Notes on Completion: Please refer to the appropriate NIA Governance Document to assist in the completion of this form. The full completed submission should not exceed 6 pages in total.

NIA Project Registration and PEA Document

Date of Submission

Jun 2022

Project Reference Number

NIA2_NGESO015

Project Registration

Project Title

FIC (Future of Interconnectors)

Project Reference Number

NIA2_NGESO015

Project Licensee(s)

National Energy System Operator

Project Start

July 2022

Project Duration

1 year and 1 month

Nominated Project Contact(s)

Magdalena Morenes

Project Budget

£400,000.00

Summary

By 2035, GB interconnector capacity is forecast to grow from ~8 GW today to 16 - 27 GW.

The net zero GB electricity system will be characterised by prolonged periods of excess or deficits of renewable electricity. Operability and capacity adequacy will be very different challenges as firm fossil plant retires and the system becomes less stable

Interconnectors have the potential to support these challenges, but the technical and commercial solutions are unclear. This project will undertake research and modelling of different net zero scenarios to investigate the role that interconnectors could play in the net zero electricity system.

The ESO proposes that nodal pricing should be introduced to the wholesale market. The impact of this on the operation of interconnectors needs to be understood.

Third Party Collaborators

AFRY Management Consulting Ltd

Nominated Contact Email Address(es)

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Problem Being Solved

ESO's Future Energy Scenarios (FES) 2021 forecast there will be 16-27 GW of connected interconnector capacity by 2035. This is an increase of 8-20GW from today. The UK Government has also set an ambition to deliver at least 18GW of interconnection capacity by 2030 as set out in the December 2020 Energy White Paper.

Interconnectors will play a central role in a flexible and secure net zero electricity system for Great Britain (GB), but there are also many uncertainties that this project aims to address.

- Flexibility and balancing – as we transition to a net zero system, we must manage more dramatic imbalances of supply and demand. This will involve an oversupply of renewables at times, and there will also be periods of excess residual demand (when there is prolonged low wind). Because of their capability to rapidly change flow direction, interconnectors will be crucial to help maintain energy balance. How will interconnectors contribute to this flexibility requirement? What could different weather patterns across continental Europe mean for interconnector flows, the frequency and magnitude of their flow direction changes and the subsequent impact on GB flexibility requirements?
- Operability – interconnectors could technically provide a range of ancillary services, increasing competition, and delivering value for consumers. However, the unique technical and commercial operating models of interconnectors make their potential participation in ancillary services markets less clear. Furthermore, without strategic coordination with cross-border parties, as well as the right GB ancillary services market mechanisms and codes, interconnectors could have an adverse impact on operability of the GB system. What are the impacts that an increased level of interconnection will have on GB's system operation? How much will interconnector volume be redispatched to ensure reliable flows across boundaries on the transmission grid? In what ways could interconnectors contribute to alleviate future constraints? How does the landing point location of an interconnector affect system operability?
- Adequacy - interconnection will play an increasingly important role in the electricity supply mix and will allow Great Britain and neighbouring system operators to support each other during times of system stress, ensuring electricity supplies will continue to meet demand. How reliant will GB be on interconnectors to meet demand, and how reliant will its neighbours be on GB? How will peak requirements in GB correlate with neighbouring markets? How will reliability on interconnectors evolve into the future?
- Evolution of wholesale markets - the status quo wholesale market design is not fit for purpose for net zero as the national wholesale price coupled with locational transmission charges do not send accurate dispatch and siting signals to supply and demand assets, resulting in unnecessary balancing costs for consumers. Nodal market arrangements could provide the real-time, dynamic locational signals that are needed to inform how both supply and demand assets dispatch in operational timescales. How would interconnectors behaviour change with more locational pricing in GB? How would their provision of services and contribution to the capacity market be impacted? Would their business model change?

This project will take a first step towards providing a response to these questions, taking into consideration the uncertainty that remains about the policies and roadmap that will lead us to net zero, both in GB and its neighbouring countries.

Method(s)

Detailed modelling will be undertaken based on the ESO's Future Energy Scenarios (FES) 2022 scenarios, focusing on the 2025-2035 timeframe. These scenarios outline four potential pathways to 2050, with different assumptions in terms of energy supply and demand, reflecting the unpredictability of the energy transition. Although there is no certainty that the evolution of the energy system will follow any of these specific trajectories, they provide a robust and industry wide accepted baseline to investigate the future.

Modelling work will be complemented by extensive research activities, qualitative insights from relevant market experts, an analysis of other markets, the review of operational data, and stakeholder engagement within the ESO and externally.

These analysis and research activities will be divided in three phases:

Phase 1 will set the scene and, through modelling, provide an understanding of the energy mix attributes of each of the selected FES scenarios up to 2035. The intention of the modelling work undertaken in this phase will be to explore the issues that the system may present: how much frequency/response support will be needed in the future? What resources will be available to provide it? How much interconnector volume will be redispatched to ensure reliable flows across boundaries on the transmission grid? Weather pattern selection will be a key part of this phase, and this information will be used in the next phase to obtain insights on how extreme weather might impact the interconnectors' behaviour and exacerbate or relieve flexibility, adequacy or operability problems in GB.

Phase 2 will define the future role of interconnectors in supporting adequacy, flexibility and operability requirements for each scenario analysed in Phase 1. This will be done through a deeper interrogation of modelling data and through engagement of industry experts. Some sensitivities will be looked into as part of this phase, seeking to address specific questions about the future role of interconnectors. These include:

- Locational wholesale market: this analysis will look into how zonal and nodal market arrangements would impact on interconnectors. This will be done by splitting GB into zones and comparing the behaviour of interconnectors relative to current market arrangements. The impact of different landing points, one side and the other of boundary constraints, will also provide insights into how constraint costs might be reduced by introducing zonal or nodal pricing versus the current market design. In parallel, research will be conducted to understand how zonal and nodal pricing could impact the interconnectors business models and their participation in ancillary

services and the capacity market.

- Multi-Purpose Interconnectors (MPIs): MPIs will be modelled as an interconnector with an offshore wind farm directly connected to it. This analysis will identify the differences between MPIs and interconnectors in the areas of adequacy, flexibility and operability. The specificities and implications of “offshore bidding zone” and “home market” arrangements will also be explored.
- Ancillary services: interconnectors will be included in explicit reserve/response products, providing information on the opportunity cost for interconnectors of providing these services.

Phase 3 will then identify, develop and assess options for how the ESO and industry could maximise the potential of interconnectors for the net zero GB system. This phase will be supported by engagement with experts from ESO and the wider industry.

Scope

The scope of each phase of the project is clearly defined with specific deliverables and questions requiring an answer:

Phase 1 – Status quo and future net zero landscape

The market modelling and analysis conducted in this phase will aim at:

- Understanding current interconnector operational behaviour and business models
- Gathering insights into the energy system of each of the selected future energy scenarios and target years, in Britain and its neighbouring countries (e.g. supply and demand mix and patterns, flows and trends)
- Identifying which technologies and service providers will be available to meet the future needs of the system in the areas of flexibility, capacity adequacy and operability (e.g. how much capacity will be available to provide adequacy, other than the capacity provided by interconnectors? And from which sources?)

Phase 2 – Role of interconnectors in the net zero system

Through a deeper interrogation of the modelling data and expert engagement, this phase will provide a quantitative and qualitative assessment of the risks, opportunities, blockers and enablers related to interconnectors in the future energy scenarios analysed. Some of the questions that this phase will look into are:

- How could interconnectors provide support to the net zero system in terms of flexibility/capacity adequacy/operability? What potential barriers are there to this?
- What are the challenges brought by interconnectors in each of these areas? How can these be mitigated?
- Taking into consideration the needs of the system, what role should interconnectors take in flexibility/capacity adequacy/operability support?
- What will their impact be on carbon emissions?
- How would interconnector behaviour change if the GB wholesale market was reformed to include more locational pricing?
- How do we expect MPIs will behave relative to traditional interconnectors?

Phase 3 – Role of the ESO

Building on the conclusions delivered in Phase 2, this phase will identify a long-list of possible tools, levers or mechanisms that ESO and the wider industry could consider to lead to interconnectors benefitting the GB system more optimally. Identification of items on the long-list will not be constrained by existing commercial and regulatory frameworks or by existing organisational or institutional structures.

Because the project will model and analyse four different future energy pathways, we expect the results and findings to diverge between scenarios. There is even a risk that contradictory conclusions are reached between one scenario and another. Having visibility of this divergence will be essential in the development of recommendations.

Objective(s)

The main objectives of this work will be to:

1. Provide a clear insight into how interconnectors currently operate and behave in GB’s energy system, establishing a baseline as a reference point for future looking analysis.
2. Examine the physical characteristics of GB and its neighbouring markets under selected Future Energy Scenarios (FES) cases for 2025, 2030 and 2035, investigating the requirement for and resource availability to provide flexibility, operability and adequacy needs.
3. Assess the potential role of interconnectors, and the opportunities and challenges they can offer, in a GB net zero system.
4. Analyse how interconnector behaviour might change under different circumstances such as the introduction of locational pricing in GB or the development of MPI models.
5. Identify potential barriers to and risks of provision of system services by interconnectors in a net zero system.

6. Identify a long-list of possible tools, levers or mechanisms that ESO and the wider industry could consider to lead to interconnectors benefitting the GB system more optimally

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

The ESO does not have a direct connection to consumers, and therefore is unable to differentiate the impact on consumers and those in vulnerable situations. Benefits to all consumers are detailed below.

This project has been assessed as having a neutral impact on customers in vulnerable situations because it is a transmission project.

Success Criteria

This research project will lead to a better understanding of how interconnectors currently behave and operate in GB's energy system and how their contribution to the system might change as the number of interconnectors increases and the system evolves towards net zero. It will also enable the identification of innovative market solutions that could facilitate a more optimal use of interconnection.

The work will be developed with industry collaboration, and stakeholder acceptance and adoption of the analysis and results will be a key element of its success.

Within the stakeholders concerned by this work it is worth highlighting GB's neighbouring countries. Future interconnector operations will by nature depend not only on GB's market evolution, but also on the connecting countries electricity system changes. By sharing this analysis with its wider European counterparts, the ESO will take a leading role in shaping the conversation outside of the GB borders, and will contribute to the progression towards common net zero objectives

Project Partners and External Funding

Project partner: AFRY, no external funding contribution.

Potential for New Learning

The outputs from this project will be disseminated through a final written report that will detail the main findings and conclusions of phases 1, 2 and 3. The modelling approach and assumptions taken to reach those conclusions will also be described.

The report will provide an insight into what the future might look like for interconnection in GB, bringing to the fore the opportunities presented by interconnectors for the energy system operation and highlighting where there might be challenges that need to be addressed. The analysis will focus on three key areas that are generally approached individually – flexibility, capacity adequacy and operability – bringing these three elements together to form a single whole long-term picture.

Providing visibility on how interconnector operations might evolve, and what measures could be taken to maximise their full potential as we transition to net zero will benefit both government and the wider industry.

The modelling work developed as part of the project will provide information on the behaviour of interconnectors that has not been examined previously. Modelling sensitivities will look into areas of particular relevance given the trends currently observed in the electricity system, such as the emergence of Multi-Purpose Interconnectors and the potential transition towards locational wholesale pricing.

Additional new insights will also be provided on marginal carbon intensity and average carbon intensity from destination/origin markets, as well as views on what interconnectors can do technically based on current/leading edge technologies.

A webinar will take place at the end of each of the three phases of the project to present and receive feedback on the results of the research to key stakeholders. Further individual engagement will also take place as required while the project is being developed.

Scale of Project

This project will span 12 months with AFRY delivering the work.

This is a research and analysis project that will explore the future role of interconnection in GB through new modelling done across four different potential future scenarios in three phases of work

The modelling work will be a combination of the four FES 2022 scenarios and two European scenarios. The analysis will dig into interconnector specificities not covered by the FES and the role that the ESO could take to optimise cross-border arrangements. Each scenario may lead to different conclusions in terms of what the role of interconnection will be and therefore what the role of the ESO could look like. There is therefore the risk that final recommendations vary between the scenarios.

Technology Readiness at Start

TRL2 Invention and Research

Technology Readiness at End

TRL3 Proof of Concept

Geographical Area

This project will cover the whole of the GB network and critical connected markets including: Netherlands, Belgium, France, Norway, Denmark, Germany, Ireland.

Revenue Allowed for the RIIO Settlement

None

Indicative Total NIA Project Expenditure

£400,000

Project Eligibility Assessment Part 1

There are slightly differing requirements for RIIO-1 and RIIO-2 NIA projects. This is noted in each case, with the requirement numbers listed for both where they differ (shown as RIIO-2 / RIIO-1).

Requirement 1

Facilitate the energy system transition and/or benefit consumers in vulnerable situations (Please complete sections 3.1.1 and 3.1.2 for RIIO-2 projects only)

Please answer **at least one** of the following:

How the Project has the potential to facilitate the energy system transition:

This project will investigate new ways of managing and planning interconnector operations and working with key stakeholders and our European counterparts. This will have several benefits in the transition of the energy system including:

- Optimal operation of interconnectors, ensuring consumers get the maximum benefit out of them and that their potential operational impact is minimised.
- Security of supply through the sharing of best practices and information with the wider industry regarding interconnection challenges and potential solutions.
- Decarbonisation goals by providing modelling information on estimated carbon impact of interconnector flows, as well as analysing how interconnectors can provide flexibility and operability services to support a stable and operable zero carbon system.
- Wider picture considerations by examining GB's connecting countries energy transition ambitions and how these might impact GB's own objectives through interconnectors behaviour and operations.

How the Project has potential to benefit consumer in vulnerable situations:

Not required.

Requirement 2 / 2b

Has the potential to deliver net benefits to consumers

Project must have the potential to deliver a Solution that delivers a net benefit to consumers of the Gas Transporter and/or Electricity Transmission or Electricity Distribution licensee, as the context requires. This could include delivering a Solution at a lower cost than the most efficient Method currently in use on the GB Gas Transportation System, the Gas Transporter's and/or Electricity Transmission or Electricity Distribution licensee's network, or wider benefits, such as social or environmental.

Please provide an estimate of the saving if the Problem is solved (RIIO-1 projects only)

Not required.

Please provide a calculation of the expected benefits the Solution

Not required as this is a research project

Please provide an estimate of how replicable the Method is across GB

This research project will examine the characteristics of the future energy environment and the direction that the ESO could take to optimise interconnectors' role as the energy system evolves and interconnector capacity scales up.

In addition to the modelling results and quantitative conclusions that will result from the analysis, the project will deliver a key metrics dashboard in Power BI format. This dashboard will provide the capability to conduct future analysis through the assessment of interconnector behaviour across updated/different scenarios. This tool will contribute to the longevity of the project, facilitating further analysis after project closure and allowing a regular review of the conclusions obtained.

Please provide an outline of the costs of rolling out the Method across GB.

This research project will examine the characteristics of the future energy environment and the direction that the ESO could take to optimise interconnectors' role as the energy system evolves and interconnector capacity scales up. At this stage, costs cannot be

estimated as the project outcome will be exploring options rather than developing an implementable solution.

Requirement 3 / 1

Involve Research, Development or Demonstration

A RIIO-1 NIA Project must have the potential to have a Direct Impact on a Network Licensee's network or the operations of the System Operator and involve the Research, Development, or Demonstration of at least one of the following (please tick which applies):

☐ A specific piece of new (i.e. unproven in GB, or where a method has been trialled outside GB the Network Licensee must justify repeating it as part of a project) equipment (including control and communications system software).

☐ A specific novel arrangement or application of existing licensee equipment (including control and/or communications systems and/or software)

☐ A specific novel operational practice directly related to the operation of the Network Licensees system

☐ A specific novel commercial arrangement

RIIO-2 Projects

☐ A specific piece of new equipment (including monitoring, control and communications systems and software)

☐ A specific piece of new technology (including analysis and modelling systems or software), in relation to which the Method is unproven

☐ A new methodology (including the identification of specific new procedures or techniques used to identify, select, process, and analyse information)

☑ A specific novel arrangement or application of existing gas transportation, electricity transmission or electricity distribution equipment, technology or methodology

☐ A specific novel operational practice directly related to the operation of the GB Gas Transportation System, electricity transmission or electricity distribution

☐ A specific novel commercial arrangement

Specific Requirements 4 / 2a

Please explain how the learning that will be generated could be used by the relevant Network Licensees

Interconnectors link the electricity transmission infrastructure of neighbouring countries and this project will look into their role in the energy system as it evolves towards net zero. It will provide modelling and insights that will complement the interconnector companies' own analysis and will allow them to take better informed decisions. The research will focus on the flexibility, capacity adequacy and operability requirements of the system and will investigate the optimum role of interconnectors in each of these areas.

Or, please describe what specific challenge identified in the Network Licensee's innovation strategy that is being addressed by the project (RIIO-1 only)

Not required.

Is the default IPR position being applied?

☑ Yes

Project Eligibility Assessment Part 2

Not lead to unnecessary duplication

A Project must not lead to unnecessary duplication of any other Project, including but not limited to IFI, LCNF, NIA, NIC or SIF projects already registered, being carried out or completed.

Please demonstrate below that no unnecessary duplication will occur as a result of the Project.

This will be the first time that the ESO has undertaken this type of work in a post-Brexit world in which our relationship with the EU has dramatically changed. This is against a backdrop of the fast evolving energy system and levels of interconnection never before experienced. There is existing activity looking at the areas proposed by the project but none focus on setting an encompassing vision or direction as this one would. Data needed or this project will be provided from the follow.

ESO workstreams:

FES (July 2022): outlines four different pathways for the future of energy between now and 2050: Steady Progression, Consumer Transformation, System Transformation and Leading the Way.

Capacity Market Registers and Electricity Capacity Reports: they outline the modelling approach and recommended capacity to secure for capacity auctions.

Electricity Ten Year Statement (Nov 2021): determines future transmission network needs looking at boundary flow requirements.

NOA for interconnectors (Jan 2022): provides an assessment of the optimal mix of interconnection capacity for each of the FES scenarios by examining social economic welfare, interconnector capital expenditure costs and reinforcement costs. It excludes any analysis of the impact of additional interconnection on operating the transmission system.

Net Zero Market Reform (May 2022): explores how electricity markets need to change from 2030 onwards to meet the long-term challenges facing the GB electricity system.

Markets Roadmap (Feb 2022): provides a future vision of the markets owned and operated by the ESO from today to 2030.

Operability Strategy Report (Jan 2022): defines the ESO's operational requirements and identifies future system needs. Considers operability challenges in five key areas: Frequency, Stability, Voltage, Thermal and Restoration.

Long-term Adequacy Study (Ongoing): will define what the optimum capacity mixes are to meet demand at difficult periods.

Cap and Floor Application Window 3 (June 2022): report requested by Ofgem covering the system operability impacts of various hypothetical combinations of interconnectors between GB and its neighbours.

Cross Border Balancing Project (Ongoing): will analyse different market options to access energy from the continent via interconnectors in balancing timeframes (after gate closure). Coordination will be required to ensure no duplication of internal engagement activities.

Dynamic Containment (DC): explores how interconnectors can participate in DC.

Net Zero Strategy Flexibility: looks at alternative operability options which don't have carbon impacts whilst still maintaining security of supply. For example, using zero carbon sources like wind and solar instead of powering up a coal or gas plant, which produces carbon if we need more system services.

UK Government workstreams:

BEIS Offshore Transmission Network Review: considers the role of Multi-Purpose Interconnectors (MPI) in meeting net zero and how the transmission regime can support the delivery of MPI projects.

BEIS Smart Systems and Flexibility Plan: sets out a vision, analysis and work programme for delivering a smart and flexible electricity system, exploring the changes needed to support increased levels of interconnection capacity and how to facilitate efficient and flexible access to cross-border markets.

Ofgem Interconnector Policy Review: sets Ofgem's vision for GB interconnector regulation in the future, and the changes that will be made to the cap and floor regime for future projects.

European workstreams:

UK's neighbouring countries carry out their own future energy system analysis and reports. Examples of these are ENTSO-E's Ten Year Network Development Plan (TYNDP), Elia's Roadmap to Net Zero or RTE's Futurs Energetiques. These studies will be key inputs into this project, providing insights into the future evolution of these markets and their objectives in terms of interconnection with GB.

If applicable, justify why you are undertaking a Project similar to those being carried out by any other Network Licensees.

Not applicable.

Additional Governance And Document Upload

Please identify why the project is innovative and has not been tried before

Net zero targets and the current global energy crisis are leading to an evolution in the energy system, both in GB and its neighbouring countries. The additional interconnector capacity expected in the future 15 years will become available in a completely different environment to previous developments. Net zero in particular will present system challenges in three key areas:

- Flexibility: balancing energy variability from renewables;
- Operability: maintaining system stability in operational timescales with a more varied resource mix; and,
- Capacity adequacy: ensuring security of supply with a changing mix and price/revenue volatility

There is currently a lack of information on what the interconnectors' contribution will be in this new landscape and how this contribution might evolve as the system develops in one direction or another.

Furthermore, following Britain's exit from the EU, new ways of working with Europe are being developed that increase at this moment the uncertainties regarding cross-border developments.

Relevant Foreground IPR

The following deliverables will be generated as part of this project:

- Future landscape GB & Europe report
- Future role of interconnectors report
- Final Report

Data Access Details

Data for this project and all other projects funded under the Network Innovation Allowance (NIA), Network Innovation Competition (NIC) or the new Strategic Innovation Fund (SIF) can be found or requested in a number of ways:

1. A request for information via the Smarter Networks Portal at https://smarter.energynetworks.org, to contact select a project and click 'Contact Lead Network'. National Grid ESO already publishes much of the data arising from our innovation projects here so you may wish to check this website before making an application.
2. Via our Innovation website at https://www.nationalgrideso.com/future-energy/innovation
3. Via our managed mailbox innovation@nationalgrideso.com

Details on the terms on which such data will be made available by National Grid ESO can be found in our publicly available "Data sharing policy relating to NIC/NIA projects" at https://www.nationalgrideso.com/document/168191/download

Please identify why the Network Licensees will not fund the project as apart of it's business and usual activities

Due to the future level of interconnection expected, the specificities of GB's interconnector commercial arrangements and the impact of the EU Exit on interconnector operations, GB finds itself in a unique situation when compared with its neighbouring countries. GB has not faced a future landscape like this before and there are no other markets we can learn from as this situation is specific to GB.

Previous studies delivered by the ESO and other public and private institutions have looked into some of the long-term effects of interconnectors in GB's electricity system. However, none of this previous work has looked in parallel and in an integrated manner at the three key dimensions of GB's electricity system: capacity adequacy, operability and flexibility.

Thorough research will need to be undertaken of all the internal and external work done in this area along with new modelling work of multiple scenarios to identify the potential futures. Potential and untested developments of the future electricity system will also need to be included in the analysis, such as Multi-Purpose Interconnectors or zonal/nodal market design implications. This will be followed by the identification of solutions and options. However, given the significant potential impact of the currently uncertain future there is no guarantee that the solutions identified by the analysis will be the right ones.

Please identify why the project can only be undertaken with the support of the NIA, including reference to the specific risks(e.g. commercial, technical, operational or regulatory) associated with the project

The landscape created by the increased level of interconnection, EU Exit and net zero targets is unique to GB and new to us and the wider industry. There are many unknowns about what the future could look like and information about this potential future is difficult to find, dispersed between several sources that use different baseline assumptions. The development of new cross-border arrangements following the EU Exit is underway and no visibility exists on how these will impact interconnector operations.

In this context, there is a risk that we do not choose the right direction without thorough research and analysis of the knowns and identification of known unknowns. Without this baseline work, changes in one area could end up not being joined up with changes in another area or be overcomplicated or insufficient to tackle the challenges of the future.

An innovation project will provide the complete picture of all the alternative future directions that we could consider given the complex nature of this rapidly changing, new and therefore unknown, environment.

This project has been approved by a senior member of staff

- [x] Yes