SIF Beta Round 2 Project Registration

Date of Submission

Nov 2024

Project Reference Number

SIF_Hubs_Beta

Initial Project Details

Project Title

Flexible Railway Energy Hubs

Project Contact

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Challenge Area

Accelerating decarbonisation of major energy demands.

Strategy Theme

Net zero and the energy system transition

Lead Sector

Electricity Transmission

Project Start Date

01/12/2024

Project Duration (Months)

60

Lead Funding Licensee

SPEN-T - SP Energy Networks Transmission

Funding Mechanism

SIF Beta - Round 2

Collaborating Networks

SP Energy Networks Transmission

Technology Areas

Electricity Transmission Networks

Energy Storage and Demand Response

Project Summary

Flexible Railway Energy Hubs will demonstrate a transformative approach to accelerate the decarbonisation of the single largest electricity consumer, Network Rail. An Energy Hub is a modular microgrid solution that integrates batteries and local renewable energy with the rail traction network. By transforming the railway into a flexible electricity consumer, the project generates benefits to the electricity network and consumers by reducing wind curtailment expenses via flexibility services and reducing engineering disturbances. The project duration is 5 years and requests £8.3m SIF funding.

Project Budget

£11,081,020.00

SIF Funding

£8,256,616.00

Project Approaches and Desired Outcomes

Solution statement and solution focus

The UK government's net zero strategy predicts 60% increase in electricity demand due to switching of energy supply modes in major sectors including transport. Rail is the largest electricity consumer in the UK totalling 1.2% (~4TWh p.a.). This load is presently "inflexible", with transient peaks in demand (up to 500% higher in peak travel times) resulting in greater pressures to the transmission network to supply future rail demand. While representing the fastest route to transport decarbonisation through the electrification of diesel routes (~62% of total, saving 1,788 ktCO2e), the rail network is set to grow by 2TWh in the next 20 years creating significant problem for grid network operators. This will add additional stress to electrified railway routes, increasing the fluctuation of the voltage outside the regulation bands, introducing harmonics and degrading both assets and service.

Rail electrification requires extensive updates of both the power and railway networks, which are extremely expensive and timeconsuming to deploy, e.g. rail electrification costs £1~2.5m per single track kilometre (stk), and a feeder station costs over £20m, while the current connection lead times are over 15 years, and investment in transmission capacity is falling behind deployment, leading to \>£1b cost of managing constraints in 2022.

Solution and Project Evolution

The Energy Hubs (**Hubs**) project aims to demonstrate the **first microgrid technology to interface cross sector with both railway network and power grid**, offering configurable, flexible and controllable components to transform the railway system from the single largest inflexible load to the **single largest flexible demand.**

This **whole system approach** across the demand and electricity network owner will mitigate engineering risk of harmonics and reduce both average and peak power demand, thus deferring or avoiding conventional network reinforcement.

We aim to demonstrate a minimum viable microgrid incorporating a battery at Ayr rail depot at a scale able to prove the concept and derisk future investment.

Challenge Alignment

Our project meets challenge 4 of accelerating **transport** (railway) decarbonisation by optimising the energy and infrastructure demands which the railway traction power system makes on the transmission grid, whilst simultaneously contributing to mitigating wind-power curtailment, load-balancing, and ancillary (voltage and frequency regulation) services. Where Hub sites can also accommodate solar PV generation, this will provide a further contribution to decarbonisation. Hence the proposed Hubs offers an **integrated** approach to supporting decarbonisation of two of the UK's biggest sectors: **energy** and rail **transport**.

Potential users & understanding of their needs

Our NIA-funded work has demonstrated the potential for concurrent usage of Hubs to deliver services to the electricity network. Thus, the Hubs will have two distinct user groups. The **electricity network organisations** (ESOs and DNOs), electricity suppliers and the **railway network organisations** (Network Rail, TfL, HS1 and train operators).

Hubs can also avoid new overhead line electrification by powering battery trains, delivering faster and more cost-effective decarbonisation to rural routes. Further benefits include back-up power provision to railway depots and provision of flexibility services to benefit rural communities.

Innovation justification

Challenge theme

Energy Hubs (**Hubs**) will deliver the first microgrid hub that supports cross sector decarbonisation by facilitating, managing, and integrating transport and flexibility services.

Innovations

Our microgrid approach will be **the first scaled demonstration** of a battery powered microgrid that couples two large complex networks, rail, and electricity, facilitating cross-sector decarbonisation.

Hubs will use the railway traction power network as a **conduit for delivering flexibility** and **ancillary services** to the electricity transmission network. The "reach" of the traction power network gives access to a wide range of low-cost sites for battery storage and solar panel locations. The traction power network also reaches regions experiencing significant wind curtailment, where Hubs offer **significant wind curtailment reduction** potential.

Through simulation modelling and predictive control, **Hubs will mitigate unwanted interactions of power electronic devices between electricity grid and the railway network** as demand grows, while also reducing voltage drops at weak spots around the grid and improving voltage stability.

Counterfactual solutions and approaches

Without Hubs, decarbonising the rail network by 2050 will involve ~450km of track electrification per year, with CAPEX over ~£30n, and will increase the load on electrical networks without introducing any demand flexibility traditional rail electrification methods have no potential to support the electricity grid or deliver carbon savings. Furthermore, lead times for **new major grid connections are currently up to 15 years**, implying significant delays in meeting rail decarbonisation targets.

Learning from preceding projects

Hubs stands out as a timely and crucial initiative for cross sector decarbonisation. SP Transmission's leadership in the **whole system design** and **facilitating railway decarbonisation** further reinforces the project's importance.

Engagement with stakeholders

Hubs brings together a strong partnership to ensure we can deliver on the ambitions.
We have effectively engaged with: National ESO, National Grid, **all ENA TO/DNO members and Network Rail.**

Changes in TRL, IRL, CRL

As elaborated in the Innovation appendix, the current Hub technology is at TRL 6, IRL 5, and CRL 5. At the end of the Beta phase, it will be uplifted to TRL 9, IRL 7 and CRL 8.

Rationale for project size and scale

The proposal is proportional and strikes the **balance** of a demonstration at a suitable scale complemented by effective use of digital modelling. Ayr Depot was selected to host the demonstration, based on electricity grid access, available land ownership rights, minimal risks to railway operations and, demonstrating the greatest range of use-cases. This will also be sufficient to generate engineering practices to support new standards.

The scope of the demonstrator has been developed to utilise existing regulated traction energy. Digital simulations will allow us to model the increase in performance available by removing the following limitations:

- Minimum battery capacity and charge/discharge power possible to demonstrate the principle of traction voltage regulation.
- Limiting the grid services demonstrated to those which only require import of power.
- No installation of solar PV.

We will:

- **Generate a blueprint** that can be scaled for different sized Hubs.
- Establish **industrial standards.**
- De-risk the technology rollout.

Impacts and benefits selection (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

New to market - services

Impacts and benefits description

Current position and Counterfactual (pre innovation baseline)

The rail network is already the **UK's largest electricity consumer** (4.21Wh p.a. ~1.2% of total UK demand, emitting 1.2 million tCO2e). At present this **single largest electricity consumer is not flexible**, without benefits for the electricity system or the rail system.

Diesel trains consume 648 million litres of diesel per annum, emitting an additional 1.8 million CO2e. Replacing diesel trains with electric trains would nearly double rail electricity demand, requiring 448km of track to be electrified every year to meet the net zero target by 2050, representing over £30b investment. The lead time for critical new projects to be connected to the grid is currently >15 years, implying a high risk of delayed railway electrification.

Benefits of the Energy Hubs

The Hubs project is an innovative engineering demonstration which aims to **create a blueprint for accelerating decarbonisation of major UK electricity demands**. The project also balances commercial and regulatory considerations, with staged outcomes. The project will also verify our forecasts of significant and tangible benefits of up to £2 billion by 2070, including reduced construction costs and investment in conventional grid reinforcement, reduced electricity bills and network outages.

Benefits from Hubs comprise of:

For Electricity Network Operators:

- Reduced Wind Curtailment costs.
- Benefits from Demand Flexibility Service.
- Carbon Emission Reduction.

For Railway Industry as the major demand:

- Avoided Overhead Line Construction CAPEX.
- Savings by Time Shifting Electricity Use.

Teams and resources

Partners include **SP Energy Networks, Ricardo, Network Rail, University of Leeds and GE Verona and support from NESO**. Each partner brings invaluable complementary expertise and represents key sections of the value chain and route to market for the technology.

SP Transmission is the electricity transmission licensee for the Central and South Scotland where this project will be completed. SPT is the Lead Network operator and project manager for Hubs. James Yu, Head of Innovation, initialised this project with the senior sponsor Eric Leavy, Head of Transmission network. Ross Davison senior project manager has extensive experience leading multi-million-pound network funded innovation projects, he will lead **WorkPackage1** Project Management Coordination, **WorkPackage5** Knowledge capture, dissemination, and stakeholder engagement, and **WorkPackage6** Commercial model, regulatory framework, and rollout to BAU transition.

Network Rail have been onboarded as they own, operate, and develop Britain's railway infrastructure -- 20,000 miles of track; and over 2,500 stations. They have identified the trial site and are preparing to provide funding of their activities at c. £2m, demonstrating strong commitment and derisked the project. Brian Sweeney, Engineering Manager with extensive engineering experience has developed the equipment and site selection criteria. Network Rail will lead **WorkPackage3**, Design and Build of the Hub; and **WorkPackage4** Hub integration and operation with Railway; and support other **WorkPackages**.

The University of Leeds (UoL) Project team members are from the institute for High-Speed Rail and System Integration, Institute for transport Studies and Smart Energy Systems, which are among the UK's leading departments for teaching and

research in transport studies, railway, and electrical engineering. UoL conducts world leading research, running 107 live projects with £148m funding from EPSRC. **UoL team** co-developed the Energy Hub concept. They were the technical lead in the SIF discovery phase and the NIA design phase, and will lead **WorkPackage2**, Design, Innovation and Simulation of the Hub. Leeds will also support all other **WorkPackages**.

Ricardo is a global strategic engineering and environmental consultancy that specialises in the transport and energy innovation. Ricardo will provide a safety case assessment for the proposed Hubs site in Ayr. Ricardo will work in consultation with Network Rail to provide support and input into **WorkPackage4** relating to trial scoping, data analysis and write up of the findings. In addition, Ricardo will work with SPT and the project partners and provide support for **WorkPackage5** and **WorkPackage6**.

GE Vernova (GEV) will design, engineer and supply the Power Conversion System for the Hub and will lead technical development of the secondary & tertiary control system, systems integration and provide installation supervision, commissioning and ongoing engineering support for the duration of the demonstration phase. GEV will derisk the project through implementation of an innovative solution using provenGEV technologies and control solutions while working collaboratively with the project partners. GEV will be responsible to support **WorkPackage2**, **WorkPackage3**, and **WorkPackage4**.

NESO will support **WorkPackage6**, providing guidance on flexibility and ancillary service provisions from the Hubs.

Project Plans and Milestones

Project management and delivery

As a leading licensee, SPT has established its leadership in flagship innovation management. This end-to-end and agile mechanism ensures successful **delivery**, **future rollout**, and **benefits realisation** for our customers.

The project has **six WPs** to enable effective management. Detailed tasks and descriptions, timings, dependencies, deliverables and milestones are shown in the PM workbook.

WP details:

WP1: Project management (SPT). Deliverables: Regulatory and regular reports

WP2: Design, Innovation and Simulation of the Hub (UoL). **Deliverables**: Technical report to the demo Hub design; Final verification report on outcomes and conclusions.

WP3: Design and Build of the Hub (Network Rail and GEV). **Deliverable**: Completion of Hub construction on time and on budget.

WP4: Hub Integration and Operation with Railway (Network Rail, GEV, UoL, and Ricardo). **Deliverable**: Safety and assurance strategy; Safety Assessment Report, DOCOR and Authorisation; Provide output of results from live trial.

WP5: Knowledge capture, dissemination, and stakeholder engagement (SPT). **Deliverable**: Stakeholder mapping, publications, stakeholder events and dissemination report.

WP6: Commercial model, regulatory framework and rollout to BAU transition (SPT, Network Rail). **Deliverables**: Definition of commercialisation and rollout modelling; Final Rollout Model; Final CBA model; Outline the BAU transition.

Key outputs and dissemination

The Beta project will demonstrate the **technological and commercial viability** of using Hubs to transform the UK's largest commercial electricity load from **inflexible to flexible**, whilst simultaneously **accelerating decarbonisation of the railway network**. Providing new flexibility benefits to the electricity grid, and electricity consumers, while accelerating the decarbonisation of the railway network. The core objective is to integrate, build, and commission a Hub demonstrator at the Ayr Deport for live connection to the 25kV traction network, trial a range of services and use cases and finalise the commercialisation plan for future rollouts.

The key outputs include:

Output 1 (**O1**): Hub design specifications for the Ayr depot and the tertiary control specification report.

O2: Digital simulation of the Hub and user interface to display the services of Hubs.

O3: Hub demonstrator commissioned and live trial of the system functionalities at the Ayr depot.

O4: Report on demonstrator data analysis and evaluation of operational, economic, and environmental impacts of the live demonstrator.

O5: Report on stakeholder mapping and dissemination activities.

O6: Report on commercialisation and rollout model, CBA model and the BAU transition.

O1 and O2 will be led by UoL who will disseminate scientific/academic breakthroughs in conferences (e.g. IEEE/IET conferences/Energy-Policy/Electricity-markets) and scientific papers (e.g. IEEE Proceedings/Applied Energy/NatureEnergy/Science), subject to commercial priorities and IP protection.

GEV will support the commercialisation of the hub technology (hardware and software).

O3 and O4 led by Network Rail and supported byGEV involves the installation and testing of the Hub demonstrator, including **connection and energisation with the railway traction network**. A series of trials will be undertaken with support by GEV and UoL to test the concept of operating the Hubs across a series of operating modes, which is the core innovation focus in the live demonstration. UoL and Ricardo will undertake data analysis to form conclusions on the outcomes of the trials, ready for dissemination.

O5 and O6 led by SPT and supported by all partners will **disseminate the learnings** and BAU route of Hubs technology to market.

SPT and the partners have substantial track records and experienced teams to handle the knowledge sharing and engagements by:

1) Regular webinars and UKRIShow/Tell sessions at relevant innovation and sector conferences such as Energy Innovation summit and Rail decarbonisation events.

2) Publication of annual reports and learnings.

3) Organise regular outreach and publicity events to promote the innovation to other licensees.

4) Work with Ofgem, NGESO, other licensees, Network Rail, independent aggregators, entrepreneurs and investors to establish the types and levels of flexibility services that the networked hubs can and are allowed to provide, evaluate the regional market, firm the customer value proposition and associated business case.

5) Events with the Rail Industry Association, RSSB, and the energy storage industry.

6) Supply chain engagement events with developers of commercial battery projects, the first of which is on 12 June.

7) Working with project partners and industry advisory board members in previous SIF/NIA projects, external key suppliers who have both UK and global involvement in the rail technology, to define the design/provision/creation of hardware/software adding value to the project, particularly around power assets monitoring.

To ensure the energy Hub technology has suitable business as usual adoption, the consortium will further develop the stakeholder network and continue engagement to scale more towards the remaining opportunities, such as other non-electrified railway routes, London Underground, bus depots, and ports, etc. This will further develop business models to **benefit both electricity and railway customers**. The consortium will work collaboratively with other projects funded by previous SIF phases, gaining insights from their successful experiences in delivering the project objectives.

Commercials

Intellectual Property Rights, Procurement and Contracting (not scored)

Intellectual Property Rights

Each partner will sign a collaboration agreement with SPT which will outline the IPR terms. The default arrangement is planned to be used on all agreements apart from the one between Network Rail and SPT.

The planned future roll-out into business as usual and commercialisation route of the Hubs concept sees Network Rail playing a leading role in the procurement of energy services. Foreground IPR produced by the project will be relevant to the interface between the traction network and the energy network. As such, Network Rail will need to utilise Foreground IPR in order to implement the Method being developed or demonstrated by the Project.

For this, it was deemed appropriate that **Network Rail will be granted a perpetual non-exclusive royalty free licence touse the Resulting IP** and any patents granted in respect of it, solely in connection with the railway's permitted business of operating, maintaining and renewing the rail network. This will ensure alignment with the planned commercialisation path, dissemination of knowledge and a wider realisation of benefits.

Procurement and subcontracting

As an arm's length body of Government, Network Rail is subject to public procurement regulations. As such, the works directly procured by Network Rail for the site compound and rail integration will be undertaken by an EPC Contractor via an existing railway Framework.

Commercialisation, route to market and business as usual

The commercialisation strategy, a collaborative effort among consortium members, builds on comprehensive market analysis.

To enable supply chain readiness a **Work Package 6** 'Commercial model, regulatory framework, and rollout to BAU transition' will determine the most appropriate commercial model and approach for rollout opportunities for electricity and rail networks.

This work will refine commercial arrangements for key stakeholders, such as defining the responsibilities of Network Rail, Transmission & Distribution Network Operators (including NESO), and third-party suppliers and developers of commercial flexibility projects.

Route to market

The collaboration demonstrates confidence in the commercial opportunity associated with the Hubs. Modelling has been performed from both the rail and power network perspective, to understand the rollout routes. Ricardo will lead commercialisation activities, developing the customer value proposition and business case. This work package will also mature modelling and its learnings from stakeholder engagement.

We have arranged a prior information notice (**PIN**) and organised an industry engagement day targeted at the companies who develop commercial scale battery projects. A questionnaire will be issued to gather feedback on the Hubs proposal and the commercialisation route. Further supply chain events will be undertaken during the Beta project.

Policy, standards and regulations (not scored)

The scope of the Beta demonstrator project has been developed to **operate within existing regulations.**

For instance, SPT are unable to operate a battery under its licence conditions. Therefore, **Network Rail** will operate the battery for the period of the trial. **No derogation or exemption is foreseen through the project**.

The project team are not aware of any regulatory barrier that would affect the demonstrator project to progress into business as usual. We are working closely with NGESO, SPT, Network Rail and project partners to ensure that the project outcome will

contribute to the ongoing design of electricity and rail decarbonisation landscape from engineering and policy perspectives.

We are aware that the future roll-out of the Hubs concept will require regulatory approval from the Office of Rail and Road (ORR) on how grid balancing, and flexibility services align with Network Rail's licence conditions. For this, and to navigate the regulatory framework, the Work Package 6 'Commercial model, regulatory framework, and rollout to BAU transition' will determine the most appropriate commercial model for rollout post-trial. Additionally, the demonstrator will undertake **digital simulation modelling** to provide lessons learned and data evidence to inform regulatory discussions. We will host workshops with regulators to ensure their input is captured and inform potential to change to existing regulation.

Through engagement on the regulatory aspects, we will then inform the refinement of the commercial arrangements for example fully defining the responsibilities of Network Rail, Transmission & Distribution Network Operators and third-party developers of commercial battery projects.

Consumer impact and engagement

This project combines partnership of both **system operators** (SP Transmission) and **railway infrastructure owner and manager** (Network Rail) in accelerating power and rail transport decarbonisation in a **whole system** approach.

Electricity consumers will benefit from reduced constraints and constraint payments which are passed on equitably to all customers and will have the greatest benefit for low-income consumers. These are provided by charging the Hubs battery at times of high renewable generation - estimated to reach £15.7m per annum from 2043, with the total benefit escalating to £535m per annum by 2070.

For rural communities along non-electrified railway routes, Hubs will provide flexibility services to local distribution networks to improve power quality and enhance power system resilience under extreme weather conditions.

Using existing grid connections will also avoid connection costs and enable battery capacity to be added more quickly than on greenfield sites, reducing socialised costs of connections for battery systems.

Consumer engagement during the Beta project

Engagement with consumers and the associated operators will include:

- Electricity Consumers: This will be indirect through NGESO, a supporting partner, using their role in design and implementation of transmission flexibility markets -- the key route to reduce bills.
- Rail System Operators: This will include in depth collaboration with the key stakeholders in Network Rail Scotland + the other Network Rail central and regional teams, plus TfL and High Speed 1 and other operators. We will use the Rail Industry Association, Rail Safety and Standards Board and similar channels to engage with the rail stakeholders.
- Battery Project Developers: Essential for the capital and expertise to roll out Hubs -- we are issuing a PIN and holding a market information event with the sector. This will continue during Beta.
- Community Engagement: Dissemination of benefits, risks and impact via local community energy and transport groups.

Value for money

The Hub consortium presents a compelling value-for-money (VfM) proposal that holds significant importance in the overall system design and decarbonisation effort.

From a financial perspective, the whole life NPV will reach £2.1b, bringing significant benefits to both energy users and rail customers. This presents an opportunity for faster and more cost-effective rail decarbonisation without causing engineering and project delivery barriers.

By combining financial commitment, rigorous processes, and strategic supplier partnerships, the Hub consortium is poised to drive impactful decarbonisation efforts.

Contribution from Partners:

Network Rail's Funding:

*Network Rail, our key partners, is currently following internal governance to seek commitment to fund all trackside project activities and efforts.

*Their direct contribution would be £1.8m.

Leeds University's Contribution:

*Leeds University is actively participating by contributing 20% of their costs.

*Additionally, they are providing a PhD studentship, further enhancing our leveraged funds.

Value for money and additional value over business-as-usual activity.

- Leverage findings from over £1m of past and current relevant research and innovation projects from consortium.
- Leverage £2.8m in-kind contributions from the consortium.
- Improve customer satisfaction with reduced service delays due to power faults. Over 400,000 delay minutes in 2019-2020 alone related to power faults.

The project is also complementary to the following challenge projects:

- Implementing Energy Reduction Activities to Reduce our Carbon Impact.
- Smarter, more efficient Electrification.
- Using large Scale Renewable Developments to Enable Decentralised Supply to the Rail Infrastructure.

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

Flexible Railway Energy Hubs Annual Report 1 - 864.8 KB
SIF Beta Round 2 Project Registration 2024-11-08 3_44 - 77.5 KB
SIF Beta Round 2 Project Registration.pdf - 76.6 KB

Documents uploaded where applicable?

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