SIF Alpha Round 3 Project Registration

Date of Submission

Nov 2024

Project Reference Number

NPG_SIF_XXX

Initial Project Details

Project Title

Fuel Cell Renewable Energy Equity (FREE) Round 3 Alpha Phase

Project Contact

Emma Burton

Challenge Area

Novel technical, process and market approaches to deliver an equitable and secure net zero power system

Strategy Theme

Net zero and the energy system transition

Lead Sector

Electricity Distribution

Other Related Sectors

Gas Distribution

Project Start Date

01/10/2024

Project Duration (Months)

6

Lead Funding Licensee

NPg - Northern Powergrid (Northeast) Limited

Funding Licensee(s)

Northern Gas Networks

Funding Mechanism

SIF Alpha - Round 3

Collaborating Networks

Northern Gas Networks

Technology Areas

Active Network Management

LV & 11kV Networks

Meshed Networks

Demand Side Management

Electric Vehicles

Project Summary

The project will explore how fuel cell micro-Combined Heat and Power (CHP) systems can provide UPS functionality for individual homes as well as support to other nearby homes which depend on direct electrification to provide heat, power and mobility. Fuel cell technology can generate at efficiencies equivalent to the highest efficiency central generation plant even at micro-generation level. Its location within the LV network further ensures that system losses are minimised, byproduct heat can be utilised, and local balancing is more easily achieved. This results in increased resilience and lower operating costs for consumers and the energy system.

Add Preceding Project(s)

NPG_SIF_009 - Fuel Cell Renewable Energy Equity (FREE)

Add Third Party Collaborator(s)

LCP Delta

Robert Bosch Ltd

University of Strathclyde

EA Technology

fifty5North

EoN

Project Budget

£525,812.00

SIF Funding

£472,235.00

Project Approaches and Desired Outcomes

Animal testing (not scored)

- ○ Yes
- ◉ No

Problem statement

The drive to Net Zero will place increasing demands on the UK's electricity system as many energy demands and services are transferred from current incumbent fuels such as transportation fuel and natural gas to electricity. This will result in two major factors that need to be addressed to ensure system resilience:

1. The supply of electricity. The challenge around the mismatch between intermittent low carbon electricity supply and demand has been extensively discussed. The Committee on Climate Change and UK government policy both recognise that in a net zero electricity system, we cannot rely entirely on intermittent renewables and in addition to short-duration storage we will require some form of fuel-based generation to meet peak (winter) demands.
2. Some customers will become increasingly dependent on the electricity system for most if not all of their energy needs. As highlighted at the ENA basecamp
(2023), the problem is exacerbated by our increasing dependence on electricity as the only energy vector at the point of use to meet not only existing loads but additionally to decarbonise heat and mobility for residential customers, and the consequently increasing importance of providing a resilient electricity system.

Overcoming these challenges will require innovative approaches which can address both the supply and resilience issues. Up to now, the concept of "cross vector" thinking has still largely been addressed through existing system processes, for example at the demand end using hybrid heat pumps which can use either electricity or gas, and at the generation end using low utilisation gas generation to provide peak electricity generation (potentially with CCUS or hydrogen). The methods don't fundamentally address the cross-vector dynamics or the resilience needs and customers will still need the electricity system to be robust and reliable for all of their needs.
These two major factors led to the development of the FREE (Fuel Cell Renewable Energy Equity) project which aims to address the cross vector need using fuel cell micro Combined Heat and Power (CHP) systems which can provide UPS functionality for individual homes as well as support to other nearby homes which depend on direct electrification to provide heat, power and mobility. Fuel cell technology can generate at efficiencies equivalent to the highest efficiency central generation plant even at micro-generation level. Its location within the LV network further ensures that system losses are minimised, by-product heat can be utilised, and local balancing is more easily achieved. This results in increased resilience and lower operating costs for consumers and the energy system.
The concept has been explored at a feasibility level in the Discovery project which demonstrated at a high level the technical feasibility at a single dwelling level in new build developments and communal schemes, alongside the cost effectiveness. However a number of problem areas need to be addressed at the Alpha stage to further demonstrate viability prior to conducting field trials. These areas include:

- How can fuel cells be integrated into local electricity systems and controlled to enable the local network to be resilient and operate in islanded mode? Whilst this is being explored as part of NPG's Resilient Customer Response project using embedded energy storage, it has never been explored using long duration and controllable technologies like fuel cells in residential areas.
- What is the impact on local networks under a range of operational scenarios and case studies and can power flow modelling be used to analyse the impact to minimise risk on local network operation in trials?
- How can the concept be more widely adopted, particularly in poor resilience areas, using non-network gas supplies alongside networked gas?

Innovation justification

FREE presents a novel solution which builds upon previous work by LCP Delta and NPG in Community DSO {NIC) and Resilient Customer Response {SIF and NIA) exploring how embedded electricity storage and generation can be used in local networks, improving resilience and reliability for customers whilst reducing the stress on networks and generation. Whilst existing approaches and counterfactuals have largely explored how upstream mechanisms (e.g. system lexibility, grid scale storage, H2 to

power) can be used, this suite of projects (FREE, CDSO, and RCR) take a highly innovative approach of addressing these issues in local communities and in customers properties to provide highly efficient cross vector capabilities at the point of use, and 'real' resilience by not relying on upstream networks.
The Free project is aligned with the aims of Innovation Challenge 2

- It proposes an innovative technology configuration allowing islanded network operation in resilience events with new network management and operation processes to enable this.
- Alongside the technical concept, LCP Delta will be exploring new tools and methods to support this operation including novel approaches to analysing and forecasting resilience needs building upon AI techniques for forecasting.
- Embedding fuel cells in local communities provides greater system flexibility and efficiency, reducing the need for centralised fossil power generation for peak demands.
- The cross vector integration of heating and electricity at the demand side will allow for more flexibility on networks and improve the utilisation of intermittent renewables and minimise curtailment.

FREE is considered highly innovative because:

- It combines local electricity generation with the potential for islanded networks under resilience events, alongside offsetting centralised fossil generation under normal operation conditions.
- It provides a cross vector solution to improving resilience for customers, reducing network impacts, alongside providing system benefits using established, albeit early stage, fuel cell technologies.
- It provides the basis for site scale individual or communal heating and power schemes supporting low carbon housing policy and district heating policy alongside mitigating network reinforcement.

Whilst Resilient Customer Response CR and CDSO are built on prior innovation work by proposing solutions which combine local communities and market drivers with existing network topology, FREE takes this further by embedding reliable cross vector operation within local networks. We are not aware of any other projects exploring this approach and objective.
The project concept and this bid has drawn on external stakeholder engagement. During the Discovery Phase, a workshop and 1-2-1 engagement was conducted with energy suppliers, fuel cell manufacturers and housing developers to test and refine the proposition. The work has also drawn extensively on LCP Delta's research and stakeholder engagement covering more broadly the network sector, heating market players and innovative service providers.

Whilst the central fuel cell technology is established, a robust technical analysis is required in Alpha to demonstrate the technical viability of network integration prior to conducting field trials. The novel connection, control, and power flow analysis is beyond BAU activities and the proposed SIF funding enables a suite of analysis to be conduced to de-risk a field trial with customers, drawing additionally on RCR and CDSO. The research will move the concept through TRL 3 and 4 to prepare for a TRL 5 field trial project.
Our work across innovation (network and non-network projects) has informed this bid:

- Understanding of the market dynamics, counterfactuals and need to consider the soft and hard factors in feasibility.
- The need to robustly address all areas of innovation to incrementally move the concept forwards with no significant challenges or barriers.
- The need to engage with the broader network community, alongside the broader stakeholders involved in delivery the concept and the next trial stage.

Impact and benefits (not scored)

Financial - future reductions in the cost of operating the network

Financial - cost savings per annum on energy bills for consumers

Financial - cost savings per annum for users of network services

Environmental - carbon reduction – direct CO2 savings per annum

Environmental - carbon reduction – indirect CO2 savings per annum

Revenues - improved access to revenues for users of network services

Revenues - creation of new revenue streams

New to market – products

New to market – processes

New to market - services

Impacts and benefits description

FREE will support a resilient and low carbon electricity supply to individual homes. This builds on existing resilience trials involving home or communal energy storage, or back-up fossil fuelled generation, by providing long duration embedded electricity supply to individual homes based on high efficiency low or zero carbon fuels.
The counterfactual
The FREE concept is considered in the context of a decarbonising energy system with key demands including transport and heating being electrified. As our problem statement demonstrates, this would increase strain on the network and increase customers risk due to greater reliance on a single vector.
Economic modelling
The Discovery phased economic modelling considered the costs and benefits associated with FREE implementation relative to a counterfactual using electric heat pumps and PV for domestic heating demand. The modelling include a range consumer, network and societal impacts referenced below. For the Alpha submission we have included an additional green H2 powered fuel cell option, and have increased costs for the communal strategy with the inclusion of heat network costs. Whilst the CBA covers a range of direct benefits, we believe that a much wider range of system and customer benefits will also be realised through a more reliable and resilient electricity network.
Overall cost benefit
Full details are in the CBA spreadsheet and can be summarised:

- Option 1 (individual fuel cells): No returns and therefore rejected.
- Option 2: Positive NPV of £749k. The phased reduction in fossil fuel use results in some early years carbon costs, but these are offset by the capital and societal; benefits.
- Option 3 (Option 2 with green H2): Positive NPV of £99k. Carbon costs removal is offset by higher hydrogen fuel costs (based on LCP Delta LCOH modelling).

Both communal solutions with and without hydrogen show a cost benefit and will be considered in Alpha.
Customer benefits

- Future network resilience events may increase in frequency or duration with increased impact as customers become more reliant. Options 2 and 3 currently assume societal benefits associated with 500 interruption events across the case studies, and a combined 90,000 lost load minutes.
- Financial modelling shows that a positive NPV could result in marginally lower energy bills for customers if a suitably business case can access the resilience value

Network and system benefits
Local CHP generation combined with improved resilience provides a range of system benefits:

- Low carbon gas CHP generation directly reduces peak electricity system demand from central gas peaking generation.
- Microgrid (island mode) operation can further reduce peak electricity demand, alongside providing customer resilience.

These combined mitigate the need for electricity network reinforcement. A conservative 1 /3 capacity reduction for new housing development connections was calculated in Discovery, with the added benefit of speeding up new development connections.
Environmental benefits
Benefits associated with the reduced use of peaking power generators (which are expensive and carbon intensive) are not realised in the CBA due to the templates use of average carbon factors. Fossil use (and transitioning to low/zero carbon gas) in CHP with heat offtake is more efficient and lower carbon than CCGT or OCGT peaking generation.

Additional and new revenues

- Dispatchable generation in embedded CHP assets can be aggregated to capture significant system flexibility values using innovative business models.
- Innovative propositions will help local communities benefit from reduced infrastructure connection costs alongside the broader FREE system cost benefits. Community DSO is exploring this and will inform FREE.
- Cross vector integration at customer homes could deliver new efficiency related revenues, and enable local balancing with the use of innovative business models to equitably benefit all customers.

Teams and resources

A successful Discovery phase project was delivered by Northern Powergrid, LCP Delta and EA Technology. During Discovery we mapped stakeholders to identify potential partners for the Alpha stage scope. We have identified the following partners which we believe have the appropriate experience, skills and capabilities to carry out the tasks set out in our Alpha project:

Project Team Changes and New Partners/Subcontractors:
Northern Powergrid: As a lead partner, Northern Powergrid brings expertise in electricity distribution networks. Their existing relationship with the project ensures continuity and alignment with previous phases. Their engineers will collaborate on grid integration, ensuring seamless interaction between the fuel cell CHP systems and the grid.
LCP Delta: A key partner, LCP Delta specialises in energy analytics and optimisation. We chose them for their data-driven approach and experience in similar projects. Their team and analysts will optimise system performance, considering load profiles, demand response, and grid constraints.
E.ON UK: A new partner, E.ON UK, contributes their knowledge of energy markets, customer engagement, and regulatory compliance. Their team includes energy market specialists, regulatory experts, and customer engagement professionals.
fifty5north: A pre-existing relationship, fifty5north provides insights into consumer behaviour and demand-side management. Behavioural scientists and user experience designers from their team will enhance consumer adoption and participation.
Worcester Bosch: Also, a pre-existing project stakeholder, Worcester Bosch offers expertise in fuel cells systems and integration. Their engineers will focus on system integration, reliability, and safety.
Northern Gas Networks: Their experience in gas distribution complements the project's cross-vector approach. Gas network engineers from their team will explore hybrid energy solutions.

EA Technology: As a pre-existing partner, EA Technology assists with grid modelling and resilience analysis. Their grid modelling experts will assess resilience and recommend improvements.

PNDC (University of Strathclyde): PNDC is a unique research and development facility, which brings together academics and industry. They operate closely with Distribution Network Operators (DNOs), gaining an intrinsic understanding of both macro challenges faced by the industry, such as the changing requirements of the DSO, and the micro-challenges, such as the transition from Innovation to Business as Usual (BaU).

Additional Resources, Equipment, and Facilities:
Fuel Cell CHP Systems: Data of fuel cell systems for testing and validation. These systems are critical for demonstrating the feasibility of uninterrupted power supply using fuel cells.

Data Analytics Platform: Utilising existing software tools for real-time monitoring, predictive maintenance, and performance optimisation. This platform will enable us to analyse data from the fuel cell systems and make informed decisions.
Grid Simulation Software: Utilising existing licensing and computational resources for modelling interactions with the grid. Accurate simulations are essential for understanding how the fuel cell systems will interact with the existing electricity grid.
External Parties and Network Users:
Consumers: Engaging end-users is crucial. We'll collaborate with local households to pilot the systems and gather feedback. Their experiences and preferences will shape the project's success.
Local Authorities: Cooperation with local councils ensures regulatory compliance and permits for installations. We'll work closely with them to navigate any legal requirements.
Energy Regulators: Regular communication with regulators is essential. We'll keep them informed about the project's progress and seek their input on compliance matters.
Energy Suppliers: Coordination with energy providers is vital for grid connections and tariff structures. Their support ensures

seamless integration of the fuel cell systems into the existing infrastructure.
The Alpha phase involves a mix of existing and new partners, each contributing their specialised skills. We'll leverage additional resources and engage external stakeholders to ensure the successful delivery of the project. By fostering collaboration and innovation, we aim to create a resilient and sustainable energy solution for the future.

Project Plans and Milestones

Project management and delivery

We will maintain weekly management calls between the project lead (NPg) and the delivery lead (LCP Delta). We will conduct monthly meetings with all partners to cover; learning, timings, forthcoming tasks and risks. LCP Delta will act as research lead and coordinate input between the different parties, supported by NPg.
The Project Management document and risk register will be maintained as a living document, reviewed weekly to ensure alignment of all members and scrutiny of fund spending. This will provide a governance framework which will be managed by N Pg as lead partner.
The Alpha work packages (defined in detail in the Project Plan worksheet} include:
WP1: Definition and technical modelling of cases [WP Lead: LCP Delta] -
£68, 120 [13. 7%]
*Aims: To further develop and test the communal FREE concept on a range of different use cases to demonstrate viability in different network areas.
WP2: Power flow analysis [WP Lead: PN DC] -- £78.132 (15. 7%}
*Aims: To understand the technical implementation viability of FREE on the operation of local electricity networks
WP3: System integration [WP Lead: fifty5north] - £102,000 [20.6%]
*Aims: To understand the technical potential of FREE in providing resilience and mitigating the impact of electrification on LV electricity networks.
WP4: Further development of the business case for a specified use case based on a real circuit [WP Lead LCP Delta] - £52,000 [10.5%]
*Aims: Further develop the business case for FREE, this would include an evaluation of different models and the inclusion of additional revenue streams that haven't yet been considered (e.g. provision of wider system flexibility).
WPS: Stakeholder engagement [WP lead: LCP Delta] £60,120 [12.5%]
*Aims: To provide a robust evidence base for contribution to the debate around the future of gas networks and low carbon gases in the UK.
WP6: Reporting and recommendations [WP lead: LCP Delta] £60, 120 [12.5%]

*Aims: Communicate the outcomes, findings, and lessons learned from the project.
WP7: Project management [WP lead: Northern Powergrid, LCP Delta support] - £57, 123 [11.5%]
*Aims: To deliver the project on time, to budget, and to check that project objectives and learnings are achieved.
Deliverables and success criteria are fully outlined in the Project Plan.
Interdependencies between work packages and milestones are detailed in the Gantt Chart. Risks and their associated mitigations are detailed in the Risk Register.

Key outputs and dissemination

The project will build upon the high-level feasibility assessment and demonstrate the technical and commercial viability of a fuel cell based technology solution to the resilient and low-carbon supply of electricity to individual homes regardless of the status of the distribution network. This concept goes beyond previous UK resilience trials involving energy storage (either individual home or communal) or backup generation using large, fossil-fuelled "gensets", and will instead provide long-duration electricity supply to individual homes based on high efficiency low or zero carbon fuels.
By the end of the project, we will demonstrate:

- How the concept can be configured in a number of example case
studies/typologies and the technical feasibility of the scheme to operate in different configurations.
- How connections and controls can be configured to enable the local network to be resilient and operate in islanded mode powered by embedded fuel cell generation and storage. Whilst this is being explored as part of NPg's Resilient Customer Response project using embedded energy storage, it has never been explored using long-duration and controllable technologies like fuel cells in residential areas.
- The viability and associated impacts and benefits on local distribution networks through power flow modelling. This will be used to ensure that subsequent Beta trials can be effectively and safely conducted.
- The broader applications and rollout of the concept taking into account future gas scenarios, and also the potential for off-gas-grid operation in remote or rural areas.
- How the commercial model works and business models which may be used to support this to the benefit of networks and local

communities.

A detailed dissemination plan will be developed at the project's inception and kept under review. We plan to complete the following activities:

• NPg will promote the learnings both internally, to key stakeholder groups and to the wider ONO community through existing innovation and dissemination forums

- LCP Delta will coordinate central project dissemination activities and we anticipate:
- The project team developed press releases, biogs, social media articles, etc.
- A project webinar with all project partners disseminating the final project outcomes.
- Conference presentations provided by each partner organisation covering the networks, fuel cells, and flexibility arenas.
- Production of a simple summary report which can be used for promotional activities.
- Our individual partners have also agreed to participate in leading at least three promotional activities. We suggest all project partners manage their content and agree on where coordination is required.

Key deliverables to highlight and exploit are WP1 has a deliverable titled
"Methodology for strategic probabilistic forecasting" which is a new modelling approach considering risk. WP2's deliverable "Free Network Impact Model" includes a summary of modelling methodology and assumptions.
In WP3, deliverables include "Connection sizing methodology and template for the proposed scheme" and "Regulatory overview for the proposed scheme". WP4 provides a deep dive into the "Business Model" and offers Beta recommendations.
WP5 is critical and offers a sub-objective of ensuring value for money, with strategic deliverables for "Stakeholder engagement" and "Exploitation and commercialisation".

Commercials

Intellectual property rights, procurement and contracting (not scored)

The parties agree to adopt the default IPR arrangements for this project as set out in Section 9 of the SIF Governance document.

Commercialisation, route to market and business as usual

This Alpha project is the next step in demonstrating the viability of the FREE concept and as such the next step in showing how this could become business as usual. Due to the nature of the concept it is clearly essential for a subsequent physical trial step to proceed to demonstrate the scheme operationally with real demands on the live distribution network. As part of this overall process, there are a range of areas which can be considered in terms of the commercialisation and business as usual strategy, some of which can be explored in this Alpha phase project.

Market opportunity

The intention is that FREE will be highly replicable (the partner concept in Community DSO has been developed to be viable in virtually all network areas) and has such has the potential to become a baseline component or tool in future network operation. We will be exploring through the use of typologies how replicable the concept might be and the associated level of potential uptake.

Understanding the potential and resilience risk

As part of this project, LCP Delta will be further developing analytical tools to provide probabilistic modelling of future network loads to understand the risks and associated need for resilience mechanisms. Building on existing LCP Delta technology platforms (including using some of the machine learning intelligence in our Enact market forecasting tool), LCP Delta aims to construct Beta version of our network forecasting tool in the next 12 -- 18 months which is part of our technology development roadmap. Testing elements of this in FREE will be important in understanding how and where the FREE concept should be trialled, and in the long term operated as BAU.

Controls and operation

A fundamental element of this Alpha project is the analysis and design of control and operation procedures to allow the successful integration and operation of the FREE concept, allowing FCs to provide resilient operation of islanded networks under resilience events. The outputs from this project will inform all networks in the design and specification of these control processes supported by PNDC and EA Technology. The commercialisation and route to market of these could differ:

- Elements of this work will be adopted by networks into their existing in-house systems and processes.
- *The research will also inform third party controls companies in the further development of their products for networks.

Assets

Fuel cells are a major component of the solution and the involvement of two leading fuel cell companies is important to the success of this project. Understanding the current capabilities and operational characteristics of the fuel cells will be important for the modelling and testing, but in reverse the project will provide information to the fuel cell companies on the types of responses and operation needed for successful FREE operation. Given the potential market opportuntiy of the FREE concept, this will help FC companies with further development and configuration of their products for the UK market.

Local energy propositions

This project is centred around how innovative approaches can deliver resilience at a local level. A large number of innovators (e.g. SNRG, SERO, Wondrwall) are looking at how innovative propositions can be used to work with developers and communities to deliver innovative site wide solutions which limit impacts on the networks. We anticipate engagement with these types of organisations during the project, and for the outputs of this project to be used by these companies in developing and refining their propositions for the UK market.

Lead Senior Sponsor

The Head of System Flexibility continues to be senior sponsor within Northern Powergrid and will closely monitor project's progress and outputs.

Policy, standards and regulations (not scored)

For the delivery of this Alpha phase project there are no issues with respect to regulations, policy or standards.

The long-term viability of fuel cells depends on the policy decision of Government, and whether hydrogen will replace natural gas as the predominant source of energy to heat homes. A strategic decision is expected in 2026.
A number of regulations would need to accommodate a move to use hydrogen instead of natural gas. Until the HSE amend these which is not planned prior to the government 2026 decision, any hydrogen trials need to satisfy the HSE of sufficient safety for all those involved.
Whilst there are regulatory barriers, these would not prevent a pilot or trial taking place as the regulator Ofgem has put in place an Energy Regulation Sandbox to allow innovative trials to be carried out that would not otherwise be possible due to the regulatory framework. These would need further investigation once the asset ownership and commercial models were progressed further.
Operating a network in island mode is technically feasible, as the Network Islanding Study conducted by Western Power Distribution (now NGED) has shown. Challenges exist with the proposed scheme on how the output of a cluster of micro-generators could be matched to demand when operating in island mode following a grid outage. Therefore, it is believed that there are no policy, legislative, regulatory barriers or technical barriers that would prohibit a trial of natural gas fired fuel cells capable of operating in islanded mode.
Throughout the project, we will keep this situation under review and maintain a log of regulatory and policy considerations. This will be used to help identify and highlight any potential interactions and then assess the nature of these interactions in relation to both the Beta trial phase, and more generally for a BAU roll out.

Value for money

The associated project this submission is built on top of is the Discovery phase project FREE reference number: 10106474. The total project cost is £525,812 and the project team is requesting £472,235. The funding arrangements demonstrate that the required 10% is being contributed by each partner as an investment in the project. With the large consulting input to this project due to the desktop analysis nature, and the commercial benefits likely to be gained by other parties in the future, the 10% contribution is largely through in-kind contributions in the form of discounted day rates. Aside from the project partners, we do not anticipate any subcontractors to be required. All planned work is within the project partners.
Whilst additional funding has not been obtained, a large element of knowledge will be coming from the existing Resilient Customer Response (RCR) and Community DSO projects involving LCP Delta and NPg. We are therefore maximising the benefits of this existing innovation funding for FREE.
Due to the desktop nature of the work, no pre-existing assets or facilities are required specifically for this project. However, the use of existing models and methodologies across LCP Delta, EA Technology and PNDC will be used, such as:

- Fuel Cell CHP Systems: Data of fuel cell systems for testing and validation. These systems are critical for demonstrating the feasibility of uninterrupted power supply using fuel cells.
- Data Analytics Platform: Utilising existing software tools for real-time monitoring, predictive maintenance, and performance optimisation. This platform will enable us to analyse data from the fuel cell systems and make informed decisions.
- Grid Simulation Software: Utilising existing licensing and computational resources for modelling interactions with the grid. Accurate simulations are essential for understanding how the fuel cell systems will interact with the existing electricity grid.

Associated Innovation Projects

- (•) Yes (Please remember to upload all required documentation)
- ( ) No (please upload your approved ANIP form as an appendix)

Supporting documents

File Upload

SIF Alpha Round 3 Project Registration 2024-11-13 11_22 - 80.0 KB

Documents uploaded where applicable?

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