SIF Alpha Project Registration

Date of Submission

Dec 2022

Project Reference Number

10037453

Project Registration

Project Title

A Holistic Hydrogen Approach to Heavy Duty Transport (H2H) - Alpha

Project Reference Number

10037453

Project Licensee(s)

SP Energy Networks Distribution

Project Start

Aug 2022

Project Duration

6 Months

Nominated Project Contact(s)

Ross Davison

Project Budget

£449,783.00

Funding Mechanism

SIF Alpha - Round 1

SIF Funding

£401,864.00

Strategy Theme

Net zero and the energy system transition

Challenge Area

Zero emission transport

Project Summary

The H2H project will demonstrate how the decarbonisation of rail using hydrogen can save costs, carbon and time for electricity and rail consumers.

Specific SIF Innovation Challenge

The project addresses all of the Zero Emission Transport Challenge aims by "developing the technologies, infrastructure and processes required to accelerate zero-emission transport options", plus the project "maximises the connection of renewable energy and storage" using green hydrogen.

Network Innovation Involved

Conventional rail electrification would lead to 8.7TWh of demand controlled by the railway timetable. Hydrogen-electric trains offer a cost-effective solution to the two sectors; by introducing flexible green hydrogen production, we can reduce constrained renewable generation and offer flexibility benefits to TSOs and DSOs, whilst decarbonising the railway.

From Discovery to Alpha

Our Discovery phase project assessed capital and operating costs, and emissions for 2 rail lines, comparing 4 options. This identified hydrogen-electric trains as the option with the lowest long-term costs for longer rural rail lines and the greatest decoupling of rail and electricity demand - offering the highest potential for flexibility benefits for both sectors.

Alpha Project

Theme 1: Flexibility

- Develop concepts for the flexible green hydrogen production, distribution, storage and use
- Assess half hour demand for green hydrogen production for the selected line
- Quantify the benefits of flexible green hydrogen production for electricity and rail consumers
- Define the scope of the demonstration needed to prove the benefits to stakeholders in both sectors

Theme 2: Preparation for Demonstration

- Confirm the locations, availability of sites for a demonstration project
- Address the safety, procurement and commercial issues
- Assess the costs and timescales for each element of the demonstration
- Agree partners for delivery

How the solution addresses the challenge

H2H offers a route to decarbonise the growing rail electricity demand -- with the highest flexibility and cost benefits for both sectors.

This project will help:

- Electricity and rail customers gain quality, service and cost benefits.
- Electricity asset owners gain toolsets for providing cost connection offers to Network Rail that meets both sectors' requirements.
- Network Rail to develop tailored and different electrification programmes to switch from diesel to electricity on the 60% of the rail network that is not presently electrified.
- Provide more load within the distribution and transmission networks that allows for Network Operators to connect more renewable generation, meeting the UK Government's 2022 British Energy Security Strategy to accelerate homegrown power for greater energy independence.

SP Transmission will be the lead organisation with five key partners:

- **Network Rail** (infrastructure provider) brings information about the rail network and electrification costs for traditional transmission connections
- **Ricardo Energy and Environment** (3rd party innovator) bring expertise in decarbonising electricity supplies and connecting traction networks to distribution networks through novel power electronic devices.
- **Ricardo Rail** (3rd party innovator) brings expertise engineering/procurement and certification/approvals for the rail industry.
- **Leeds University** (academic user) brings rail and power electronics expertise from their Institute for High-Speed Rail and System Integration
- **ScottishPower** who have a new Hydrogen division set up to drive this topic

Users:

- Electricity: Conventional electrification adds to the costs paid by electricity consumers. H2H offers lower connection costs and the highest level of flexibility in energy supply for rail decarbonisation

- Rail: Hydrogen trains are quicker, quieter and reduce pollution and can be introduced at much lower costs than other options

Project Description

The rail industry has a target of removing all diesel passenger trains by 2040 (2035 in Scotland).

In the next 5 to 10 years the rail sector will decide which rolling stock to use (electric, battery or hydrogen). Conventional rail electricity connections will commit 8TWh of demand to be controlled by rail timetables for many decades, a large uplift of inflexible demand.

Our Discovery project assessed three solutions to make rail electricity demand more flexible:
1. Full Electrification -- Overhead 25kV connected to higher voltage electricity networks
2. Discrete Electrification with Battery Trains: Using storage on the train and recharging under 10km sections of overhead 25kV line
3. Hydrogen-Electric: Green hydrogen production and fuel cell trains

For the longest lines Hydrogen-Electric proved to have the lowest overall costs, over 50% fuel carbon savings and the lowest embodied carbon.

Hydrogen-Electric trains supplied with Green Hydrogen:

- Will be fuelled at a rail depot between midnight and 6AM.
- Green Hydrogen will be stored at the rail depot -- so can be produced days in advance of need by the railway

This offers the potential to reduce constraint payments and benefit electricity and rail consumers.

Of the solutions assessed, Green Hydrogen also offers the clearest route to provide flexibility benefits for TSOs, DSOs and hence reduce costs for consumers.

For example, in 2020 onshore wind generation of 3.5TWh was curtailed, costing £243million or £8.5 per household -- future rail electrification is over 3TWh p.a. thus, Hydrogen-Electric trains supplied with Green Hydrogen in rural areas can reduce constraint costs.

In Discovery we assessed 2 rail lines in Scotland, developing an outline Business Case that showed:

- Green Hydrogen is the lowest cost option for the 280km line from Inverness to Thurso & Wick
- Battery trains with trackside batteries are the lowest cost option for the 65km line Girvan to Stranraer

The H2H Alpha project will focus on Green Hydrogen. The related Hubs Alpha project led by University of Leeds will focus on the trackside battery solutions.

In H2H Alpha phase we will:

- Assess in full the benefits of flexible green hydrogen for rail traction
- Develop concept for full demonstration
- Develop the team and proposal for demonstration in a Beta Phase project Scottish Power, Network Rail, ScotRail & Transport Scotland will support throughout as the project Steering Group.

Preceding Projects

10025738 - A Holistic Hydrogen Approach to Heavy Duty Transport (H2H)

Nominated Contact Email Address(es)

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Project Approaches And Desired Outcomes

Innovation Justification

The problem that is to be solved

The rail industry aims to remove all diesel passenger trains by 2040 (2035 in Scotland).

Current solutions result in 8.7TWh of inflexible rail electricity demand (3% of present UK demand):

- 4.5TWh of existing high voltage demand with AM and PM commuter peaks;
- 3TWh of new rail demand by 2040;
- HS2 adding over 1.2 TWh.

Meanwhile, in 2020, £243million of onshore wind constraint payments cut generation by 3.5 TWh. H2H focuses on two solutions that break the inflexible link between the rail timetable and electricity demand.

Why your project is innovative, novel or risky

H2H will provide the evidence to enable the electricity and rail sectors to implement Green Hydrogen as a decarbonisation solution with the benefit of flexibility; trains refuelled at night will offer high flexibility for rural rail lines.

Our Alpha and Beta projects aim to demonstrate both solutions on a live rail system, including passenger train operation with:

- Innovation: Combining new and innovative system elements to deliver complete rail decarbonisaton solutions and proving flexibility benefits for electricity customers
- Novelty: New technology, new electricity and rail systems and operating procedures
- Risk reduction: Electricity & rail planning, operation & procurement

Reason your project is important to the energy sector

Government supports an agile approach for sustainable, affordable and reliable solutions for decarbonisaton. H2H offers significant flexibility in existing and future rail energy supply, over 8TWh by 2040.

H2H aligns to Future System Operator aims:

- A whole energy system approach when operating, planning and developing the network
- Delivery of transport decarbonisation and the "accelerated production, transportation and use of hydrogen"

For electricity customers, flexible rail demand provides an early and long term route to reduce constraint payments that have been up to £8.5/household.

How your solution addresses the problem

Hydrogen allow flexibility in electricity demand. Our Alpha project will undertake feasibility and practical assessments -- quantifying the benefits and costs for both sectors.

H2H focuses on Scotland where wind constraints are most common and rail decarbonisation takes place by 2035 -- ideal for early demonstration.

Knowledge missing from a previous or related project, how will your project overcome these gaps

The electricity sector has offered conventional connections in response to rail industry requests.

The rail sector has assessed the decarbonisation options but not how novel flexible solutions could benefit the electricity sector.

Though collaboration H2H will develop two solutions that benefit both sectors and both groups of customers.

The impacts of not doing your project

Rail & electricity sectors take a long term view on investment. Without H2H, decisions in the next 5 years will increase the inflexible link between electricity demand and rail timetables for 30 years (rolling stock life).

The value of delivering your solution
This project supports the delivery of zero-emissions rail: making the removal of diesel trains quicker and cheaper for the electricity, hydrogen and rail sectors. It meets aims 2-5 of the SIF Discovery phase for Zero Emission Transport and reduces energy bills and carbon emissions.

It addresses the rail industry, and their passengers needs by taking a collaborative approach (with all key stakeholders) to address the SIF Zero Emission Transport Innovation Challenge

Why your project can not be funded elsewhere within the price control or considered as part of BAU activities.

There is no allowance for these activities within our current business plans, therefore the project cannot be considered as part of BAU activities. This is the first innovation collaboration between rail & electricity -- an opportunity like the Alpha Phase is unlikely to present itself again.

Benefits

At Discovery, the project assessed both solutions for two rail lines. The following provides quantified and qualitative details of the benefits:

End consumers

- Electricity: Reducing wind constraint payments (up to £8.5/household)
- Electricity: Fewer higher voltage assets & reinforcements for rail electrification
- Rail: Quicker, quieter trains & less pollution

Economic benefits for users, supply chain, industry, and the UK economy

- Users: See above
- Supply chain: Creation & demonstration of solutions for UK and international markets
- Broader industry: Rail as a competitive low carbon transport mode
- UK economy: Lower reliance on imported fossil fuel for rail

Impact on government priorities and any associated benefits

- Electricity: Path to flexible electricity system that also decarbonises transport with lower fixed assets
- Rail: Decarbonisation by 2040 and lower passenger fares

Positive Environmental impacts

- Fuel CO2: Reduction by 100% through Green Hydrogen
- Embodied CO2: Reduction of 196 tonnes of CO2 for each km of rail electrification avoided
- Air Quality: Diesel trains impact air quality through NOx and PM10 emissions

Regional & wider energy supply resilience benefits

- Regional: New full electrification will be in rural areas.

The H2H green Hydrogen solution offers:

- Local flexibility of significant new demand
- Reduction in higher voltage assets and reinforcement in rural areas
- Less single-phase load and impact on Negative Phase Sequence limits

Wider Energy Supply: Standard rail electrification will lead to over 8TWh of inflexible rail demand.

The solutions covered in H2H offer:

- Existing Rail (4.5TWh): Potential to add additional connections with trackside battery storage on existing lines
- Diesel Lines: Hydrogen and trackside battery options

Impacts on consumers of the whole energy system

- With fuel poverty expected to reach 40%, the need to reduce electricity costs is more urgent and a greater necessity.
- Conventional rail electrification bakes in over 8TWh of inflexible demand -- whereas H2H offers a flexible solution that can help reduce constraint payments for all customers.
- These benefits will be most valued by households in fuel poverty.

What benefits and impacts have you been able to quantify from the identifying part of Discovery?

In addition to the quantified examples above we undertook a Net Present Value (NPV) assessment (30 year basis 3.5% discount rate) for the two lines assessed in Discovery.

Business Case

In the Discovery Phase the 280km line from Inverness to Thurso then Wick proved suitable for Green Hydrogen:

- Hydrogen-Electric rail traction is the lowest cost option (£119 million) -- compared to Full Electrification (£1,389 million) and Discrete Electrification with battery train (£360 million)
- Hydrogen fully decouples the timing of rail demand from the electricity system as trains refuel overnight at Inverness. This maximises the potential for flexibility benefits for electricity & rails sectors & their customers e.g. reducing the £8.50/household paid for wind constraints
- Hydrogen-Electric will reduce fuel carbon emissions by 50%, falling to 100% as Green Hydrogen will be produced.
- Hydrogen-Electric has the lowest embodied carbon emissions as there is no overhead line installed on the railway.

This line run through areas with significant windfarm capacity and all sub-stations are constrained for new generation.

Further details of the business case, assumptions etc are in the appendix.

In the Alpha phase we will use more detailed electricity and rail modelling to add the value of flexibility to the NPV case plus a more accurate assessment of the

costs of these flexible solutions. Using this, and further work with stakeholders, we will develop the scope and plan for a Beta demonstration.

Risks And Issues

What risks and issues are you presently aware of, such as technical, political, commercial, managerial, and environmental factors

Our attached risk register, compiled prior to commencing Alpha phase , will be used as a starting point for our collective risk management process. In addition, we are conscious that the following topics will also need to be discussed between all Stakeholders and further risks identified/recorded for mitigation:

- Rail industry is conservative and reluctant to take risks.
- Any risks are required to be mitigated before hydrogen trains could enter services.
- All new technology and modification to existing technology require an extensive and expensive safety case before operation on the railways is granted.
- Rail procurement is extremely complex and new train purchases can require multiple pages of complex contracts and agreements.
- Fuel security is required before hydrogen trains can be deployed.

How you will identify new risks or issues early

Any project partner, or stakeholder, is able to raise any risk, at any time, on any subject and regardless of perceived "severity". All shall be recorded within the central risk register. Our project governance procedures ensures all risks are promptly recorded and discussed so suitable mitigation measures can be collectively agreed.

What approaches you will take to monitoring and mitigating risks and issues

As a minimum, all will be discussed during a monthly risk register meeting between project partners. In addition, if any Partner identifies any risk they believe to be "major" then additional ad-hoc meetings can be convened.

What specific mitigation actions are you putting in place for the risks or issues you are already aware of

Please refer to our attached risk register which describes the mitigation measures associated with the preliminary risks identified to date. In addition, we are conscious that the following activities may mitigate risks and will be discussed with stakeholders on commencement of Alpha:

- Safety: The standards and processes to be used for risk mitigation so a common approach is used across hydrogen supply and use
- Procurement: The process to add potential stakeholders and suppliers and the types of information that will be shared and not shared so there is no risk to future procurement of any part of the hydrogen solution
- Background IP: Defining what can be shared and not shared with the stakeholders

Your assessment of how the risks will change as a result of your mitigation actions

The risk register will be actively managed and used as a tool to identify, record and discuss all risks (perceived or actual) between all Stakeholders, the mitigation measures agreed by all shall be robustly applied, ensuring the level of risk will diminish.

How you will raise awareness of risks or issues with stakeholders

We will maintain the live risk register throughout the duration of the project and circulate it to all stakeholders on a regular basis. The risk register will be subject to all-Party review during the regular stakeholder meetings and all risks discussed and mitigation measures identified and agreed.

How you would handle any intellectual property (IP) issues which might arise during the project

These will all be maintained in a central register for Stakeholder discussion; all anticipated foreground IP will be captured in the same register and any changes to this will be regularly reviewed and discussed. All partners have already agreed to the default IP position in collaboration agreements with SPEN.

Project Plans And Milestones

Project Plans And Milestones

The partners have agreed to work on the H2H project preparing for the Alpha Phase. This activity will:

- Continue dialogue with project partners and suppliers on costs and timescales for Alpha and Beta
- De-risk key issues e.g. the testing of flexibility services or demonstration train services
- Develop the procurement timetable for Beta and hence specification and procurement tasks for Alpha
- Update the Alpha project plan and align with Rail PACE project management requirements

The activity is an expression of the team's commitment and enables Alpha to be more effective and improve the proposal for Beta demonstration.

The Alpha Phase will:

- Agree project plan incorporating insights from the Bridging project
- Undertake a detailed feasibility study for the Hydrogen-Electric rail solution with electricity flexibility services, covering:
    1. Estimate the value of the flexibility services, using the proposed Whitelee Green Hydrogen supply as case study.
    2. Develop detailed planning, procurement & costs.
    3. Identify and plan the rail safety cases required for hydrogen train demonstration.
    4. Assess practical issues for the proposed Beta test site.
- Prepare the Beta Phase costing and programme.
- Identify and engage with partners required for Beta phase.
- Consider how to rollout the hydrogen solution -- so these are addressed in Beta.

Milestones

Milestone 0: Discovery Phase = Complete **Milestone 1:** Bridging = to continue momentum, see Overview **Milestone 3:** Covering:

- On-Going Governance and stakeholder buy-in
- Assessment of Flexibility Services
- Beta project preparation: Safety, procurement & test track
- Hydrogen logistics

Milestone 4: Preparation for Beta

Project Management takes place throughout and there are 3 Steering Group meetings.

The timings are shown in the attached Gannt chart.

Success criteria for Alpha

- Flexibility benefits and connection benefits for electricity customers: Criteria = Local and national significance
- Safety and Procurement: Criteria = Solutions for Beta demonstration agreed
- Refined cost and benefit data via dialogue with suppliers: Criteria = Confirmed Business Case
- Detailed plan for Beta via dialogue with partners and suppliers: Criteria = Confirmed and Detailed Project Plan for Beta

- Beta project team defined roles: Criteria = Detailed Budget for Beta
- Beta Go/No Go: Criteria = Senior management sign off from all Beta partners

Identified project management processes

Ricardo, providing the Project Manager (PM) and Project Director on the H2H project, will provide the overall PM for the works progressed during Bridging and Alpha. Ricardo PM procedures will be used to progress internal reporting and contractual/commercial management.

Ricardo will work closely with Eric Leavy, the Project Sponsor at SPEN.

The PM process, policies and systems fully meet the requirements of ISO9001 (quality), ISO14001 (environment), ISO27001 (information security management) and ISO45001 (occupational health and safety). All management systems are subject to regular checks by management and biannual audit by the accreditation body.

Acknowledging that H2H will be undertaken within an operational NR environment, we shall also accommodate NR's PM procedures dictated within PACE (NR Standard NR/L2/P3M/201). The first two stages, Project Initiation and Development, and Project Selection, will be addressed during the Discovery-to-Alpha phase, with the third phase, Project Design, being addressed during the Alpha Phase. The Beta phase would then address the remaining PACE PM procedural requirements.

Payment schedule by milestone or month

We propose to invoice by month. Expected monthly expenditure: -

August -- £75,000

September -- £75,000

October -- £75,000

November -- £75,000

December -- £75,000

January -- £74,783

Total = £449,783

Resources and Changes to the team

We have added one partner; Ricardo Rail. This adds experience on rail project delivery, safety and procurement.

We have also increased the size of the teams by adding hydrogen and flexibility specialists.

Regulatory Barriers (Not scored)

Regulatory barriers which may hinder the delivery of your Alpha or Beta Phase

Electricity: The flexibility benefits are accessed by open competitions. Each has its own rules to qualify and offer successful bids. These rules will be included in the Alpha feasibility assessment.

Hydrogen: Hydrogen is already widely used as an industrial gas, so safety, storage & transportation are addressed through existing industrial and HSE

legislation.

For the Beta phase we expect to use a temporary hydrogen refueller -- these have been used for several previous hydrogen demonstrators and we have spoken to suppliers.

Railway: The railway refuels with diesel at depots. Discovery has shown that there is a preference for local green hydrogen production for rail refuelling, which is a factor that we will focus on in Alpha and Beta.

Hydrogen trains will need certification to operate on Network Rail's network. Ricardo Rail certified one early hydrogen non-passenger demonstration train -- hence Ricardo Rail are a partner for the Alpha project.

Procurement: In Alpha we will review electricity & rail procurement processes for hydrogen & rolling stock, so we have a path for Beta and for long term roll out.

Longer term regulatory barriers to transitioning your project into business as usual

With the UK hydrogen strategy in place and several new policy measures being implemented the key barriers to hydrogen are being rolled out.

In Alpha we will review the new measures so that we align the Beta and long term roll out with the principles and details of these measures -- see below.

Policy considerations for longer term implementation

With the UK hydrogen strategy in place and several new policy measures being implemented the key barriers to hydrogen are being rolled out.

In Alpha we will review the new measures so that we align the Beta and long term roll out with the principles and details of these measures. Examples include:

- Road Traffic Fuel Obligation (RTFO): This was recently extended to cover alternative fuels for rail and the options for location of renewable electricity generation have been relaxed
- Net Zero Hydrogen Fund: Capital grant funding, initially with £240million. For permanent systems this will be important for roll out of green hydrogen for the electricity and rail sectors
- Hydrogen Business Model: A Contracts for Difference mechanism to provide revenue support for low carbon hydrogen, an alternative to RTFO as a longterm support measure

Rail policy is to remove diesel passenger trains. Lower passenger numbers potentially slow this transition, however many diesel train fleets are already well beyond their expected life. Investment in life extension would be a false economy as this would gain few extra years of service, prolong the use of diesel and delay the introduction of better quality, faster and quieter trains. The fleets for the lines we have chosen will be retired in 2027 so the decision on which fuels will be used for the replacement fleets needs to be made in 2024 thus the timing of Alpha & Beta is excellent.

Proposed approach to overcoming them

We see the policy measures supporting the use of flexible production of green hydrogen for rail traction increasing. Discovery and Alpha will be used as evidence with the relevant policy stakeholders to substantiate the benefits.

Business As Usual

Steps to ensure your innovation has suitable business as usual adoption

The network interaction with the business as usual solution will be to use the information to make planning decisions that will account for the deployed (or planned to be deployed) solutions. A crucial component in this is ensuring that the people in our business and other licensees are aware of the new solution, are briefed on the changed policies, the impact on processes and are behind the changes.

At SPEN, we have committed time from the appropriate teams who would be involved in these BAU transition processes to ensure that the developed solutions are appropriate and aligned. We will disseminate directly to other licensees to ensure that the learning is applied and maximised, to enable others to adopt as the project progresses.

Eric Leavy, SPEN Head of Transmission Networks, will sponsor this project and ensure the strategic direction to benefit the electricity customers. This commitment will safeguard business pull and the Business as Usual impact when the learning is available. In the meantime, the Innovation Team at SPEN are supporting from the overall project management perspective.

The key interaction is with the SPT planning team and therefore they will be best placed to ensure the adoption of incoming changes as their team will account for this innovation in their BaU processes.

We will make sure the relevant learnings will be taken to our colleagues in UK TOs and DNOs to support their own planning processes and interaction with the rail service. We intend to use already established forums such as the ENA and working groups where we can introduce such concepts and influence the conventional practices.

The results of H2H are directly relevant to three long rural rail lines in Scotland that the project partners and steering group have responsibility:

- Far North Line
- Kyle Line
- West Highland Line

Several lines in the North of England, Wales and East Anglia are ear-marked for hydrogen trains. We have contacts in all three other rail regions and will effectively disseminate the project's learnings. We will be committed to supporting the uptake of the adopted solutions across key sites to help prove the scalability so to realise maximum value.

A key part of ensuring quick rollout is ensuring all relevant decision makers are briefed and onboard.

The project partners and steering group make all the decisions on roll out of zero carbon rail solutions in Scotland:

- Transport Scotland (Policy & funding)
- Network Rail (Rail infrastructure)
- Scotrail (Trains)
- Scottish Power Energy Networks (Power system)
- Scottish Power Hydrogen (Green hydrogen)
- Ricardo (Energy & rail consultancy)
- University of Leeds (Academic & innovation insights)

So we have in place the team needed for business as usual roll out.

The H2H system reduces the capital and on-going operating costs of rail decarbonisation. The use of flexible green hydrogen production offers benefits to

electricity consumers and electricity network operators as well as the rail sector and their customers. From our perspective, the funding strategy will be from our T2 TOTEX which will be utilised in a manner which support the decarbonisation of transport at the lowest cost to the consumer.

As the primary change to SPEN in BaU adoption will be our processes, we do not anticipate additional funding required.

Commercials

Commercialisation

Why your project does not undermine the development of competitive markets

The H2H project will accelerate the development of competitive markets to provide flexible, affordable production and use of green hydrogen for rail.

The rail sector needs evidence and collaboration to adopt new solutions. SIF funding will provide this evidence and involve all stakeholders to create a pathway for implementation.

Renewable electricity for Green Hydrogen production will be connected behind the meter and hence there is no impact on competitive markets.

Flexible hydrogen production will allow the system to provide system services. These are contracted on a commercial basis, so there will be no undermining of these markets.

The value the product or service will bring to the networks or consumers

The focus of H2H is on reducing the cost of constraint payments for consumers:

- In 2020 3.5TWh of wind was constrained costing £243million, £8.5/household
- 4.2TWh pa of electricity will be needed to decarbonise rail, adding to 4.5TWh used by rail
- Conventional rail electrification means this demand is directly linked to rail timetables with no flexibility
- Hydrogen trains refuel between midnight and 6AM enabling green hydrogen production days in advance using constrained wind generation
- Rural rail lines suitable for hydrogen and constrained wind generation regions of the UK

The value to networks is in increasing flexibility and reducing network investment.

- Conventional rail connection with higher voltage single phase load needs significant deep reinforcement and enduring costs
- Green hydrogen avoids these deep reinforcements and single phase load in rural networks

Who is the primary customer segment for your innovation

The owners and operators for the H2H solution are:

- Green hydrogen producers: Whose electrolysers will use constrained wind generation, stored in advance of train refuelling
- Network Rail: Who will lease land for hydrogen refuelling at rail depots
- Train Operators: Who will lease and operate hydrogen trains

The other beneficiaries are:

- Electricity customers -- through reduced constraint payments and avoided additions in network costs for deep reinforcement to connect railways through

conventional electrification

- TSOs and DSOs who need flexibility services from green hydrogen producers
- Developers of future renewable generation through reduction of constraints in rural areas

Electricity and rail sectors in other countries have similar commercial roles: regulated monopolies (electricity & rail networks) and commercial operators (renewable generators, hydrogen production & train operators).

Ricardo has businesses in several relevant markets: US, Australia, Spain & Netherlands all of which are looking at hydrogen for rail traction.

The customer value proposition and associated business case

Discovery Phase demonstrated a clear business case for green hydrogen for the line from Inverness to Thurso and Wick. On a 30 year, 3.5% discount rate basis Hydrogen was the cheapest at £119million vs £1,399million for conventional electrification.

In Alpha we will quantify the flexibility benefits using detailed time series analysis.

An outline of any requirement for new partnerships to ensure a successful route to market

No new partnerships.

Electricity and rail sectors have had a transactional relationship for connecting rail traction. This has not stimulated innovation leading to inflexible rail demand.

H2H creates an opportunity for co-operation to introduce flexible solutions which reduce costs for electricity and rail customers.

What additional capital do you hold or plan to secure in order to commercialise this innovation

Compared to conventional inflexible electric rail traction the H2H solution has lower costs:

Electricity:-

- Capital -- No deep reinforcement for rail electrification
- Operational - Lower constraint costs

Rail:-

- Capital -- Over £1billion cheaper
- Operational -- Lower infrastructure O&MAlpha and Beta are needed to provide the evidence and pathway for investment by the hydrogen and rail sectors.

No additional investment request is needed.

Intellectual Property Rights (Not scored)

The Discovery Phase has confirmed the outline business case for hydrogen for rail and identified that hydrogen provides the highest electricity system benefits for any of the rail decarbonisation options.

It has also outlined the scope of a Beta project which will be assessed in more detail in the Alpha Phase. Beta will add additional project partners to provide hydrogen trains. Alpha will also identify the existing IP and potential for new IP, for existing and new partners.

The H2H solution comprises a number of elements to deliver the benefits of

flexible green hydrogen for Hydrogen-Electric trains:

- Flexible Green Hydrogen production: Electrolysers operated by hydrogen supplier (2 candidates consulted) - Potential new IP is the selection and operation of the electrolysers.
- Rail Depot: Hydrogen storage and fuelling system owned and operated by hydrogen provider. ScotRail staff refuel trains - Potential new IP is the safe and effective installation & operation. (Green Hydrogen providers, Network Rail & ScotRail consulted)
- Hydrogen-Electric trains: Built by OEM, maintained by OEM, operated by ScotRail (OEMs consulted in Discovery -- Potential new IP is the operational experience and training of rail staff

So we expect Alpha, and to a greater degree, Beta, to create: "information, understanding or skills necessary to reproduce or simulate the outcome" -- IP as defined in the Governance Document.

In the Alpha Phase the details of each element of the H2H system will be defined in detail which will also allow clarity over the potential new IP and the IP that will be held by others (e.g. the OEMs for the electrolysers and Hydrogen-Electric trains).

The rail and electricity sectors both have comprehensive competitive procurement systems. So part of the scope of Alpha is to map out how the insights from Alpha and Beta can be shared to encourage OEMs to provide information without compromising competitive procurement. This is expected to drive an inclusive approach to supplier conservations.

So the following provides our outline view, based on the IP treatment set out in the SIF governance.

Alpha Phase

The Alpha Phase will start the creation of IP in the form of knowledge that will allow an effective Green Hydrogen for Hydrogen-Electric system to be implemented. In the Alpha Phase we will make a more detailed assessment of the flexibility benefits -- how controlling electrolyser use of renewable power can access flexibility benefits that are of value to electricity & rail customers.

The Alpha project partners have seen and reviewed the SIF Governance document and the default IPR guidance. Each Alpha project partner has agreed to these IPR arrangements for the Alpha Phase.

Beta Phase

The Beta Phase will:

- Have additional partners to implement a fully functional H2H solution demonstrating the flexibility benefits of green hydrogen production for use on the railway.
- Create significant IPR as defined in the Governance document

As an example there will be IPR from the operation of the electrolysers to produce green hydrogen at the scale and on the timeframe needed for operation of hydrogen trains. There will also be IPR in the performance and fuel use of the hydrogen trains.

So the discussions with the new partners will include the IPR arrangements as set out in the SIF Governance document.

Prior Experience on IPR

SPEN and Ricardo Energy & Environment have worked on NIA and NIC funded

innovation projects and developed the agreements with project partners on the IPR arrangements. Our proposed project manager has worked on NIA and NIC funded innovation projects so we have the insights and experience to establish and manage IPR arrangements.

Costs and Value for Money

The total project costs

Total Project Cost - £449,783

The funding you are requesting

Toral SIF Funding - £401,864

How your project will fund the minimum 10% of total project costs as a contribution from private funds

Scottish Power, Ricardo Energy & Environment, Ricardo Rail and Network Rail will not charge for 11% of the days spent on the H2H Alpha project.

This will be funded out of the internal budgets for each organisation.

How it compares to what you would spend your money on otherwise

SPEN's expenditure is on activity allowed by the price control. This is an addition to allowed expenditure.

Network Rail is focused on operation of the railway infrastructure across England, Scotland & Wales. This includes developing plans for future infrastructure which has focused on conventional electrification. The SIF funding allows Network Rail to develop new approaches and solutions by working in a collaborative way with the electricity sector.

Ricardo is working on a wide range of client funded work to deliver net zero solutions for our clients. Recent energy price increases have further increased this client funded activity. We see flexible green hydrogen for rail use as having great potential for future growth. So, we are pleased to have the opportunity of SIF support to develop a new solution that benefits electricity & rail customers.

The University of Leeds is funded by a range of public sector and private research organisations.

Costs and SIF funding across the project partners

SP Transmission:-

Total cost- £79,650

SIF Funding- £71,685

Ricardo Energy & Environment:-

Total cost- £140,481

SIF Funding- £125,136

Ricardo Rail:-

Total Cost- £121,058

SIF Funding- £107,685

University of Leeds:-

Total Costs- £37,614

SIF Funding- £33,476

Network Rail:-

Total Cost- £70,980

SIF Funding- £63,172

Total Project Cost - £449,783
Toral SIF Funding - £401,864

How this is complementary to, and provides additional value over your business as usual activity

Scottish Power Energy Networks: H2H is the first project that SPEN have undertaken to assess innovative ways to power the railway. All previous railway connections have been standard solutions with no provision for flexibility and wider benefits.

Network Rail: All previous rail electrification projects in Scotland have used conventional 25kV overhead line, with high capital and operating costs and no opportunity to be flexible on power demand.

Ricardo Energy & Environment: Enables us to link solutions from the electricity sector to the rail sector.

Ricardo Rail: Enables us to link solutions from the rail sector to the electricity sector.

University of Leeds: Supports applied rail energy models in a new application.

How the costs outlined compare to normal industry rates

The costs for Scottish Power, Ricardo Energy & Environment, Ricardo Rail and Network Rail (private and public partners) include:

- No profit
- 11% Benefit in Kind through days that will not be charged to the project

Ricardo Energy & Environment and Ricardo Rail are profitable consultancy businesses who work for the clients in the electricity and rail sectors. For these clients we charge rates that include profit.

Changes you have made to the project team

Compared to the Discovery Phase we have:

- Added Ricardo Rail to provide expertise in rail safety, procurement and engineering aspects
- Increased the Network Rail team to include engineers with track and signalling infrastructure
- Increased the Ricardo Energy & Environment team to increase the focus on the benefits of flexibility

Supporting Documents

Documents Uploaded Where Applicable

Yes

Documents:

SIF Alpha H2H Business Case.pdf

SIF Alpha H2H Project Overview Appendix.pdf

SIF Alpha H2H Skills and Expertise Appendix.pdf

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This project has been approved by a senior member of staff

☑ Yes