SIF Discovery Round 2 Project Registration

Date of Submission

Apr 2023

Project Reference Number

10056144

Project Registration

Project Title

REWIRE (REsidential Whole system Integrated REsilience)

Project Reference Number

10056144

Project Licensee(s)

Electricity North West

Project Start

Apr 2023

Project Duration

3 Months

Nominated Project Contact(s)

InnovationTeam@enwl.co.uk

Project Budget

£186,389.00

Funding Mechanism

SIF Discovery - Round 2

SIF Funding

£149,947.00

Strategy Theme

Whole energy systems

Challenge Area

Improving energy system resilience and robustness

Lead Sector

Electricity Distribution

Other Related Sectors

Funding Licensees

Lead Funding Licensee

ENWL - Electricity North West Limited

Collaborating Networks

Electricity North West

Technology Areas

Control Systems, Hydrogen, Photovoltaics

Equality, Diversity And InclusionSurvey

Yes

Project Summary

Aim: REWIRE will explore the technical viability and economic benefit of integrating vector conversion and energy storage technology at a domestic level to increase whole system resilience.

Whole system resilience: The energy system's ability to recover from disruptive events will be significantly improved with the integration of localised storage, provided by REWIRE's multi-energy systems.

Context: The challenge of whole system energy balancing will grow with increasing penetration of intermittent renewables, with 50GW of offshore wind predicted by 2030, and 40GW of embedded distributed generation in the form of domestic solar predicted by 2050.

Growing electrification of residential transport and heat further increases the likelihood of system imbalances. The role of hydrogen as an option for decarbonising heat remains uncertain, with domestic demand forecasts ranging from 145 to 0 TWh, potentially leaving infrastructure redundant.

Additionally, climate change and geopolitical instability are increasing the likelihood of extreme weather and infrastructure attacks, respectively, further impacting system resilience.

Specifically, two scenarios – low wind, low solar at peak demand and low demand, high renewable generation – would cause resilience issues on a decarbonised national grid, with the latter incurring costs for generation reduction.

Solution: REWIRE is a domestic cross-vector storage system, exploiting power-to-gas and gas-to-power technology with integrated local hydrogen storage. REWIRE brings benefits for consumers through improved energy security, and for networks as a fast-response flexibility service provider.

The solution will alleviate network constraints by increasing availability of flexibility services for demand electrification, reducing reinforcement and system balancing costs. Additionally, low-pressure gas network infrastructure could be used for transporting hydrogen to point of use or as local energy storage, optimising the use of existing resources. This would enhance utilisation of existing assets, producing net cost benefit for networks and consumers.

Project Partners:

- Electricity North West Limited (ENWL) is lead partner and will lead WP2, using their understanding of consumer requirements to rank network archetypes based on their requirements for improved resilience.
- Imperial College London will lead WP3, applying their world-leading whole-energy system modelling expertise to analyse the resulting techno-economics and cost benefits.

Subcontractors:

- Frazer-Nash Consultancy will lead WP1 and WP4, using their experience of network innovation projects to assess the factors affecting implementation of REWIRE.

Cadent Gas Distribution Network have committed to joining the project in Alpha Phase. Their experience with gas network operation and future hydrogen transition activities makes them an ideal partner to aid the assessment of gas network integration.

Project Description

REWIRE aims to improve energy system resilience through its development of innovative domestic level multi-energy systems. By exploiting the cross-vector storage capability of gas-to-power and power-to-gas technologies, properties equipped with REWIRE systems will provide flexible demand profiles to alleviate network constraints and maintain security of supply. This Discovery phase project will explore the technical viability and economic benefits of these domestic level multi-energy systems, which will be specified, designed, prototyped and deployed in the Alpha and Beta phases.

REWIRE's innovation lies in the use of multi-energy systems at the domestic scale, rather than the larger-scale versions previously envisaged. Using a domestic scale solution will necessitate innovative combinations of technologies, and innovative management and operation of the distributed system. This innovative solution provides potential benefits around the speed and flexibility of energy system response, alongside the ability to provide benefit to distribution networks on a granular scale.

Future energy networks are expected to experience both low demand, high generation and high demand, low generation scenarios due to an increased prevalence of intermittent renewable generation. A wide deployment of REWIRE systems would enable demand to be artificially increased, alleviating resilience issues and curtailment of generation for the low demand, high generation scenario. Alternatively, in the high demand, low generation scenario REWIRE systems can preferentially use energy from storage or other vectors to alleviate demand and balance the network. This could include using existing gas distribution assets as energy storage,

optimising the use of these assets. In addition to the network benefits, REWIRE systems will allow consumers to adapt their energy use around prices of localised renewable generation.

The benefits provided by REWIRE manifest in reduced costs for network reinforcement, generation curtailment and system balancing which, alongside maximising the use of existing gas distribution assets, would reduce costs to consumers. REWIRE would also increase local resilience and provide improved security of supply for domestic properties. Additionally, the ability for consumers to control the timing of their energy use and to fully leverage domestic generation will lead to further reductions in their bills.

Third Party Collaborators

Frazer-Nash Consultancy

Nominated Contact Email Address(es)

innovation@enwl.co.uk

Project Description And Benefits

Applicants Location (not scored)

Electricity North West Ltd, Borron Street, Portwood, Stockport, Cheshire, SK1 2JD

Imperial College London, Exhibition Road, South Kensington, London, SW7 2BX

Project Short Description (not scored)

REWIRE will develop innovative domestic level multi-energy systems that exploit cross-vector technologies to provide flexible demand profiles, thereby alleviating network constraints, maintaining security of supply and improving overall energy system resilience.

Video description

https://www.youtube.com/watch?v=Mc5vqkmP6QQ

Innovation justification

Problem: Decarbonisation of the power system with increasing generation from intermittent sources and growing demand from electrified domestic heating and transport means that maintaining future network resilience will require costly and labour-intensive network reinforcement. Additionally, vast quantities of low-cost renewable energy is curtailed when demand is low, indicating a requirement for significantly increased energy storage. GB has an extensive gas pipeline network, which many studies suggest will be largely redundant at low pressure tiers by 2050. The use of this infrastructure may help to increase resilience whilst reducing the need for reinforcement of local electricity networks.

Novel approach, overcomes knowledge gaps: Previous work focussed on decarbonising domestic demand through electric heat pumps or substituting natural gas with hydrogen rather than considering a combination of gas and electricity systems that could also support network resilience. Building on work to review domestic heating technologies by Imperial College, REWIRE will provide new research on the benefits of, and necessary adaptations for, installing hydrogen tanks, electrolysers, fuel cells and hybrid heat pumps at a residential level for varying domestic archetypes.

Risk: There are technical and regulatory barriers associated with using this solution in domestic properties and how it interfaces with network operation. High risk areas to be explored include the operational feasibility, funding and owning of assets, commercial feasibility, safety, and societal preconceptions.

Value: A cost benefit analysis will be undertaken to understand the economic benefit of improved resilience and optimised utilisation of gas and electricity infrastructure through the use of domestic level combined green hydrogen. This economic review will assess network reinforcement, gas network decommissioning and curtailment of renewables as appropriate counterfactuals. Effective valuation of the benefits will include monetisation of resilience, most appropriately expressed as Value of Lost Load (VoLL), which incorporates asset losses, perishables, business interruption costs, and recovery costs.

Sustainability benefits shall be valued as equivalent carbon emissions, versus equivalent counterfactuals such as fossil fuels, and how the reduced requirement for reinforcement may accelerate the electrification of heat and transport.

Strategic Innovation Funding: This project aligns with SIF as it is a novel and high-risk exploration of an approach to improve system resilience, whilst offering consumers opportunities to engage with the market and increase personal energy security. There is clear progression towards a Beta demonstration project, with potential to pilot the technology in a local network region.

Benefits Part 1

Environmental - carbon reduction – direct CO2 savings per annum against a business-as-usual counterfactual
Environmental - carbon reduction – indirect CO2 savings per annum against a business-as-usual counterfactual
Financial - cost savings per annum on energy bills for consumers
Financial - future reductions in the cost of operating the network
Revenues - creation of new revenue streams
Revenues - improved access to revenues for users of network services

Benefits Part 2

Network operating costs: The additional storage and flexibility available from the REWIRE system improves network system resilience and balance and mitigates network reinforcement.

Consumer bills: In 2021 the Electricity System Operator spent £143 million curtailing 2.34 TWh of wind energy; REWIRE would avoid this curtailment, reducing consumer bills.

Domestic level energy storage forms part of the REWIRE system and will help consumers shift energy demand to when costs are cheapest and national demand is lowest, if using a flexible tariff, thereby reducing their bills.

There is also potential for consumers to engage with the flexibility services market, increasing their revenue and reducing average energy consumption costs. These benefits can be amplified through optimisation of the vector conversion based on economics and real-time market conditions.

REWIRE will maximise utilisation of existing assets, e.g. by using the gas distribution network for localised energy storage, reducing costs for both networks and consumers.

Direct CO_2 savings: REWIRE can directly affect carbon emissions by avoiding curtailment of renewable generation. Without REWIRE, if 50 GW of offshore wind is installed by 2030, with capacity factor of 40% and curtailment rate of 14%, nearly 25 TWh could be curtailed per annum – equivalent to 7.61 $MtCO_2e$ from natural gas generation.

Additionally, using electrification or hydrogen for heating through REWIRE would result in significant carbon benefits as it will replace natural gas. According to Ofgem, the average domestic property uses 12 GWh of natural gas per annum, which equates to roughly 2.19 tCO_2e per property.

Indirect CO_2 savings: REWIRE can also save carbon by accelerating the rollout of low carbon technologies, due to reduced reinforcement requirements and reduced emissions associated with system losses through storage of domestic and locally generated energy.

Revenues: domestic consumers will have improved access to revenue through the provision of flexibility services. There is potential for creation of new markets and flexibility services relating to domestic hydrogen injection to the low-pressure network for distribution or storage.

Additional benefits: Consumers in vulnerable situations, particularly those who require constant supply for medical equipment, will benefit from increased security of supply.

Properties without connection to the gas grid can produce and store hydrogen for domestic use or fast-response power generation, increasing their choices.

The metrics required to quantify these benefits will be defined in the Discovery phase, but will predominantly be avoided costs of curtailment and reinforcement, which are calculated via standard CBA counterfactuals.

Project Plans And Milestones

Project Plan and Milestones

WP1: Domestic Archetype Development

Success Criteria: Set of detailed domestic archetypes

This WP will produce a set of domestic property archetypes which map technologies to property types including technical and financial viability assessments. Specifically, it will:

- Define residential scalability requirements for different property types.
- Assess technology viability assessments for behind the meter applications.
- Map the technologies to property types.
- Assess financial viability of technology.

Milestone: Report detailing the domestic archetypes.

WP2: Network Archetype Development

Success Criteria: Set of prioritised network archetypes.

This WP will produce and rank a set of network archetypes based on geospatial characteristics and requirements for improved resilience. Specifically, it will:

- Define the geospatial characteristics.
- Allocate the geospatial characteristics to generate the network archetypes.
- Rank network archetypes based on resilience improvement priority.

Milestone: Report detailing the final network archetypes.

WP3: Cost Benefit Analysis

Success Criteria: Quantification of all benefits associated with REWIRE.

This WP will produce a high-level assessment of costs and benefits of the proposed domestic level multi-energy concept including:

- The benefits of flexibility services.
- Mitigation of electricity infrastructure reinforcement.
- Utilisation of existing gas infrastructure for transporting and storing hydrogen.
- Benefits of domestic level multi-energy concept in enhancing resilience of supply.

Milestone: Report detailing all the benefits associated with the solution.

WP4: Implementation Assessment and Roadmap

Success Criteria: Implementation roadmap for REWIRE

This WP will define and assess the implementation roadmap for the REWIRE solution. Specifically, it will:

- Conduct a Social, Technological, Economical, Environmental, Political, Legal, Ethical (STEEPLE) analysis.
- Assess risks, opportunities, and blockers to implementation.

· Refine challenge statement for Alpha Phase.

· Produce a roadmap defining future archetype development and application to network resilience upgrades.

Milestone: Report detailing the implementation roadmap.

WP5: Project Management (Lead: ENWL/ Funding: £8,583.42)

Success Criteria: All work packages delivered in line with the project plan.

This WP will manage the Discovery Phase project in line with the project plan and project direction.

Milestones:

· Contracts signed, kick-off meeting held.

· Report detailing the findings and learnings from the Discovery Phase.

Risks: The main risks to project delivery are resource availability and timescales. Mitigation involves robust project management, an experienced project team with access to the latest academic and industrial information.

Regulatory Barriers (not scored)

The project will explore and understand any regulatory barriers, as well as suggest potential amendments that could enable development and implementation of REWIRE, including:

System Ownership: Networks are unable to purchase behind the meter equipment so it is unclear who will finance the solution and promote its use. This is due to regulatory restrictions on networks owning generation assets, including storage systems and networks purchasing equipment on behalf of the customer. To allow the solution to become fully embedded, the regulatory restrictions would need to be reconsidered or funding would potentially need to come from government subsidies, such as the Renewable Heat Incentive, which often have their own requirements.

Health and Safety: The solution would need to comply with the relevant health and safety regulations for installation behind the meter, or at least offer the same level of safety as current household installations.

Furthermore, safety regulations that exist for the domestic use of natural gas rely on calculations that would be difficult to translate for hydrogen. There is no simple conversion factor, so new approaches would be required.

Market Landscape: There are multiple government policies in place to aid market engagement for future hydrogen technology, such as the Net Zero Hydrogen Fund, the Hydrogen Business Model, and more. The Hydrogen Regulators Forum was created in 2021 with the aim of formulating regulations to support market engagement. They were due to have a first meeting in January 2022; however, no public information has been released as of now.

Flexibility Services: Flexibility services already exist with regulations in place for larger scale generators/ storage owners. However, as the DSO transition gathers momentum, there is still work to do to improve facilitation of domestic scale market entry. Also, producing hydrogen at a domestic level and feeding into the network is a novel concept, which would require new market and regulatory considerations in a similar way to current flexibility services for the electricity grid.

Hydrogen: Lack of hydrogen-specific regulation could be another barrier as there is currently no formalised route for approval of a hydrogen and fuel cell installation, or scheme for training tradespeople to install and operate it. Future regulatory framework updates will need to be assessed, as rapidly changing policy has implications on the role of the gas network infrastructure.

Commercials

Route To Market

As REWIRE progresses through the SIF Project Phases, more broad and detailed assessment of the route to commercialisation will be undertaken, including market, policy, and regulatory framework requirements.

Accelerated Adoption: To achieve the quickest possible BAU adoption, consideration of the whole system integration strategy will be necessary. REWIRE aims to investigate the deployment strategies that optimise national resilience, consumer energy security and cost. Development of a robust roll out strategy will increase in fidelity through the SIF phases, alongside consultation with wider industry.

Ultimately, adoption will be dependent on the demonstration of net benefits for the energy networks and consumers, whilst ensuring required stakeholders and policy makers are adequately informed.

Energy networks are not able to purchase or own generation/ storage assets, or systems that operate behind the meter. Nonetheless, significant coordination with the networks will be crucial for BAU adoption.

Market Competition: Rather than undermine competitive markets, REWIRE will strengthen them. The heating and cooking appliances market will see increased competition, as hydrogen-ready technology remains an option. Battery energy storage systems would also see competition, if small-scale hydrogen storage and conversion technology is proven to be viable at a domestic level.

Implementation: Identification of key market participants and relevant stakeholders will take place to understand who the most suitable owners and operators of these systems will be. This is likely to depend on the most viable consumer use cases, investigated as part of the Discovery Phase. Relevant third-party involvement in the project will increase through the SIF process, and appropriate partners will be acquired for the Alpha and Beta Phases.

Customer Segment: The customer segment is likely to depend on the domestic and network archetypes, as application solely to support uninterruptible supply will benefit consumer groups differently, compared to the application to support grid flexibility. REWIRE offers national and international opportunities, the extent of which will become more apparent once the benefits for the different domestic and network archetypes have been fully assessed.

Funding Strategy: Without performing the proposed commercial viability assessments, it is difficult to predict costs required to install, operate and maintain this solution. However, the proposed project will undertake an assessment of relevant policy levers that may be appropriate to support market entry and growth. For example, analysis of the levels of subsidisation that may be required.

Intellectual property rights (not scored)

REWIRE will be compliant with the default position on IPR as outlined in the SIF Governance Document. Innovation is an essential mechanism for driving positive change across industry and, as such, it is important that knowledge can be disseminated effectively to all relevant stakeholders.

Background IP: The following background IP was generated prior to REWIRE:

· Each project partner will be providing their knowledge and knowhow. The team can provide extensive relevant expertise across the whole energy system and relevant analysis. This includes extensive experience of undertaking network innovation projects.

· ENWL have previously undertaken work, with support from Frazer-Nash, to develop a functional variable VoLL model to investigate how different consumer groups are impacted by loss of supply.

· Imperial College London will be utilising the novel Integrated Whole Energy System (IWES) model to quantify the minimum of the total cost of long-term infrastructure investment and short-term operating cost by optimising the energy system capacity and system operation using the existing and potential new resources, while considering the flexibility provided by the cross-energy vector interactions, while meeting security of supply and specified carbon targets.

Foreground IP: It is anticipated that the following foreground IP will be generated during REWIRE:

· Domestic archetypes for the application of vector conversion technology and storage systems.

· Development of network archetypes.

- Findings from the cost benefit analysis.
- Assessment of wider macroenvironmental considerations and implementation roadmap.

Costs and value for money

Total Funding Required: The total Discovery Phase cost is £186,389 with a SIF funding request of £149,944 to undertake this feasibility study.

As innovation projects of this type are key to ensuring the Net Zero emissions targets are achievable by 2050, each project partner has agreed to discount their day rate by at least 10% as a contribution to the project. Each project partner is dedicated to contributing to Net Zero and understands that securing energy system resilience plays a pivotal role in reaching this goal.

Value for Money: REWIRE assembles a consortium of organisations focused on achieving the Discovery project's aims. It will be undertaken by energy system experts with extensive understanding of the approaches that are required to tackle this type of problem. This includes applying novel modelling techniques that will offer unique insight to the long-term and short-term costs and benefits associated with the proposed solution.

REWIRE will investigate a breadth of consumer and network benefits, with the focus scaling from small-scale domestic energy security to maintenance of national energy resilience. The novel technical consideration of using behind the meter vector conversion and storage can potentially enable increased consumer optionality and market competition, providing long term value for money, whilst simultaneously offering additional revenue streams through flexibility markets. Increasing the penetration of storage and reducing the curtailment of renewable energy will contribute towards improved resilience and greater flexibility for the distribution network, supporting grid balancing and reducing the substantial cost associated with reinforcing the network.

Document Upload

Documents Uploaded Where Applicable

Yes

Documents:

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REWIRE~1.PDF

WP1DOM~1.PDF

WP2NET~1.PDF

WP3 System Benefits REWIRE.pdf

WP3VAL~1.PDF

WP4IMP~1.PDF

This project has been approved by a senior member of staff

☑ Yes