SIF Round 3 Project Registration

Date of Submission

Jun 2024

Project Reference Number

10098557

Initial Project Details

Project Title

Realistic modelling of power-to-gas operability

Project Contact

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Challenge Area

Enabling power-to-gas (P2G) to provide system flexibility and energy network optimisation

Strategy Theme

Net zero and the energy system transition

Lead Sector

Gas Transmission

Other Related Sectors

Gas Transmission

Project Start Date

01/03/2024

Project Duration (Months)

2

Lead Funding Licensee

National Grid Gas Transmission

Funding Licensee(s)

National Grid Gas Transmission

Funding Mechanism

SIF Discovery - Round 3

Collaborating Networks

National Gas Transmission PLC

Technology Areas

Hydrogen

Project Summary

The project will develop an integrated hierarchical network of established models for simulating the operation of decarbonised future GB energy system scenarios with highly interconnected gas and power networks. The realistic modelling of power-to-gas and storage operators' behaviour will be emphasised. The integrated models will be demonstrated on a simulation platform as real-time digital twins for future system scenarios.
Considerable novelty will lie in the combination of modelling scale and granularity; representation of many autonomous decentralised agents making sub-optimal decisions; and the optimal resolution of dilemmas arising from the finite energy budgets constraining primarily weather-driven low to zero carbon scenarios.

Add Third Party Collaborator(s)

Edinburgh Innovations Ltd

TNEI Services Ltd

Project Budget

£142,751.00

SIF Funding

£128,475.00

Project Approaches and Desired Outcomes

Problem statement

Greater interaction between the electricity and gas systems could be essential for achieving net-zero. In particular, such systems could enable the otherwise wasted energy from intermittently constrained renewable generation to produce green hydrogen that can be stored for long periods to reflect seasonal demand profiles. The combination of hydrogen generation and storage technologies could provide great benefits to energy consumers, but their introduction requires much greater coordination between the different energy vectors and their (finite capacity) networks.
One crucial new feature of decarbonised and strongly interconnected energy systems -- that derive most of their energy from localised weather -- will be the simultaneous uncertain constraints on the total, cross-vector energy consumption over many timescales, ranging from hours to months. System operators (electricity and gas) must therefore ensure that demands are met subject to all cross-vector energy constraints, along with physical and network constraints, and will require suitable tools to support decision-making. Hydrogen storage, P2G, and hydrogen power station operators will need to have access to these tools.
This project will demonstrate an integrated hierarchical suite of well-established statistical and optimisation models that could support that decision-making. We will then develop digital twins of the interconnected networks, realistically modelling weather patterns and other random factors that affect them as well as demonstrating simultaneously how system operators, P2G plant and hydrogen store operators would use the tools under those realistic conditions. Although the tools focus on operational decisions, they can also contribute to long term planning by demonstrating the realistic operation of a proposed system scenario and providing insight about which interactions within the hierarchical system are the most important.
Modelling complex systems inevitably involves considerable trade-offs. Our innovative methods will therefore rely on data science, operations research, power systems and gas network engineering to simultaneously achieve scalability and fast computations, while also capturing realistic interactions that modelling often overlooks, such as the warming of boilers, minimum zero times (MZTs), and
market power.
Intelligent Gas Grid's goal of "use of near real time data and machine-learning techniques" to achieve "better coordination, planning and network optimisation" is relevant. The models it establishes could be adapted as a component of our modelling ecosystem. The HyNTS FutureGrid Deblending project would help us understand the potential demand for hydrogen through deblending, while HyNTS FutureGrid Compression project could guide our modelling of compression and flexibility through linepack where gas contains hydrogen.

Video Description

https://www.youtube.com/watch?v=FBf043GcjFA

Innovation justification

Multi-vector energy systems have been the subject of considerable study in recent years and are assessed in models to support investment plans, policy, and strategy related to P2G systems. However, these interconnected systems are complicated, with many interactions across regions and between times of day and times of year. Existing models will typically simplify many aspects to make models

user-friendly but, in the long-run this might make their insight and recommendation less robust. Therefore, the core innovative aspect of this project is the development and demonstration of a realistic P2G modelling suite drawing on techniques from a wide range of analytic disciplines which can balance scalability, computational efficiency, and physical realism, and the application to the specific GB context. The insight this project will provide for long-duration hydrogen storage and P2G systems make it a natural fit for this SIF theme.
We are confident that none of the existing SIF and NIA projects reduce the novelty of our proposal, but many offer learnings, with over 50 relevant ongoing or recent projects identified.
Specific areas include:
(i) energy system management under finite total energy resource
(ii) energy systems meteorology, an evolving branch of applied meteorology specific to energy systems;
(iii) physically realistic and granular co-optimisation of highly coupled gaselectricity networks; and
(iv) modelling of decentralised energy systems

Gaps in whole-system modelling capability will be further investigated in the Discovery phase, to be carried into Alpha and Beta.
Prior to discovery, individual elements of the modelling suite have relatively high TRLs (between 4 and 9, depending on the element), but the TRL, IRL and CRL of a full suite of integrated hierarchical models are only 1. These will increase to 2 after the Discovery phase, with an aim to reach 7 by the end of Beta.
The scope and effort of this project is consistent with the need to model the whole energy system -- to our knowledge, no previous work has considered the interaction of the gas and electricity systems at the scale we intend to, while capturing all the realistic and complex factors that might affect energy constraints.
Relatively low readiness levels, collaboration between many stakeholders, and the specialist skills required mean that this solution is not ready or appropriate to be deployed through business-as-usual activity.
We have not yet disregarded any approaches that could inform the solution, and all options will be considered in more detail during Discovery.

Impacts and benefits selection (not scored)

Financial - future reductions in the cost of operating the network

Financial - cost savings per annum for users of network services

Environmental - carbon reduction – indirect CO2 savings per annum

Revenues - improved access to revenues for users of network services

New to market – products

New to market – processes

Impacts and benefits description

Financial - future reductions in the cost of operating the network
When used in decision-making, the project's modelling suite should allow energy system operators to achieve lowest cost options for operating integrated energy systems, electrolysing, storing, and burning hydrogen at times which are optimal across the whole system, helping to minimise renewable curtailment in theprocess. Operation of the energy system cost over £3bn in 2021 and 2022, and
these costs will rise in the future, meaning benefits of £10ms per year are easy to imagine. The tools demonstrated in this project will help to keep these costs as low as possible.

Financial - cost savings per annum for users of network services
Reducing operating costs will ultimately lead to annual cost savings for energy customers. The tools would aid efficient investment planning for whole energy systems. One recent report estimated this infrastructure might cost up to £1 bn by 2035, and it seems likely that these costs would increase through the 2040s and 2050s. These tools will also ensure resilience of energy supply, meaning customers get greater value for money from the network.

Environmental - carbon reduction – indirect CO2 savings per annum
The modelling suite could lead to an indirect carbon benefit from capturing more curtailed renewable energy through hydrogen, avoiding the need for other generation sources. While the energy system decarbonises, this might require carbon intense generation sources, with potentially 1,000 of kT CO2 (e) saved per year in the 2030s. This could have indirect cost savings associated with any costs imposed on carbon emissions

Revenues - improved access to revenues for users of network services
The recent Royal Society report on large-scale energy storage highlighted that new market mechanisms may need to be defined to incentivise long-duration storage, including storage volume capacity markets. This project could inform how such markets are designed and operated. It could also help developers of electrolysers and hydrogen storage to understand the value they can add to the system, possible revenue streams and business models.

New to market - products and processes
This solution is the first-of-its-kind integrating the concepts mentioned in Question 3. This system could be deployed across the globe on other integrated energy networks and there is opportunity for the partners to export this capability to other markets.

Metrics for measuring these benefits will be assessed in WP6 and may include net present values, energy-not-served, and carbon intensities.

Teams and resources

NGT is in a unique position, as the owner and operator of the gas National Transmission System (NTS), to take a lead role in whole system energy innovation. We have worked closely with UK electricity and gas networks to enable future interactions across energy networks, especially where gas networks play an important role. We aim to drive the most efficient and cost-effective solution possible and bring benefits to the customers.
NGT has worked previously with TNEI on innovation projects involving sophisticated data analysis and modelling tools, gas system operation and planning, and interactions with the electricity system. In addition, the academics at UoE have considerable expertise in cutting-edge modelling of energy systems, including both electricity and gas systems, and will ensure the project benefits from the latest research in this area.
NGT will lead on project management (WP1), stakeholder engagement (WP4), implementation planning (WP5) and the business case (WP6). In Alpha and Beta, NGT will also lead the demonstration of the model (WP7) in Alpha & Beta phase. TNEI will lead the definition of the model requirements (WP2) and model development activities (WP3) and contribute significantly to the business case (WP6) and model demonstration (WP4). The University of Edinburgh will support all workstreams as required, particularly WP2 and WP3.
In Discovery/Alpha, most work will be desk-based, completed at NGT, TNEI and UoE offices throughout GB. The key resources required for delivery of this project are the experts in each organisation. Through Alpha and Beta, there will be an increased need for access to NGT's IT systems to demonstrate and trial the

modelling tools -- this is included in the scope.
Other external parties we expect to involve in the project include:
Academic researchers in other specialist areas such as energy meteorologists (we have already engaged the University of Newcastle about this role).
Parties with an interest in the development and operation of future hydrogen energy systems (including storage, but also electrolysers and hydrogen power stations). Such parties would be involved in the decision-making processes in hydrogen energy systems.
Other energy networks, including either electricity or gas distribution networks and electricity transmission.
In the Discovery phase, we would aim to involve these parties in the project's Advisory board, and bring them on as partners in the Alpha and/or Beta phase as required.

Project Plans and Milestones

Project management and delivery

We will ensure that the Discovery phase project is delivered in line with the project plan by tracking and monitoring progress against the project plan and budget, proactively monitoring and addressing risks and potential issues through the project, and through regular (weekly or biweekly) check-ins among the project team. We have defined three milestones for the project:
Milestone 1, at the end of Month 1, will provide an opportunity for project partners to report on initial progress from Discovery.
Milestone 2, at the end of Month 2, the bulk of the technical Discovery work will be complete.
Milestone 3 is for completion of all reporting and the Alpha application.
One key dependency is the model requirements (WP2) informing the model development (WP3). To the greatest extent possible, we have sought to plan discovery activities which minimise this dependency, however, we expect that some of the WP3 activities will not be able to start in earnest until after the first milestone. Both WPs are led by TNEI which will help to ensure that this coordination is as seamless as possible.
Assessment of risks and anticipated mitigations are reflected in the risk register. These risks will be assessed and updated on a regular basis throughout the project. These will be discussed with the project Steering Committee if risks become issues that influence success criteria. We will raise this issue with the project manager of Ofgem and Innovate to reach agreement on appropriate next steps which will guarantee consumer value for money if there is no suitable action taken.
We have agreed and approved deliverables at the application stage and project partners' commitments to mitigate the risk on delay delivery. The continuedly active engagement and demonstration of potential business benefits to stakeholders in the project is included in the scope of work to maintain the interests of stakeholders. The discovery phase is vital to providing insight into these key risks and mitigating/eliminating them prior to the Alpha Phase development.
There are no other envisaged commercial and environmental constraints on this project.
The project does not involve any plans for supply interruptions, and we do not believe it will increase the risk of unplanned interruptions. The project will not have any interaction, engagement, or impact on energy consumers.

Key outputs and dissemination

Work Package 1: Project Management -- National Gas Transmission (NGT)
Ensure that the Discovery Phase is delivered to scope, budget, plan and aligned with business case. Alpha application successfully developed.
Work Package 2: Model Requirements and Definition -- TNEI
Understand the state-of-the-art for this type of modelling (from commercial R&D and academia), and have defined initial user and technical requirements for the modelling suite.
Work Package 3: Model Development and Evaluation -- TNEI
Develop a plan for the development and evaluation of the modelling suite in the Alpha and Beta phases, including a model specification.
Work Package 4: Stakeholder Engagement and Strategy -- NGT
Engage with all identified stakeholders and successfully attain user's insights, identify potential use cases and acquire relevant data for Discovery & Alpha phase

and ensure expectations for ongoing engagements.
Work Package 5: Implementation Plan -- NGT & TNEI
Have external and internal implementation plans for the Beta demonstration
phase.
Work Package 6: Business Case - TNEI
A high-level business case and cost-Benefit Analysis (CBA), ahead of a
subsequent phases' detailed CBA, with possible impacts identified in both energyfocused and wider landscape.
In Alpha, we aim to develop and evaluate the modelling suite and design a plan for
demonstration. A proof-of-concept deployment, scaled demonstration and
workshop exercises with stakeholders will be carried out in the Beta phase,
including testing with external stakeholders.
We have received great support from Newcastle University, hydrogen developers,
network operators, to drive this innovation in the next stages.
The project team will be keen to hold a dissemination meeting the Energy Network
Association both to share the findings from the project but also discuss how they
can be embedded in this innovation. We will also explore the opportunities to disseminate findings through presenting results at industrial workshops and
conferences. Cross network learning can be shared to improve the solution's
performance.
Alongside demonstration, later phases will consider options to allow widerstakeholders to engage with the modelling suite, allowing them to gain realistic
insights and operate more efficiently. We anticipate that the model we develop will
be adopted by the GB network operators and hydrogen storage developers. A
road map will be created for implementing the innovation into BAU. Part of this
roadmap will include trialling of the ongoing operational or demonstration projects
and directing the model into the energy market. It is also possible that elements of
the modelling suite could be exported internationally.

Commercials

Intellectual Property Rights (IPR) (not scored)

Default Arrangement.
For SIF projects, each Project Partner shall own all Foreground IPR that it independently creates as part of the Project, or where it is created jointly then it shall be owned in shares that are in proportion to the work done in its creation.
The exact allocation of Foreground IPR ownership will be determined during the contractual negotiations with the Project Partners on the agreement for the project.
On creation of Foreground IPR the creator of the IPR will notify the project partners to enable it to be recorded and ownership agreed in line with the contract terms.
Also if the party appoints a sub-contractor, the agreement with that sub-contractor should have similar IP provisions to those in this agreement and which at least achieve the same aims as the agreement regarding IP. Once the Project is completed, Relevant Background IPR will be licensed for use by the Project Partners in connection with another Project Partners' Foreground IPR solely to the extent necessary to use that Foreground IPR, upon terms to be agreed.
We intend to ensure each Project Partner will comply with Chapter 9 SIF Governance Document through the contractual terms governing the project.
However, precisely how this is done will be subject to contractual negotiations with the Project Partners on the agreement for the project.

Value for money

The total discovery project cost is £142,751 and we are requesting £128,475 of funding. National Gas Transmission (NGT) will be providing the compulsory 10% contribution (£14,276) in full.
TNEI will provide an in-kind contribution of 5% to their project costs through a discount on our standard daily consultancy rates, with a value of £4,000.
There are no other Business-as-Usual (BAU) financial mechanisms to cover these costs outside of further Network Innovation Allowance (NIA) process funding. A successful SIF application will provide benefits for the wider energy system including generation, storage, electricity, etc., through collaboration and engagement from all parties to tackle integrated energy challenges more effectively and accelerate the implementation of realistic modelling in to BAU in the future. This initial Discovery Phase funding is potentially the first step in an innovation journey that will ultimately deliver improved network resilience and thus reducing risk costs whilst delivering significant additional advantages and wider benefits to all GB networks and consumers.
The project team delivers value of money by offering favourable labour rates recognising the unique experience and knowledge they bring. Each partner brings the following critical expertise to the project:
National Gas Transmission (NGT) provide expertise on gas transmission and a suite of projects that are exploring the role of hydrogen within the National Transmission System (NTS), including projects considering the modelling of integrated energy systems. Our base rates have been used for this project.
The TNEI team provide expertise on data analysis, forecasting, energy systems modelling and optimisation, and a thorough understanding of the operation of the electricity system, which will be essential given the whole-system nature of this project. TNEI's activities have been costed using their standard consultancy rates, but have then provided a 5% discount to these as an in-kind contribution.
The University of Edinburgh (UoE) provide expertise from the cutting edge of energy systems risk and optimisation modelling, including experience with decentralised models and models of gas system planning and operation.

Supporting documents

File Upload

Realistic modelling of power-to-gas operability - Milestone 2.pdf - 2.8 MB
Discovery End of Phase Report - Realistic modelling of Power-to-Gas (P2G) operability.pdf - 73.1 KB
20240331 - Realistic Modelling of Power to Gas Operability - SIF Discovery - Milestone 1.pdf - 907.6 KB
SIF Round 3 Project Registration 2024-06-20 4_05 - 94.1 KB
Realistic modelling of power-to-gas operability - Discovery Show Tell.pdf - 1.8 MB
Modelling of P2G operability - Project Directions & Conditions -10098557.pdf - 219.9 KB

Documents uploaded where applicable?

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