 2050 is reflected in our analysis during this cycle.
- We will reassess the levels of tidal stream capacity within our analysis.
- Our Capacity Expansion Model (CEM) will test the economic viability of the future capacity mix.

Key areas of uncertainty:

- The amount of nuclear that is expected to be delivered: the target stated is "up to 24 GW by 2050".
- Inflation rate and impact on development of new generation projects.
- Levels of interconnection post-2035.
- Optimal interconnection capacity vs forecast interconnection capacity.

Summary of views from interested parties

An explanation of how these responses are being considered in the design of our framework and pathways

Electricity supply and modelling: Distributed generation and storage

Summary

- We received mixed feedback on our storage forecasts – some feel that the forecasts, particularly for battery storage, are too high and that that the market can't sustain such levels of capacity. Others feel that the forecasts don't take into account the pipeline of accepted to connect projects.
- We have also received feedback that our storage modelling should be more integrated cross vector, and demand flexibility has been highlighted as another possible alternative to storage. Stakeholders highlighted that this should also be modelled using an integrated approach with storage, as there is a trade-off between both forms of flexibility.
- For distributed generation, improved visibility of sites with less than 1MW has led to recent changes in the Embedded Capacity Registers (ECR). We have also received feedback around where distributed generation is likely to connect geographically - this has been particularly the case for onshore wind. Our engagement has also highlighted concerns around alignment between changing national policy and the results presented by key stakeholders in the sector.

How this will or won't be taken forward:

- We will examine the flexibility requirements based upon demand to test whether this will support the balance between large storage capacities and demand flexibility.
- Our Capacity Expansion Model (CEM) will test the economic viability of the future capacity mix including, but not limited to energy storage.
- We will undertake a review of our distributed generation growth rates across technologies, particularly renewables.
- Our load factor assumptions will be reviewed following new information and stakeholder feedback.

Key areas of uncertainty:

- Collation of all Embedded Capacity Registers to understand the current Distributed Generation (DG) capacity per technology type will require improvements to data accuracy and coordination.
- Uncertainty around growth curves for DG after the end of connection queue (2035): growth curves may not necessarily continue to be linear after 2035.
- How much long-duration storage we will need in a net zero system/what technologies will play a role and how we can build the required amounts i.e. routes to market.
- How much domestic-scale battery storage will we have by 2050.

ESO Innovation projects

A summary of key innovation projects during 2023

Consumer Build Blocks

The Consumer Build Blocks project aimed to better understand the energy consumption patterns of households and businesses. It developed a series of standard archetypes for domestic, industrial and commercial users to help us more accurately model consumer energy use scenarios and plan a future-ready energy system.

The project involved extensive research into energy consumption patterns, as well as engagement to understand consumer energy needs and preferences. We are currently assessing how to integrate the outputs of the project, alongside other changes, to our FES modelling.

Understanding consumers is an essential part of decarbonising the electricity network and achieving zero-carbon operation by 2025. The archetypes this project develops will give the ESO, and its whole energy system partners, a common approach to modelling consumer behaviours, which will deliver value for money through a more consistent and informed approach to network planning now and in the future.

Find out more **Funding:** Network Innovation Allowance (NIA)

Working with: Centre for Sustainable Energy, Element Energy

Demand Flexibility Service - Evaluation

The Demand Flexibility Service (DFS) is the largest demand response scheme to have taken place on Britain's electricity network to date. The service ran from November 2022 to March 2023, with 20 test events and two live events. 1.6 million households and businesses participated, delivering in total of 3,300MWh of electricity reduction.

The evaluation was run to consider the range of factors that may have shaped household engagement with the DFS. Data about household experiences and household smart energy capabilities were collected from four sources: diaries, opinion polls, online surveys and semi-structured interviews.

Important lessons can be drawn from the households who took part in this engagement evaluation. These should be used in future flexibility service design by procuring organisations like ESO as well as by flexibility service providers to consider how to improve household engagement with domestic flexibility services.

You can read the full report by using the link below.

Find out more **Funding:** Network Innovation Allowance

Working with: Centre for Sustainable Energy

ESO Innovation projects

CrowdFlex

CrowdFlex is exploring how interconnected consumer demand and flexibility models can enable the forecasting, planning and delivery of useful day-to-day domestic flexibility. This will include using smart devices (e.g. smart white goods, EV chargers and heat pumps). Data will be gathered from trials of two kinds of domestic flexibility services:

Utilisation payments: Consumers will be paid to turn up or down demand.

Availability payments: Consumers will be paid a regular fixed payment to make their assets available (e.g., to plug in their EVs).

This large-scale demonstrator is a use case for the Virtual Energy System and will provide a crucial step in establishing domestic flexibility as a reliable energy and grid management resource. It will help consumers reduce their energy costs and enable the energy industry to meet its ambitious decarbonisation goals.

Find out more **Funding:** Strategic Innovation Fund

Working with: Octopus, OVO, Ohme, Centre for Net Zero, ERM, AWS, National Grid Electricity Distribution and Scottish and Southern Electricity Networks. Supported by The Smith Institute and Centre for Sustainable Energy.

Hydrogen Production for Thermal Constraints Management

This project is exploring whether excess renewable energy generation could be used for green hydrogen production to help manage thermal constraints on the network.

The project will build models and tools to get a detailed understanding of the potential for hydrogen production to be used as a balancing service to benefit both the operation and decarbonisation of GB's electricity and gas networks. Technical considerations, along with commercial and regulatory viability, will be considered, so we understand what obstacles need to be overcome to allow a commercial facility to offer constraint management.

The project will ascertain whether green hydrogen plants are an attractive prospect for ESO to reduce its thermal constraint costs and/or defer network reinforcement works, to help run the network in a more cost-efficient way and improve value for consumers. Green hydrogen has the potential to improve system operability by delivering flexibility at times of high generation, supporting the increased use of renewables and the decarbonisation of the network.

Find out more **Funding:** Network Innovation Allowance

Working with: Arup and National Gas Transmission

ESO Innovation projects

Powering Wales Renewably

Powering Wales Renewably is designed to accelerate the decarbonisation of the Welsh energy system through the creation of a connected digital twin of Wales' electricity transmission and distribution network, and will demonstrate the benefits of the Virtual Energy System (VES).

A digital twin will provide a whole-system view of the Welsh electricity grid, allowing us to collaborate with industry to assess the impacts of increased renewable generation on Wales' electricity network and support the Welsh Government with their ambition to generate 70% of its electricity requirements from Welsh renewable energy sources by 2030, and be fully decarbonised by 2035.

The use of a connected digital twin will provide a greater understanding of the Welsh energy system and facilitate faster connections to the electricity grid to provide local communities with locally generated electricity.

Find out more **Funding:** Strategic Innovation Fund

Working with: CGI, the Welsh Government, National Grid Electricity Distribution, National Grid Electricity Transmission, SP Energy Networks and CENIN Renewables.

Scenarios for Extreme Events

High-Impact, Low-Probability (HILP) extreme events can have serious impacts on Great Britain's energy system as we rapidly transition towards an increased dependency on renewable generation and reliance on electrification.

The increasing frequency of extreme weather events along with influences of other geopolitical events can also have direct and indirect impacts on the system.

The Scenarios for Extreme Events project will build understanding of how whole-energy system resilience can be impacted by extreme events, identifying vulnerabilities, and informing future investment planning decisions.

The project output is anticipated to be a prototype model that predicts the impacts of future HILP events. This capability would be developed and integrated into business-as-usual activities, including resilience planning and our Future Energy Scenarios.

Find out more **Funding:** Strategic Innovation Fund

Working with: University of Strathclyde, Frazer-Nash Consultancy, Cadent Gas, National Gas Transmission, Scottish Hydro Electric Transmission, and the Met Office.

ESO Innovation projects

Stability Market Design

As we move towards operating the system with less fossil-fuelled generators and more renewables on the transmission network, we need to ensure the tools to source the balancing services we require from different providers are sufficient.

The Stability Market project is exploring how short, mid and long-term markets for stability will work in practice. A similar project is also looking at voltage (reactive power). These projects are exploring who might be eligible to participate and the best way to design the markets to encourage competition and future investment.

The Stability Market project will help the ESO use more renewable and alternative technologies to provide stability services, which aims to reduce the cost of operating the system and accelerate the transition to a net zero system. The establishment of long-term markets will send signals to the market to encourage future investment in new solutions, including grid-forming capability for otherwise non-synchronous technologies (e.g., wind, solar and battery storage), which will further aid the energy transition.

Find out more **Funding:** Network Innovation Allowance

Working with: AFRY

Virtual Energy System – Common Framework

The Virtual Energy System (VES) programme is an industry-wide mission to digitalise Britain's energy system. The programme is a portfolio of projects, the foundation of which is underpinned by the development of the socio-technical Common Framework.

The Common Framework will create the common language, recommended infrastructure, and processes to connect and federate individual digital twins from across the energy sector.

We are now stress-testing the standards and governance framework that will soon facilitate collaboration and compatibility across the energy industry as we move to turn the Virtual Energy System into a reality.

The Virtual Energy System will emerge when industry build their digital twins, in line with the common framework, and then bring them together to connect as an ecosystem. The Virtual Energy System will be built piece-by-piece as more digital twins are interconnected to solve problems they cannot solve in isolation.

Find out more **Funding:** Network Innovation Allowance

Working with: Arup, in collaboration with Energy Systems Catapult and Icebreaker One.

Next steps

Our engagement, together with our modelling and analysis, will continue for FES 2024 until the time of the publication and programme of launch events in the summer.

We will continue to provide updates about our engagement activities, the launch events and thought pieces through the FES newsletter in conjunction with the FES website.

We welcome your contribution, insight and discussion throughout the year and encourage all our stakeholders to join the ongoing conversation about the future of energy.

To contact the team to provide feedback, or to subscribe to our FES newsletter, please contact us via email on FES@nationalgrideso.com.

Glossary of abbreviations and acronyms

BECCS	Bioenergy with Carbon Capture and Storage
BEV	Battery Electric Vehicle
CEM	Capacity Expansion Model
CCS	Carbon Capture and Storage
CfD	Contract for Difference
CSNP	Centralised Strategic Network Plan
CT	Consumer Transformation
DFS	Demand Flexibility Service
DFES	Distributed Future Energy Scenarios
DG	Distributed Generation
ENA	Electricity Network Association
ETYS	Electricity Ten Year Statement
EV	Electric Vehicle
ECR	Embedded Capacity Registers
FES	Future Energy Scenarios

FYF	Five Year Forecast
HGVs	Heavy Goods Vehicles
HILP	High Impact Low Probability
HFC	Hydrogen Fuel Cell
IC	Interconnector
ICE	Internal Combustion Engine
LW	Leading the Way
NIA	Network Innovation Allowance
OHA	Offshore Hybrid Assets
PHEV	Plug-in Hybrid Electric Vehicle
SoS	Security of Supply
ST	System Transformation
tCSNP	transitional Centralised Strategic Network Plan
V2G	Vehicle-to-Grid
VES	The Virtual Energy System
ZEV	Zero Emission Vehicle

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Future Energy Scenarios: ESO Pathways to Net Zero

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