SIF Beta Round 2 Project Registration

Date of Submission

Dec 2025

Project Reference Number

10117736

Initial Project Details

Project Title

SF6 Whole Life Strategy

Project Contact

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Challenge Area

Improving energy system resilience and robustness

Strategy Theme

Net zero and the energy system transition

Lead Sector

Electricity Transmission

Project Start Date

01/12/2024

Project Duration (Months)

48

Lead Funding Licensee

NGET - National Grid Electricity Transmission

Funding Licensees (not required)

SSEN - Scottish Hydro Electric Transmission

SPEN-T - SP Energy Networks Transmission

Funding Mechanism

SIF Beta - Round 2

Collaborating Networks

National Grid Electricity Transmission

Scottish and Southern Electricity Networks Transmission

SP Energy Networks Transmission

Technology Areas

Asset Management

High Voltage Technology

Carbon Emission Reduction Technologies

Electricity Transmission Networks

Environmental

Substation Monitoring

Substations

Project Summary

Based upon Alpha phase findings the project will further develop selected aspects of SF6 management in the fields of techno-economic comparison for intervention strategies, laboratory-scale greener-disposal of SF6, leakage-rate modelling ofSF6 equipment, and long-term, in-service evolution of non-SF6 gas-blends.
The feasibility of retro-filling passive gas-insulated assets without OEM support will be fully assessed and a pilot solution developed & deployed (subject to feasibility outcomes). The scalability of energy-efficient disposal of SF6 will be demonstrated. Asset leakage prediction tools will be developed based upon data from existing and newly installed gas-density sensors. Long-term stability of non-SF6 gas-blends will be assessed.

Add Preceding Project(s)

11061098; NGET/SF6 Whole Life Strategy/SIFIESRR/Rd2_Discovery - SF6 Whole life strategy

UKRI10084569 - SF6 Whole Life Strategy

Add Third Party Collaborator(s)

The University of Manchester

DNV

DILO Armaturen und Anlagen GmbH

WIKA Instruments Limited

Project Budget

£9,790,949.00

SIF Funding

£8,500,724.00

Project Approaches and Desired Outcomes

Solution statement and solution focus

UK targets of 50GW offshore wind by 2030, combined with growing electrification of heat and transport, will require a radical transformation of GB national electricity infrastructure. An extensive reinforcement of existing networks is necessary, where new power-dense gas-insulated substations (GIS) must be installed/energised to enable fast-growing renewable generation. Sulphur hexafluoride (SF6) is widely used in transmission level GIS, accounting for majority of UK's SF6 inventory (in excess of 1,000 tonnes). The significant global warming potential (GWP) of SF6, 24,300 times greater than CO2, is a critical obstacle to UK's ambition of clean energy transition before 2050.

Environmentally friendlier alternatives to SF6 are vital to facilitate an expediated global transition to sustainable electricity networks. New GIS technology utilisingnon-SF6 alternatives is in its infancy with limited user experience (~6-7 years) and comparatively more expensive than conventional GIS. It is in the interest of UK consumers to also explore non-replacement solutions to minimise emissions at optimum cost.

Alpha Phase has allowed the consortium to develop the underpinning knowledge to tackle the evolving SF6 problems through practical trials of onsite gas sampling/analysis in live GIS, develop/refine methodologies of replacement interventions, leakage analysis and forecast, laboratory demonstration of energy-efficient incineration approach, and cost benefit analysis of the proposed approaches to reinforce the innovation pathways forward. The valuable experience gained has further refined our innovation priorities to deliver the greatest return on investment for consumers.

The project addresses the SIF Innovation Challenge 3 where the installed volume of SF6 might be expected to increase substantially in the coming years given the growth in renewable generation and uprating of existing electricity infrastructure with compact SF6-designed equipment. However, the regulatory risk of a ban on new SF6 switchgear could significantly delay the clean energy transition. The use of new SF6-free solutions with limited user experience will introduce major uncertainties on reliability and resilience of the electricity infrastructure. Hence, this project also addresses the need to 'strengthen the UK's energy system robustness to support efficient roll-out of new infrastructure'.

Past innovation project (NIA_NGET0199) between NGET and the University of Manchester (these two partners are leading or co-leading 4 technical work packages of Beta Phase) built confidence and technical understanding to support the world's first retro-fill solution in Richborough supported by an original equipment manufacturer (OEM), removing 19,000 tonnes CO2 equivalent from service. The aim of Beta Phase is to bridge the key gaps that will ensure efficient economical roll-out of retrofill replacement across GB transmission GIS.

Main beneficiaries are transmission & distribution network operators who possess the largest SF6 inventory. The core user needs that will be addressed are:

1. The feasibility of breaking the link between retro-filling different GIS equipment families and OEMs' involvement.
2. Monte Carlo modelling of degrading profiles of GIS assets to further elucidate leakage modelling reliability and optimise maintenance schedules.
3. Scale-up and accelerating towards commercialisation for optimal low-energy disposal of SF6 that cannot be reconditioned and reused to enable a circular lifecycle approach.
4. Determine the long-term stability of new SF6-free alternatives to instil confidence in user base.
5. Cost benefit analysis of the proposed approaches to determine the most optimal pathways to phase-out SF6.

The successful completion of Beta Phase will result in a holistic strategy for deploying different interventions across GB transmission networks as part of utilities' business-as-usual operations. This will provide a complete solution that can cover majority of existing GIS equipment families and accelerate towards business-as-usual by T3/T4. We will further refine our dissemination plan to other network owners and operators in UK/EU, increasing adoption rates and broaden the impacts of our project to the wider global electricity business.

Innovation justification

The project addresses the SIF Innovation Challenge 3 on 'improving energy system resilience and robustness'. New F-gas regulation places prohibition date on new SF6 switchgear to market. This introduces a significant risk that electricity utilities may

have to bring forth expensive capital replacement schemes in a time-sensitive manner that could create great uncertainty to the energy system's resilience.

The two major questions that emerged from Alpha Phase that will inform the design of Beta Phase are:

1. UK TOs are early adopters of non-SF6 technology globally. However, there is a clear need to solve the underlying challenge of ensuring network resilience while roll-out new technology at pace. The rapid change in technology needs further innovation to develop underpinning know-how/solutions that can accelerate the clean energy transition while keeping the light on.
2. NGET possesses one of the largest SF6 inventories (in excess of 900 tonnes) in the world. Optimised SF6-free replacement interventions and energy-efficient SF6 disposal methods must be developed to ensure timely and economical phase-out of SF6 for UK electricity consumers.

Appendix shows the overview of innovation projects on SF6 replacement by the electricity utilities. The following identifies the novel key innovation challenges to be tackled in Beta Phase (anticipated TRL at the end of project is indicated in bracket)

1. Practical trials of onsite gas sampling/analysis (business-as-usual)

Unlike SF6, binary/tertiary mixtures may experience differential leakage due to varying molecular sizes. Alpha phase established valuable gas sampling and measurement experiences in a live substation. The sampling frequency and long-term stability/reliability of new SF6-free alternatives will be determined in the Beta Phase.

2. Develop non-OEM-supported retrofill interventions (TRL6)

Retrofilling the existing SF6 asset across different GIS equipment families is challenging given the limited user experience (Richborough is the only retrofill trial globally to date). A key emerging question is the feasibility of breaking the link between retrofilling a specific GIS equipment family and the original equipment manufacturer (OEM). This will provide a complete solution that can cover majority of existing GIS equipment families and accelerate towards BaU by T3/T4. A techno-economic analysis will ensure the Beta Phase target the most appropriate steps that will deliver the greatest return on investment for consumers.

3. Leakage analysis and forecast (business-as-usual)1.

It was found during Alpha Phase that leakage monitoring data (pressure, density, temperature, etc.) has certain seasonal effects across multiple years with various sensory data demonstrate strong correlations. In Beta, degrading profiles of typical assets will be modelled using Monte Carlo simulations and Bayesian uncertainty quantification based on historical data. Such profiles will be embedded to further elucidate leakage modelling reliability and optimise maintenance schedules.

4. Laboratory demonstration of energy-efficient incineration approach (TRL4)

It was identified in Alpha Phase that new, more efficient technologies may be required to dispose SF6. Our feasibility work showed that non-thermal plasma treatment that uses high energy electrons to bring about the initial decomposition of SF6 at significantly lower temperatures than conventional thermal method. Scale-up and acceleration towards commercialisation are key considerations in Beta Phase to facilitate optimal disposal of SF6 that cannot be reconditioned and reused.

The SIF Beta project jointly delivered by end-users/academics/gas-analysis suppliers informed by technical inputs from the supply chain is the faster approach to accelerate impacts on an industrial scale. SIF of UKRI-OFGEM fosters innovation, allowing operational freedom to proactively pursue solutions leading to BAU and higher TRL impactful research strategies such as retrofill beyond the commercial needs of major switchgear OEMs.

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

Environmental - carbon reduction – direct CO2 savings per annum

Environmental - carbon reduction – indirect CO2 savings per annum

New to market – products

Others that are not SIF specific

Impacts and benefits description

NGET is a major beneficiary due to their large SF6 inventory, but outcomes will benefit all partner TOs and end-users globally. Without a viable alternative, the negative economic impacts are borne by electricity consumers (industrial, commercial or domestic). Impact also extends to switchgear manufacturers with an expected global market of approximately £20 billion by 2025. Progress in this project could shape future UK/EU F-gas regulations, informing policymakers' decisions through evidenced case studies.

Major impacts/benefits are:

Financial - cost savings per annum on energy bills for consumers and future reductions in the cost of operating the network

Technology: Success in WP1-2 will significantly improve user understanding of long-term performance and failure mechanisms in SF6-free technologies due to scale-up and acceleration of our technology demonstration in a representative substation environment. Developed solutions are readily transferable to other sectors where SF6 is being used for insulation purpose, including high-voltage particle accelerators for the medical industry and insulation system for future high-voltage electric aircraft. The whole life net present value for the project is £2.2million.

Environmental - carbon reduction -- direct CO2 savings per annum

Environment: SF6 is the largest controllable element of NGET's emissions accounting for 16% of their annual greenhouse gas emissions (~285,000 tonnesCO2 equivalent in 2018/19). Proposed leakage forecast tool and retrofill development will be rolled out when they are technologically viable and the primary strategies supporting NGET's mandated trajectory of reducing SF6leakage by 50% from 2019 level before 2030. The expected environmental benefit is a reduction in 67,000 tonnes of CO2 equivalent over the next 25 years.

Predictive maintenance and asset life extension: Leveraging on modern data science and methodology, WP4 of this project will deliver more reliable and consistent leakage monitoring and associated degradation modelling to power assets and networks, which will have long-lasting impacts for the sector in terms of more reliable operation, reduced costs and optimised strategic spares. It will improve efficiency and help coordinate optimal asset management and maintenance that will improve asset health (ultimately extend asset life). The project is crucial to the power industry with the rapid introduction of hybrid energy resources into the grid. The development and introduction of advanced technologies into the business will modernise the operations and keep pace with new technological advances.

New to market -- processes and (indirect CO2 savings per annum from emerging supply chain)

Success in WP3 will ensure reduction in the energy/carbon costs associated with destruction of SF6 through conventional thermal incineration (30-50MJ/kg).Results from the Alpha Phase demonstrate that this is possible on small-scale(~3MJ/kg), however, Beta phase intend to extend this to the pilot scale system. There is the prospect of new carbon tax on importing SF6, which is currently applied in Norway where there is an additional tax credit of ~2,000 euros per kg of SF6 imported. This emerging trend will further favour an energy-efficient low-carbon disposal solution in the future.

Others that are not SIF specific

Policy: This work will develop viable interventions that will inform UK/EU policy for next F-gas regulation in 2031/32, which are key SF6 reduction strategies (retrofill, leak repair) not considered in the current 2024 version and will be developed in Beta Phase. The consortium through new findings will engage Defra//REACH/EU/ECHA in future F-gas consultations.

Pre-standardisation/standardisation: There are pre-competitive aspects inWP1-2 such as high-voltage testing and gas analysis/handling/disposal standards that will unite IP-conscious OEMs. The required pre-competitive studies will be applicable to manufacturers, academics, end-users and insurance providers. Beta Phase will support the development of new international working groups for SF6replacement activities through pre-standardisation (CIGRE) and standardisation (BSI/IEC/IEEE) organisations.

Teams and resources

Our project team remains largely unchanged except for WIKA becoming a formal partner (previously a subcontractor) and the addition of SP Transmission (SPT) as a formal project partner (previously involved in the Alpha Phase in an advisory capacity) meaning all three GB transmission owners will be project partners in the Beta Phase, maximising the potential insights and benefits from this project.

The lead partner remains National Grid ET which brings significant existing knowledge about SF6 and its alternatives. This includes retrofilling at Richborough substation in 2021, and the implementation of new-build SF6-free equipment at Sellindge substation in 2017. Besides overall project leadership, NGET will provide technical expertise and knowledge of their infrastructure and systems, provide asset data and SF6 leakage data, and provide access to infrastructure and equipment for testing. NGET will lead WPs 1, 2 and 6, co-lead WP4 with the University of Manchester (UoM), and support all other Work Packages, providing strategic oversight over the whole project.

SPT's Sustainability Plan aims to drive the development and adoption of SF6-freetechnologies, collaborating with supply chain and industry peers, piloting new technologies where technically viable, and adopting when market ready. SPT will support all WPs by providing technical expertise and knowledge of their infrastructure and systems, providing asset data and SF6 leakage data, and providing access to infrastructure and equipment for testing in WP1 and WP4.

SSEN Transmission is a leader in the adoption of SF6 alternatives and continuing to work closely with manufacturers, other users and the wider industry on SF6 alternatives. SSEN Transmission will support all WPs by providing technical expertise and knowledge of their infrastructure and systems, providing asset data and SF6 leakage data, and providing access to infrastructure and equipment for testing in WP1 and WP4.

The University of Manchester (UoM) is an academic partner and expert in HVAC switchgear technologies and alternative lower-carbon-footprint insulating gases. UoM will lead WP3 conducting representative scaled demonstration of novel SF6disposal methods at their facilities. They will co-lead WP4 developing an open-source SF6 leakage forecast model, and support WPs 1, 2 and 5.

DNV will act as overall project manager and techno-economic assessment experts on the project. DNV are experts in providing strategic conceptual, implementation and operational advice on design, economics and regulation of energy markets, as well as advise on integration of new technologies into existing commercial environments.

DILO are specialists in gas handling, measurement, including reconditioning, mixing and recovery of gases. DILO will provide reference gas mixtures that will be made available to the partners. DILO will also carry out gas mixture analyses for WP1 in its laboratory in order to validate the gas composition of the gas samples taken.

WIKA Instruments Limited is a global technology leader in measurement instrumentation and has a special business unit with industry experts and a holistic portfolio for all aspects of insulation gases in the electricity transmission and distribution industry. WIKA will be supervising the sampling procedures and carrying out gas analysis testing at their laboratory facility to determine the composition of gas mixtures and the determination of unknown components and isomers for WP1. The compartment specific and machine-learning based leakage rate determination and forecasts of WIKA will be the base for enhanced prediction, aggregating information of the equipment's conditions and history in WP4.

In addition to project partners, different subcontractors will be utilised for delivering the project in timely manner. They are: Cardiff University for gas analysis, Grosvenor Power Services for gas sampling, test labs for IEC accredited type testing, Deeside Centre for Innovation for long-term testing of full-scale equipment in representative substation environment.

Project Plans and Milestones

Project management and delivery

The project will be managed by DNV, who have extensive experience delivering innovation, research and development projects implementing the following aspects to ensure a successful and innovative project outcome:

- A strong emphasis on quality assurance and control throughout the project. All projects include a senior staff member in a Quality Assurance role to ensure projects meet or exceed customer expectations and quality standards.
- Risk assessment methodologies and tools to prioritise and manage project risks effectively, ensuring that potential issues are identified and addressed proactively.

As the Lead Partner, NGET will be responsible for providing regular oversight and support to the day-to-day project management that DNV will deliver.

WP1 - Site Handling of Non-SF6 Gas Mixtures

The results from Alpha Phase revealed the suspicion, that the different components of the gas mixture may present different leak rates and thus result in altered concentrations (long-term operational concern). The Alpha Phase only analysed one gas blend in a single asset, hence, further investigations are required to appropriately assess this suspicion.

WP1 will focus on sampling a larger population of assets, considering different gas blends, and varying asset types and age.

- Measurements will be taken to assess gas behaviour across 10 sites (5 NGET,3 SSEN and 2 SPT substations). Sampling will take place twice, two years apart.

WP2 - Retrofill Solutions

This WP aims to develop and install retrofill solutions on older equipment that lack OEM support for retrofill options.

Key activities include:

- Identify suitable sites for retrofill
- Scoping of design, identify design risks and carry out CBA including design and testing costs
- Design and testing of retrofill solution
- Carry out retrofillll at selected site with regulatory funding after pilot project success

The following stage gates are included and will mitigate cost and project success risks by enabling fail fast decisions:

1. Before proceeding with design and testing of retrofill solution, stage gate review of retrofill performance, risks, and costs against KPI
2. Before carrying out retrofill at selected site, stage gate review based on results of laboratory testing, type testing, and CBA of any re-design requirements for operational roll-out of solution

WP3 - Lifecycle Management of SF6 and Alternatives

Alpha Phase identified potential energy and cost reduction through laboratory-scale SF6 disposal demonstration at Manchester. This WP will prove the viability of Packed Bed Plasma Reactors by undertaking more representative-scale demonstration.

Key Activities:

- Develop larger-scale demonstration of non-thermal disposal of SF6
- Comparison of performance including the energy calculation for novel approach and the existing

WP4 - Visibility of SF6 Leakage

Alpha Phase found that targeted monitoring was required to determine the leakage rate distribution across the asset population. WP4 will install enhanced leak monitoring at selected sites to better understand leakage rate distribution, and develop open-source software to improve accessibility of leakage data and forecasting of future leakages

Key Activities:

- Selection of 3 NGET and 1 SSEN substations for enhanced monitoring.
- Develop a process for connecting the gas density sensors to platform and install new gas sensors at a substation.
- Take outputs from SIF Alpha phase, AGILE project and NGET data team to develop a model to predict leakage and offer as open source software.

WP5 - Project Management and Governance

WP5 focuses on the management of the successful delivery of all WPs and dissemination of the results.

Key Activities:

- Preparing yearly progress reports and presenting interim findings at conferences
- Delivering close down reporting and an end-of-project webinar.

WP6 - Technical Advisory Board

WP6 provides technical oversight to the project and bring learnings from others working on SF6 interventions

Key Activities:

- Bi-annual meetings to review progress and ensure project is meeting core objectives

Key outputs and dissemination

The primary objective of the project is to develop the underpinning knowledge for open questions around SF6 intervention strategies. The report consisting of learning and recommendations will be provided for each WP and the dissemination will be through industry (CIGRE, ENA, innovation zero, utility week), academic conferences (e.g. CEIDP, ICD). In WP1, NGET with SSEN-T and SPT will check the stability of non-SF6 gas blends and sampling frequency that are not defined given the limited user experience. This will help to operate the network reliably through updating the technical documents, gas handling procedures for IIGs; applicable to TOs globally through dissemination of WP1 gas analysis results. NGET will lead the dissemination along with TOs and partners/contractors carrying out the gas analysis.

Findings in Alpha suggest that refurbishment and retrofill are preferred interventions for reducing emissions and present high benefit ratio when including carbon societal/credit costs. Some OEMs offer retrofill for limited products (with long lead time) and WP2 will answer the most important question regarding feasibility of retrofill across different families of non-OEMs supported GIS. Stagegate 1 of WP2 will focus on CBA and by end of Year-1, if retrofill looks economic/feasible, later stages will perform the design and type testing and long-term testing, providing a complete retrofill solution for several GIS families by mid-T3. The learnings will be extended to other GIS families, TOs and T3-T4 planning team enabling the roll-out of non-OEMs supported retrofill through regulatory funding. NGET and partners will lead the dissemination across different venues.

In long term, TOs (especially NGET, lead TO) anticipate removing large amount ofSF6 from network and need to look for environmentally friendlier and economic disposal method. WP3 focuses on scale-up the SF6 disposal using energy-efficient method (about one tenth of conventional approach) after successful demonstrations in Alpha. It will provide recycling/disposal companies a greener alternative to dispose SF6 reaching end-of-life. UoM will lead the dissemination activities involving different stakeholders.

Predicting the asset performance through leakage forecast is the focus of WP4which will enable TOs to undertake interventions at opportune time and reduceSF6 leakage. At present, leakage rate is defined from top-up data with limited value to predict the asset performance. Alpha findings suggest that data from legacy assets is required for better prediction. The gas-density sensors data in substations will be accessed through IoT team. 3 NGET substations (and one SSEN) will be chosen and technical know-how will be transferred and rolled-out on other substations (in excess of 50) through T3 funding. These wired gas sensors pose a challenge in data access leading to planned trials of wireless sensors. WIKA-made wireless sensors will be installed in all 90 gas zones at a severely leaking GIS. At the half-way point, wireless sensors with IoT platform can be installed through T3 funding at other substations. Modelling of gas density sensors will be carried out, integrating the learning from Alpha and NIA-funded AGILE project by UoM and data teams of NGET overseen by SSEN-T and SPT. The open-access software will be provided to all TOs for predicting the asset performance by end of the project. Results will be disseminated by NGET and UoM.

Reporting to UKRI will be undertaken by NGET. WP6 focuses on disseminating through Technical Advisory Board including

representatives from other stakeholders, EPRI, GB DNOs, other European TOs.

The project team plans to conduct an annual "Progress and Lessons Learned” session sharing best practice and know-how to interested stakeholders.

Commercials

Intellectual Property Rights, Procurement and Contracting (not scored)

Foreground IPR produced by the project, such as from the testing of aged in-service SF6 alternative gas mixtures, will be communicated in the project reporting in sufficient detail to enable others to benefit appropriately from the learning delivered by this project. Confidential details of IPR will not be disclosed, however sufficient information will be provided to enable other licensees to understand the implications of the work carried out and its applicability to their own networks. This is in the interests of all project partners as it is hoped that the solutions can be demonstrated to be technically and commercially viable so wider licensee understanding of the new technology could lead to additional network development activity and economic benefits for the supply chain, including project partners from industry.

Project compliance with the IPR arrangements as defined in Chapter 9 of the SIF governance document will be assured via the contractual arrangements which will be put in place between NGET and each of the project partners.

There is an existing framework for NIA projects, that demonstrates compliance with innovation funding schemes, in place between the University of Manchester and NGET (leading or co-leading the delivery of 4 technical work packages),which ensures that the results of Beta Phase can be exploited to the benefit of the wider industry and academic communities. NGET is a regulated business with90% of NGET's innovation funding allocated through contribution from GB electricity bill-payers. In the worst-case scenario of banning SF6 in electricity networks, the associated negative impacts will be levied directly on GB electricity customers. Hence, there is strong expectation that the results generated in this project must be open-access and widely disseminated in relevant fields to maximize impacts. IP (i.e. know-how and patentable work) will be identified and reviewed at the review meetings and highlighted following any significant project progress.

Commercialisation, route to market and business as usual

Proposed ideas will be developed and matured through Beta Phase leading to business as usual within TOs and across other networks after the successful project completion through the following strategies:

Non-SF6 Gas Blends: Project consortium will establish a standard procedure for handling and assessing the condition of non-SF6 gas blends. This includes understanding the stability and leakage of these blends in the long run and defining the sampling frequency. The learnings from this process will be provided to the business and will feed into the preparation of technical documents. Consortium will also provide four labs for gas analysis as needed, two of which are university labs involved in SF6-related innovation projects.

Retrofill Solutions: Project consortium will conduct a feasibility study to determine if Transmission Owners (TOs) can perform retrofill operations without Original Equipment Manufacturer (OEM) support. A Cost-Benefit Analysis (CBA)and business case for retrofill, including costing and risks involved, will be developed. This will help the TOs determine if retrofill is a viable option and therefore widen the suite of potential options to reduce SF6 leakage.

Lifecycle Management of SF6 and Alternatives: Project consortium aim to build up the body of evidence to enable recycling/disposal companies to dispose of SF6 through an energy-efficient approach than the conventional thermal method.

Visibility of SF6 Leakage: Project consortium will provide access to data in existing sensors through SIF on a few substations, with plans to roll out the technical know-how through T3 funding on other GIS substations. Consortium will also install wireless sensors on transitioning substations, providing the business with an alternative IoT product. An open-access software to predict the performance of SF6 filled assets will be made available for TOs to use as part of their regular operations.

The teams managing T3 funding, condition monitoring, data analysis, Io platforms and SF6 abetment of National Grid are and will be extensively engaged to make sure the alignment of objectives and outputs of the project to that of business.

As for the commercialisation of the innovation, our Project Partners plan to leverage the results of the feasibility studies, CBAs, and technical document preparation to create a compelling case for the adoption of these innovations. The goal is to demonstrate the cost-effectiveness, efficiency, and environmental benefits of these solutions, thereby encouraging their widespread adoption across the industry. The open-access software and IoT products developed will also be marketed as valuable tools for improving the management and performance of SF6 filled assets.

Policy, standards and regulations (not scored)

The Project does not anticipate requiring any changes to government policy or standards to proceed.

The new EU F-Gas Regulation 2024 established a definitive legislative framework that specifies the 'Placing on the Market' prohibitions of new SF6 switchgear. These regulations have not been converted into UK law as yet, however our expectation is that the UK will adopt similar guidelines from the new F-gas Regulation. The EU prohibition dates are set as follows:

- For switchgear rated over 24kV but less than 145kV, the prohibition date for new SF6 switchgear is 1 January 2026.
- For switchgear rated at 145kV and above, relevant to NGET and othertransmission operators, the prohibition date is 1 January 2031.

The EU F-Gas Regulations set the regulatory outlook for SF6 replacement technologies based on a limit to the Global Warming Potential (GWP) of the alternative gas. The final regulation sets a GWP limit of 10 for alternative gases.

The consensus is clear: not only is there a move to move away from using SF6 as the default gas medium for GIS, but there is also a restriction on the use of fluorinated gases (with high GWPs) as replacement candidates. This aligns with the broader EU environmental goals, including discussions on banning per- and polyfluoroalkyl substances (PFAS) in Europe. Note that this is specific for new equipment to market and not applicable to retrofill application where the use of high dielectric strength fluorinated gases is still needed as an interim transitional solution in presently installed SF6 assets. Premature replacement of existing SF6 assets that can still operate for many years will be costly to consumers and significantly delay the UK's clean energy transition.

The ban on the manufacturing of virgin SF6 is set to commence from 2035, which will increase the need to recycle, recondition, and reuse SF6 to maintain the existing SF6 asset fleet. The regulation emphasizes the importance of regular leakage checks with enhanced accuracy or sensitivity. Accurate leakage data is crucial for understanding the asset leakage profile and developing appropriate interventions.

Consumer impact and engagement

UK has mandated the Net Zero target by 2050 and has committed to decarbonise the electricity system in the UK by 2035 to achieve the target. There are different kinds of emissions in power sector which need to be curbed. SF6 emissions are the second largest contributor to National Grid (NG) ET's GHG emissions (behind transmission power losses). NG is targeting a 50% reduction in SF6 emissions by 2030 from a 2019 baseline and no further procurement of SF6 containing equipment depending on the voltage level and technology available. To deliver the commitment towards Net Zero by reducing SF6 emission, NG and other TOs of GB have adopted SF6-free technology very rapidly. The question is how fast Tos can deliver the overall reduction of SF6 with optimum cost to UK electricity consumers (domestic, commercial and industrial) while ensuring the networks operate reliably. The innovations in the project will help TOs to minimise the risks associated with the necessary rapid adoption of the new technology subsequently providing financial savings to UK consumers.

Transmission network is the backbone of the electricity supply and keeping the light on for all consumers. Any efforts towards reducing the emission while

ensuring reliability will indirectly benefit all consumers. To do this, NG has adopted different goals in responsible business charter and science-based target. These are as per OFGEM's guidelines and incentive scheme which suggest reducing the emissions every year which is the voice of customers and TOs are regulated by OFGEM. Sustainability First, a consumer-focused lobby, also suggests in engagement through reports and webinar that work need to be done by TOs for reducing the SF6 emission within UK, especially NG having one of the largest SF6 inventory. NG is directly involved in these conversations on action points to enable this.

Consumers will not be directly involved in the design and dissemination activities of the project but the projects finding, associated risks, benefits and impact will be delivered through different organisations which are consumer's voice. The project is monitored by UKRI and OFGEM where project progress with benefits to the customers will be discussed. NG representatives will be discussing the project findings with organisations such as Sustainability First to make sure we engage and doing things as per consumers' expectation. To ensure the wider dissemination and share the learning across consumers across GB, all three Tos have partnered for the project and will work together to tackle the problems with SF6 and early adoption of non-SF6 technology.

The learnings will be shared to other TOs, Electric Power Research Institute (EPRI) of USA through discussions in WP6 inviting them to TAB meetings, enabling to share the findings with wider consumer base. To use the consumer money in an efficient

manner for wider engagement, experts on SF6 from other businesses (e.g. OFGEM, UKRI, universities, DNOs) and regions (e.g. mainland Europe, USA) will be invited on TAB. Many personnel are contacted and already agreed for the discussion.

The project outputs as will be fed to business to be implemented in T3 and further funding periods. This will save consumers' money and enable early adoption ofnon-SF6 technology efficiently. To reduce SF6-related emissions, TOs need to understand the non-SF6 gas blends in long run, feasibility of retrofill, different intervention scenarios based on data and how SF6 will be disposed after interventions. This project will help to have the understanding with integrating consumer's needs and preferences through engagement with different organisations as discussed to achieve Net Zero goals of TOs and GB.

Value for money

The project is costed for £9.79m in Beta phase with a funding request of £8.5m.13% total contribution of £1.3m is made of 10% contribution from all partners and~43% from WIKA.

The funding requested from NGET is £4.6m with total cost of £5.1m which includes all the labour cost to lead/co-lead WP1, WP2, WP4, WP6 along with monitoring and dissemination of the project. There is no cost for purchasing new equipment. £4.2m is costed to deliver WP2 and £0.9m is allocated to other WPs and activities. This cost of WP2 has benefit ratio of the 3:1 over a period of 45years and will be used to deliver the testing through labs from partners and externals - type tests and certifications, Deeside Centre for Innovation for long-term testing; depending on the feasibility results from stage gate 1. This doesn't include the benefits obtained through learnings and reducing the timescale of retrofill solution where OEMs are unable to deliver. Cardiff University will be contracted for WP1 for ~£117k enabling gas-analysis at 2 UK universities and German commercial labs providing GB TOs options and confidence to do analysis in UK or EU after the project.

University of Manchester is costed for £2.7m which will be leading WP3 and WP4(after first year of data collection) and contributing significantly to the delivery ofWP1&2. Most of the cost is made of labour cost, researchers to be hired to deliver WPs. Existing GC-MS will be used for WP1 and a refurbished GC-MS will be purchased for £70k. The return on the cost is appropriate providing open access software for asset performance prediction and greener disposal method of SF6.

DNV is costed for £738k which will be leading WP2 for stagegate 1 and WP5 with overall project management support. Cost is all labour cost with delivery of reports especially after the stagegate 1 of WP2 which will make the delivery of WP2 successful subsequently. The reports will be generated with discussions from partners and TAB members from different organisations.

All TOs of GB are partners led by NGET. SSEN-T and SPT are partners trying to solve similar problems costed for ~£100k each for supporting the project discussion and sampling the non-SF6 blends on their network. WIKA is another partner, a company providing gas measuring equipment helping with the gas-analysis expertise costed for £923k with most of labour cost as in-kind contribution. It will help to deliver WP1 and sensor installation in WP4. DILO is another partner, a company supporting with gas-analysis in WP1 and discussion in other WPs costed for £126k.

Partners also agreed on inviting other stakeholders to better understand different products available in the market and how these can help with the project objectives. The project is costed mostly in terms of labour cost. The project is not utilising funds from any other innovation projects. Existing lab facility at UoM, Cardiff University and the gas handling facility of TOs will be used for the experiments and proof of idea of the project deliverables. Existing gas measurement equipment from WIKA and DILO will be utilized for blend gas analysis and determining the gas ratios required or functional requirements in GIS.

This project demonstrates value for money for the following reasons:

- Daily rates are at UK industry norms for similar engineering or consulting services
- Significant scope is being attempted addressing the most important aspects related to SF6 interventions
- The size of the benefits associated with better decisions on the non-OEM supported retrofill, optimal intervention, lower environmental impact of disposal and increased knowledge of non-SF6 gas mixture handling procedures outweighs the cost of the project.

Associated Innovation Projects

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

Supporting documents

File Upload

SIF Beta Round 2 Project Registration 2025-12-10 12_25 - 89.9 KB
SIF Rd2 Beta SF6 Whole Life Strategy SIF Benefit Map - Q6.pdf - 166.1 KB
SIF Rd2 Beta SF6 Whole Life Strategy Roadmap.pdf - 674.0 KB
SIF Rd2 Beta SF6 Whole Life Strategy CBA - Q6.xlsx - 824.4 KB
SIF Rd2 Beta SF6 Whole Life Strategy Appendix Qu 4.pdf - 87.8 KB
SF6 Whole Life Strategy Project Management Book Template Feb 2024.xlsx - 108.1 KB

Documents uploaded where applicable?

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