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

NIA Project Registration and PEA Document

Date of Submission

Mar 2023

Project Reference Number

NIA_SPEN_0089

Project Registration

Project Title

Resilient and Flexible Railway Multi-Energy Hub Networks for Integrated Green Mobility (Hubs)

Project Reference Number

NIA_SPEN_0089

Project Licensee(s)

SP Energy Networks Distribution

Project Start

February 2023

Project Duration

1 year and 2 months

Nominated Project Contact(s)

Ross Davison

Project Budget

£500,000.00

Summary

Hubs is a novel microgrid solution for railway stations, first of its kind in the world, to interface with both traction power supply system and local distribution grid to maximize the energy efficiency while providing cost-effective solutions for railway decarbonization. The energy hub will integrate local renewable generation, recover regenerative power from trains approaching stations, and coordinate both traction and non-traction power supplies along the railway routes. The ultimate goal is to implement the energy hub solution to as many of the 2500 stations across over 10,000 miles of UK rail as energy and transport nexuses, connecting these hubs and their surrounding cities/communities to support green mobility and a future low carbon power grid that runs almost entirely on renewable sources.

Nominated Contact Email Address(es)

innovate@spenergynetworks.co.uk

Problem Being Solved

1. Rail is the single largest electricity user in the UK, consuming 4 TWh electricity pa (1.2% of UK total). Still 60% is nonelectrified, which over 2400km of tracks is unsuitable for electrification, and diesel trains produce 1.6 MtCO2e pa. The UK government has planned to phase out all diesel trains by 2040, and by 2035 for Scotland.
2. The 2500 railway stations along 10,000 miles of UK rail are passive energy users while having significant number of untapped potentials in terms of unused roof/land space that could be used for renewables and energy storage to benefit both railway network and power grid, major opportunities will become wasted if not fully utilized.
3. Conversely, redeveloping railway stations is high on the agenda of UK/European cities, largely under ‘transit-oriented development (TOD)’, but significant efficiency and flexibility potentials to benefit both rail and power industries leveraged from coordinated management of the energy mix in these stations and surrounding areas has never been properly explored.

Method(s)

This project will undertake detailed design for Ayrshire Energy Hubs, identify technical solutions with minimum viable product (MVP) features, develop implementation and commercialization plan, demonstrate the technological viability and economic, environmental and societal benefits, and address potential complexities/challenges, enabling the hub technology to become a business-as-usual activity for mass roll-out.

The project is planned to take 8 months period starting from completing 3 work packages defined as below.

WP1: Data gathering and partnership engagement

WP2: Energy hub engineering design

WP3: Energy hub implementation plan and business models, assess the transferability of the designed energy hub solutions to other rural and urban stations

Scope

This project will leverage the expertise from the existing steering group of the Energy hub project and the H2H project both funded by the Ofgem SIF fund in the discovery phase. The project steering group comprise project partners and strategic stakeholders. They include Network Rail, SP Energy Networks, Office of Rail and Road (ORR), Transport Scotland, University of Leeds, Ricardo, Costain, and Entrust Microgrid. The steering group will meet regularly prior to the commence of the project to improve the project lead time. The group will agree upon stations along the Ayr-Girvan-Stranraer route in Scotland for detailed energy hub design, and the current candidate stations under consideration include Stranraer and Newton-on-Ayr. A business engagement and impact team will be formed as well.

WP1: Data gathering and partnership engagement (2 months, Lead: Leeds, Deputy Lead: Network Rail/SPEN)

Engage with key relevant stakeholders, and collect information for hub design:

- Engage with targeted stations, understand the hub construction complexities (electrical, civil, mechanical, safety, licensing, ownership etc.);
- Work with Network rail planning team, and collect all relevant information required, including, but not limited to: infrastructure data, station and car park layout; electricity data, low/high voltage electricity layout; existing metering and SCADA systems, energy/power supply and consumption data at suitable granularity; space availability for hosting the hub including energy storage; weather condition; etc.
- Engage with Local Authority, Country Council, Environment Agency, TOCs, where appropriate to understand the broad context, complexities and impacts of building the hubs.

Milestone 1 – Detailed data and information required for the hub design should be obtained and analyzed.

Deliverable – A Report containing all technical data (electrical, civil, mechanical, safety, licensing, ownership, etc.), and information requited for the hub design.

A report giving detailed engagement activities with local authority and various agencies. This should include recordings of communications and discussions and names of the contact persons.

WP2: Energy hub engineering design (3 months, Lead: Leeds; Deputy Lead: Ricardo/ Entrust Microgrid)

Draft the hub specifications:

- Liaison with Network Rail design team, and engage with microgrid specialists, OEMs and suppliers (energy storage, PV installer, PCS supplier, protection system, digital twin, energy management system, etc.) to design hub specifications.
- The designed energy hubs should have key features of minimum viable product (MVP):
  1. meet AC and DC power exchange demands at different voltage levels;
  2. coordinate power flows from sources to loads under different operation conditions;
  3. provide ancillary services to grid when necessary, meet voltage and power factor regulations, harmonic eliminations;
  4. modular design approach to ensure robust and reliable to potential faults and disturbances from load and grid;
  5. provide secured supply to critical load under both grid-connected and islanded conditions.
- Technical validation of the hub design within software defined and hardware-in-the-loop environment.

Milestone 2 – Designs of energy hubs for two selected stations should be produced. Technical validation of these designs using software defined and hardware-in-the-loop environment should be successfully performed.

Deliverable - Report, documenting the hub design specifications, giving drawings of the electric schematics and geometric layout of each hub, Specifications should include sizes and ratings of the PV system, energy storage, all the converters, transformers switchgears and protection hardware at the level of details sufficient to ensure accurate simulation and hardware-in-loop validation. Simulation and hardware-in-the-loop validation results should be provided.

WP3: Energy hub implementation plan and business models and technology transferability (3 months, Lead: Leeds; Deputy Lead: other partners - Network Rail/SPEN/Costain/Ricardo/Entrust Microgrid)

Develop an implementation plan and business model:

- Engage with key stakeholders, including ORR, targeted stations, project & construction management companies, microgrid specialists, DNO, local authorities and other stakeholders to develop hub implementation plans including both civil and electrical installation for the targeted stations, including hub construction time scales, planning applications with different authorities (Local Authority, Environment Agency, Network Rail, TOCs, etc.).
- Assess off-the-shelf solutions for subsystems/components, assessing system costs, installation and construction costs, and project management costs to guide the installation phase.
- Engage with system operators to discuss different services that can be offered by the energy hubs and assess the benefits.
- Assess the transferability of the energy hub solutions to other rural and urban stations in the UK and globally. Stations along the Glasgow and South Western route and Stranraer - Kilmarnock – Dumfries routes are immediate options for transferability.
- Engage with different stakeholders of the energy hub (station, train operator, Network Rail, car parking owner and customers) to design suitable business models to maximize the impacts and benefits of the hubs and become business as usual activities.
- Public and stakeholder engagement activities to maximize the impacts.

Milestone 3 – Producing a Hub construction plan and design a business model.

Deliverable – A report detailing hub construction plan including time scales, potential suppliers of subsystem/components with a list of OEMs and technical suppliers, estimations of costs. Adequate schemes/methods addressing potential complexities with hub construction and installation should be presented.

A report detailing the cost and environmental benefits of the railway energy hubs to all stakeholders, and hence the layout of the business model structure.

Objective(s)

The objectives below are specified according to the three work packages defined and are listed as follows:

- Gathering all technical data (electrical; civil, mechanical, safety, licensing, ownership, etc.), and information required needed for the hub design, with full engagement of the targeted stations along Ayrshire route.
- Informing the ORR, Local Authority, County Council, Environment Agency, Road Agency, TNO and DNO, Network Rail, Train operators and other stakeholders, the project scope and requirements, hence obtaining engagement.
- Producing design specifications for Ayrshire Energy Hubs having the features of minimum viable product (MVP). Detailed electric schematics and geometric layout of each hub will be drawn. Power ratings and voltage levels of subsystems should be listed. Technical validations of hubs under various operation conditions via Software and hardware-in-the-loop environment should be performed.
- Producing a hub construction plan including off-the-shelf solutions for subsystems/components; engage with system operators.
- Developing a viable business model with well-defined public and stakeholder engagement activities.
- Assessing the applicability of the designed solutions to other rural and urban stations for roll-out.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

N/A

Success Criteria

WP1 - Identification of stations for Ayrshire Energy Hubs and compilation of associated data for identified stations

WP2 - Report documenting the hub design specifications, outlining the circuit diagrams of the whole hub including size and ratings of the PV system, energy storage, all the converters, transformers switchgears and protection hardware at the level of details sufficient to ensure accurate simulation and hardware-in-loop validation.

WP3 - Detailed report on the hub design implementation plan and business model

Project Partners and External Funding

The main stakeholders are Network Rail and SPEN, including SP Transmission plc, SP Distribution plc.

SPEN is one of the two main funders of the project, providing £250,000 through NIA, and will be able to provide information on services that can be offered by the energy hubs and assess the benefits; In turn it is also the primary beneficiary of the technology as the grid will gain ancillary services from the hubs to improve the power grid flexibility, so improve the quality of electricity supplied and raising the stability, security and efficiency levels of the power network, and reduce the curtailment of renewable energy.

Network Rail is the other funder of the project, providing £250,000, and will be the primary user of the technology developed. It provides expertise and experience in railway electrification and rail economics. It is the main provider of all the data and information relating to railway operations and stations needed for the project, including rail operations, track and station layouts, station power system structure etc.

University of Leeds is the project leader. They provide expertise in railways power electronics, smart energy systems and control, and railway economics; they lead technical work packages. The project will enhance the R&D profile of the university in innovating novel technologies for knowledge transfer to support transport decarbonization and more engagement with strategic industrial partners. It will also provide excellent training opportunities to students.

Ricardo: is one of the project partners, it provides: industrial expertise; experience on electricity supply decarbonization and novel power electronic devices; expertise in connecting the energy hub to the distribution network and installation regulations and complexities. The company will enhance their reputation in decarbonizing the railway network, gain revenue from the hub project and the roll-out of the energy hub technology, and exposure to new technology for improving competitiveness.

Costain: one of the project partners, providing railway construction and digital design expertise to the project. The company will enhance their reputation in decarbonizing the railway network, gain revenue from the hub project and the roll-out of the energy hub technology, and exposure to new technology for improving competitiveness.

Entrust: is one of the project partners, a company specializing in microgrid design and construction and is experienced providing OEMs and suppliers to design hub specifications. The company will enhance their reputation in decarbonizing the railway network, gain revenue from the hub project and the roll-out of the energy hub technology, and exposure to new technology for improving competitiveness.

Potential for New Learning

New information on the uses of power-electronics, machine learning, and other microgrid technology. More data on the effects these uses have on the network.

Scale of Project

Desk based

Technology Readiness at Start

TRL2 Invention and Research

Technology Readiness at End

TRL4 Bench Scale Research

Geographical Area

The project will first undertake designs for Ayrshire Energy Hubs. Eventually, it will enable the hub technology to become a business-as-usual activity for mass roll-out to as many of 2500 railway stations, across over 10,000 miles of UK rail to support both rail decarbonization and power grid operation.

Revenue Allowed for the RIIO Settlement

0

Indicative Total NIA Project Expenditure

Project Eligibility Assessment Part 1

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

Requirement 1

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

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

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

N/A (RIIO1 Project)

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

N/A (RIIO1 Project)

Requirement 2 / 2b

Has the potential to deliver net benefits to consumers

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

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

£46 million per annum if rolled out throughout GB.

estimated 3Mt CO_2e reduced carbon emissions per annum

Please provide a calculation of the expected benefits the Solution

The UK's annual non-traction load is 440 GWh and cost around £48 m. By building energy hubs for all stations - and looking further ahead, depots as well - the annual OPEX saving can reach as high as £32.8 m with the increased tariff.

If we take as an example, the 343 largest railway stations, providing more than 600MW power, at a scaled annual cost of £22000/MW, hubs would represent £13.2 M of additional revenue if the hubs offer ancillary services to the power grid.

13.2+32.8=£46 million per annum

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

A large majority of train stations across GB could be converted to energy hubs if the project is successful.

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

approximately £500 million to roll out across the 343 largest railway stations in the UK

Requirement 3 / 1

Involve Research, Development or Demonstration

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

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

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

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

☐ A specific novel commercial arrangement

RIIO-2 Projects

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

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

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

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

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

☐ A specific novel commercial arrangement

Specific Requirements 4 / 2a

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

The Learnings generated will improve the licensee's connection capablilities in regards to microgrids acting as renewable energy hubs.

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

n/a

Is the default IPR position being applied?

☑ Yes

Project Eligibility Assessment Part 2

Not lead to unnecessary duplication

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

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

Project was previously accepted as a SIF discovery which also disallows unnecessary duplication.

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

N/A

Additional Governance And Document Upload

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

This project is innovative due to its use of:

1) **Machine learning assisted digital twin technology** to gain insights into the energy flows within stations from supply to demand, address uncertainty issues and provide predictive energy management, hence improve overall energy efficiency and maximize system flexibility.

2) **Novel power electronics-based energy hub technology** to efficiently meet various AC and DC power requirements of the hub at different voltage levels, integrating local renewable generation and recovery of train braking energy, and supporting vehicle-to-station (V2S), vehicle-to-grid (V2G), and hub-to-grid (H2G).

3) **Advanced control framework** to effectively deliver optimal real-time performance while maintaining robustness and fault-tolerance of the hubs.

4) **Wide area optimal planning and operation coordination framework** to network and aggregate hub flexibilities to enhance rail power supply resilience and to provide services to power grid, e.g. balancing and congestion relief, grid stability, and black-start.

Relevant Foreground IPR

Bespoke designs for the construction of two seperate renewable energy hubs to be co-located on the site of two yet-to-be-determined train stations in Ayrshire.

Data Access Details

Please contact the project lead (Ross Davison) for any data requests

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

The SIF discovery phase also revealed a few challenges and constructional complexities in adapting hubs to the peculiarities of individual stations. The NIA funding is indispensable to address them through innovation projects before the technology becomes business as usual activities.

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

Technical

1) No suitable off-the-shelf solutions, delay hub construction (Risk level – medium, Impact – High, Likelihood – Medium). Action: a list of OEMs and technology suppliers were identified in discovery phase and will engage with them in the alpha phase. New industrial partners are invited to support the hub design: (After mitigation – Risk low).

2) Hub construction needs to meet various standards and requires permissions from different authorities hence delay the construction (Risk – High, Impact – High, Likelihood – Medium). Action: The consortium has substantial NIA &NIC experience on connecting railway power to grid. Alpha phase will identify suitable stations, and challenges that may delay the planning permission will be identified and addressed. (After mitigation – Risk low)

Commercial

Costs: Hub systems too expensive, cost benefit is unachievable and payback time is too long (Risk – Medium, Impact – High, Likelihood – Medium). Action: the discovery phase has designed 4 scenarios with payback time for each case. The team will work closely with all stakeholders to design the tailored cost-effective hubs. (After mitigation – Risk low).

Managerial

1) Failure of project partners to work together effectively to achieve the deliverables and milestones (Risk – Low, Impact – High, Likelihood – Low). Project management follows well established PRINCE2 principles and ISO9001 standards for project progress monitoring and tasks delivery as we did in discovery phase. (After mitigation – Risk Negligible)

2) Shortage of staff to deliver milestones in time (Risk level – Medium, Impact – High, Likelihood – Medium. The team of engineers and researchers successfully delivered the discovery phase will continue to work in alpha phase. (After mitigation – Risk Low)

IPR and Strategic

1) Failure to sign, operate and fulfil project related agreements on IPR (Risk – Medium, Impact – High, Likelihood – Low). The project will be delivered by all partners which all have well-established IPR policy and framework, and IP management mechanism. Project specific agreements covering IPR etc among existing partners have been signed in the discovery phase, these will be extended to alpha phase and sign with new partners. All foreground IP will be developed after signing an agreement. (After mitigation – Risk Low).

2) Partner commitment to project disappearing (Risk – High, Impact – High, Likelihood – Medium). To achieve net zero by 2050 is a legislated target for UK, transport decarbonization is a national priority. The project partners have developed excellent collegial relationship in discovery phase. (After mitigation – Risk Low).

Policy/regulation

Energy hubs may not be eligible to participate in network service under current policy, hence prolong payback time (Risk – High, Impact – Medium, Likelihood – High). Cost-effective modular design approach will be adopted. We will document the identified and other potential policy/regulation risks that may arise during the project period, and engage closely with government, Ofgem and Future System Operator (FSO), and to join the debates on policy reforms and unlock the substantial flexibility potentials of the hubs. (After mitigation – Risk Medium).

Environmental

Many stations are listed buildings, the additional of solar panels or close location of wind turbines may not be permitted (Risk level – High, Impact – High, Likelihood – High). We will engage with key stakeholders including local authorities to select suitable stations, and design tailored solutions with planning permissions (After mitigation - Risk Low).

This project has been approved by a senior member of staff

☑ Yes