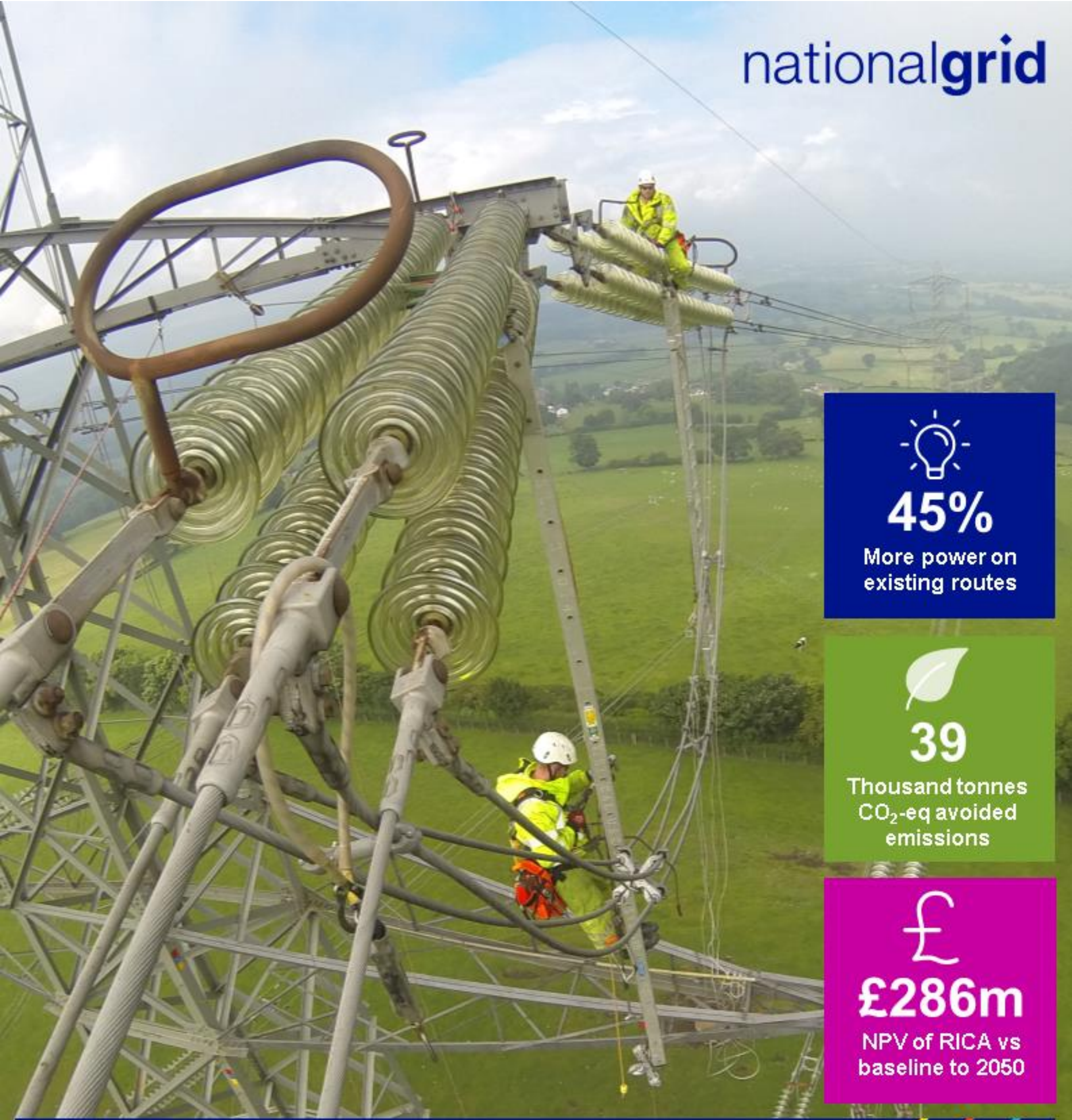
nationalgrid



45%
More power on existing routes

39
Thousand tonnes CO_2-eq avoided emissions

£286m
NPV of RICA vs baseline to 2050

Retrofit Insulated Cross Arms (RICA)

National Grid Electricity Transmission

Network Innovation Competition 2020

Network Innovation Competition: Full Submission Application [NGEN05/V1]

Section 1: Project Summary

1.1 Project Title	Retrofit Insulated Cross Arms (RICA)
1.2 Project Explanation	This project will develop a novel method of uprating Overhead Lines (OHLs), accelerating the low carbon future by allowing quicker removal of network constraints, resulting in earlier connection of renewable generation. RICA also provides the potential for cost savings and better visual amenity compared with conventional investment options.
1.3 Funding Licensee	National Grid Electricity Transmission
1.4 Project Description	1.4.1. The Problem(s) it is exploring The UK has set an ambitious, but necessary, target of delivering net zero carbon emissions by 2050. To deliver this target there will be required increases in renewable generation and the electrification of transport and heat, leading to increased demands on the transmission network. At the same time, it is becoming more difficult to deliver increased transmission capacity in a timely manner, while meeting environmental and community objectives. Finding innovative ways to deliver network capacity at minimum credible cost in line with stakeholder values, will deliver better value for money to consumers and accelerate the low carbon future. 1.4.2. The Method(s) that it will use to solve the Problem(s) Insulated Cross Arms (ICAs) replace the standard metallic cross-arms from which insulators and conductors are suspended. Retrofit ICAs (RICAs) allow licensees to upgrade the voltage rating on their existing towers by improving clearances. The project will enable conversion of NGET 275kV towers to 400kV. 1.4.3. The Solution(s) it is looking to reach by applying the Method(s) This project will provide a pathway for the GB's first full-scale implementation of RICA technology, by mitigating technology risks and accelerating its adoption onto transmission investment schemes. The project will remove the current process, technology, and specification hurdles that have prevented licensees from adopting RICA as BAU previously. 1.4.4. The Benefit(s) of the project RICAs can provide new network capacity without the need for new build OHL. This leads to shorter project timeframes, reducing constraint costs earlier (saving £180m per year) and enabling faster connection of renewable generation. The capability to operate at higher voltages also means lower losses and associated emissions (39kt reduction). Wider benefits to stakeholders include reduced customer impact due to lower construction volumes and

	better visual amenity of towers compared to new build alternatives.		
1.5. Funding			
1.5.1. NIC Funding Request (£k)	8,115	1.5.2. Network Licensee Compulsory Contribution (£k)	913
1.5.3. Network Licensee Extra Contribution (£k)	0	1.5.4. External Funding – excluding from NICs (£k)	0
1.5.5. Total Project Costs (£k)	9,133		
1.6. List of Project Partners, External Funders and Project Supporters (and value of contribution)	Project Supporters: ***Network Licensees:*** Scottish Hydro Electric Transmission plc, Scottish Power Transmission Ltd., Electricity System Operator ***Suppliers:*** Babcock Networks, Balfour Beatty, Energyline, Nanjing Electric, PACE Networks, Allied Insulators, Allied Conductors Shemar, Wood Group, ZTT. ***Academic Institutes***: Cardiff University, The University of Manchester		
1.7. Timescale			
1.7.1. Project Start Date	Jan 2021	1.7.2. Project End Date	Mar 2026
1.8. Project Manager Contact Details			
1.8.1. Contact Name and Job Title	Paul Gallagher Innovation Manager	1.8.2. Email and Telephone Number	Paul.gallagher@nationalgrid.com [redacted]
1.8.3. Contact Address	NG Warwick House, Warwick Technology Park, Gallows Hill, Warwick CV34 6UW		
1.9. Cross Sector Projects (only complete this section if your project is a Cross Sector Project, ie involves both the Gas and Electricity NICs).			
1.9.1. Funding requested the from the [Gas/Electricity] NIC (£k, please state which other competition)	0		
1.9.2. Please confirm whether or not this [Gas/Electricity] NIC Project could proceed in the absence of funding being awarded for the other Project.	0		
1.10. Technology Readiness Level (TRL)			
1.10.1. TRL at Project Start Date	TRL 6	1.10.2. TRL at Project End Date	TRL 8

Section 2: Project description

2.1 Aims and objectives

2.1.1. *The Problem that needs to be resolved*

The move towards renewable generation, necessary to achieve the UK government's net zero emissions target, is having an increasingly significant effect on transmission network constraints. A combination of renewable generation connecting in remote areas and increased demands in urban areas due to the electrification of heat and transport, are both expected to drive the need for further network development and investment.

While some of this additional demand will be offset by local generation, network modelling shows there will be significant changes to power flows across the transmission system, leading to increased constraints which will require network reinforcement to alleviate. Although new interconnectors will help to address some of these constraints, reinforcement of the GB network will also be required. This requirement will be predominantly felt at key transmission boundaries, particularly the critical North-South links.

Network constraints can be relieved through reinforcement (to increase power transfer capacity) or by controlling power flows. Reinforcement can be achieved through new Overhead Lines (OHLs); however, new OHLs are expensive, require significant stakeholder engagement to manage customer, consumer, and environmental impacts, and often require lengthy land acquisition and consenting applications. The transmission industry must balance the need for new OHLs with its commitment to conserving and enhancing the natural beauty, wildlife, and cultural heritage of the GB landscape.

Alternative options for significant capacity increase include reinforcement of existing OHLs through reconductoring with modern conductors, installing additional conductors, uprating the voltage, or a combination of these. These options also bring challenges from a cost, time-to-deliver, and environmental perspective.

On older OHLs, reconductoring with High Temperature Low Sag (HTLS) conductors can increase capacity to by around 28%, but also increases network losses and associated emissions. For further capacity increases, additional conductors can be installed, often requiring tower and foundation strengthening due to increased mechanical loading.

The GB transmission network currently operates at a mixture of 275 kV and 400 kV. Uprating a circuit's voltage from 275kV to 400kV is possible for some tower types (e.g. L2, L6) by design, however others in the GB network (e.g. L3, L34 and L66) currently require replacement with new, taller towers to meet minimum clearance requirements.

Given the increasing penetration of renewables to achieve net zero targets in the future, methods to facilitate large and fast capacity increases at transmission boundaries would be beneficial to consumers.

This project seeks to solve this problem by establishing an innovative way to greatly increase the power transfer capacity of existing lines. With this in mind, the project's first aim is to:

> ***Develop a new investment option for uprating overhead lines from 275kV to 400kV that accelerates development of a low carbon network while delivering on stakeholder priorities (lower cost, reliability, decarbonised, low visual impact).***

2.1.2. *The Methods being trialled to solve the Problem*

The Retrofit Insulated Cross Arm (RICA) is an arrangement of electrical insulators which have been retrofitted to an existing 275kV tower, allowing it to operate at 400kV without having to build an entirely new route, as shown in Figure 1. This is done by replacing the steel cross arms and suspended vertical insulators with an Insulating Cross Arm (ICA). As the conductors attach directly to the cross-arm, the electrical clearances are improved as per Figure 1.

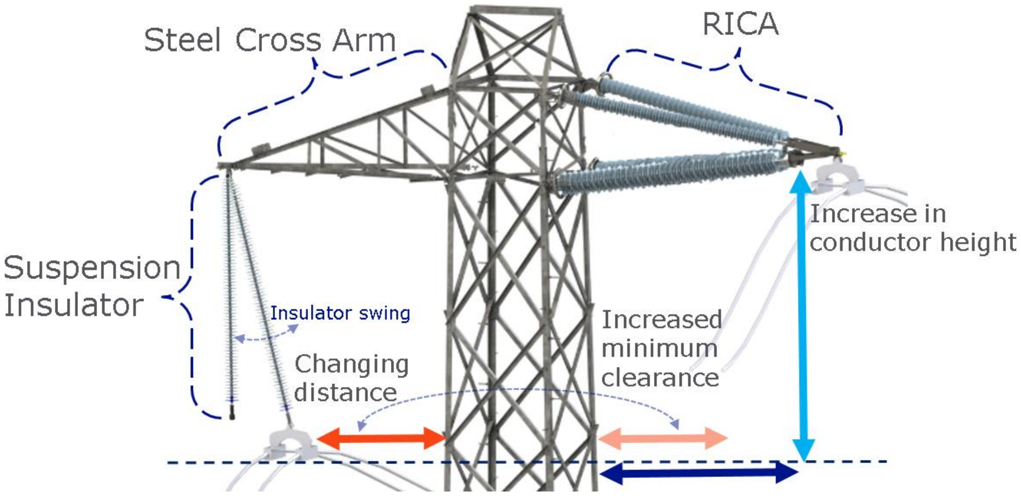


Figure 1 – Comparison of Traditional suspension insulator and RICA. Showing how the increase in electrical clearances is achieved.

The voltage uprate from 275kV to 400kV could provide an additional 45% power transfer capacity alone while also reducing transmission losses. Larger power increases have also been estimated when used in conjunction with HTLS conductor types – up to an additional 150% [1]. We estimate that this technology could be applied to 25% of the 275kV England and Wales Network, with further applications in Scotland.

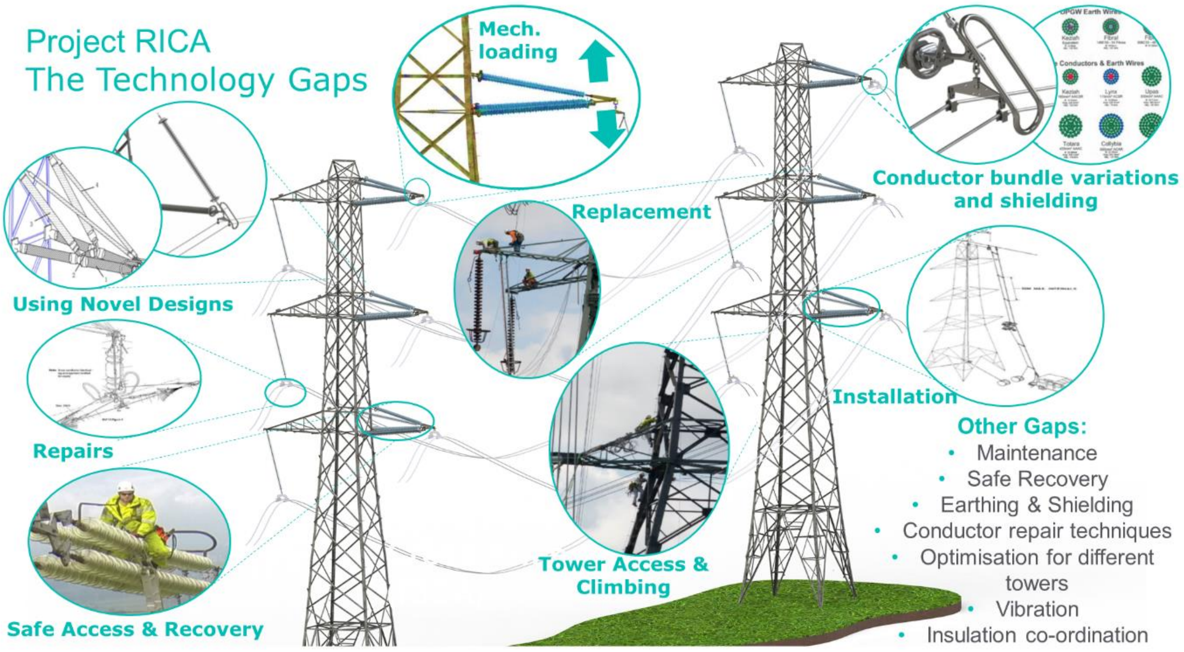


Figure 2 – Summary of technology gaps for Project RICA

The challenges for utilities in adopting this technology have always been finding a solution which can be installed, maintained, and accessed safely while maintaining network reliability and delivering at an efficient cost to consumers. A summary of the current technology gaps preventing immediate adoption is shown in Figure 2.

The project will innovate to address these existing barriers as outlined in the following sections. The project will also leverage the knowledge and expertise developed over the last 10 years relating to ICAs (from past innovation projects and the market), to bring this technology over the last hurdle to allow the opportunity for introduction into business as usual (BAU).

2.1.3. *The Development and Demonstration being undertaken*

The RICA project sets out to meet the following SMART (specific, measurable, achievable, relevant, and time bound) objectives:

1. Fill gaps in research and development related to RICA, to increase the technological maturity of the whole-line-solution. **The RICA solution should be demonstrated as ready for use as BAU by the end of the project.**
2. Develop the alternative investment option to prevent the need for new or replacement of existing towers. **There will be a clear business case for BAU use on at least one operational route by the end of the project.**
3. Develop a family of tower upgrade options which are fully compliant with all associated NGET protocols. **RICAs will be adopted as an option available for TO and ESO investment planning activities by the end of the project.**

Objective 1:

The use of RICAs as an alternative method of uprating has been explored over several smaller innovation projects over the past 10 years. However, further development of the technology and system designs are required to resolve the outstanding issues with live network implementation and ensure risks are effectively managed. The technology needs to be matured and validated to meet the requirements of multiple tower types and conditions, along with all of the associated long-term performance, delivery, health & safety, and asset management implications.

We will select a supplier through a competitive procurement process to develop the RICA method from design through to type-testing for all relevant tower types and configurations. The project's development scope contains all the technological and process-related design complexities that need to be resolved before the solution can be rolled-out on the network (in order to demonstrably reach technology maturity of TRL 8). A technical gap analysis has been undertaken for RICA technology and used to inform the specific areas of design the project will address (see Appendix V.1 for details).

Objective 2:

This will involve developing a detailed investment case that includes identifying which routes will benefit from RICAs, and differences in costs and project timescales between the RICA option and existing options. This will require continual development with scheme delivery teams, and interfaces with ESO's network options analysis (NOA) process. This will support the project implementation into BAU and help to establish greater certainty for the market.

Objective 3:

Once the project delivers on Objective 1, there will be clear technical requirements for the market to deliver solutions against. It will then be possible to develop a meaningful set of documentation (standards, specifications, processes and procedures) against which RICAs can be developed and tested.

The demonstration of the RICA technology to validate its performance on multiple tower types and under the conditions of the live network will be carried out via a series of full-scale demonstration trials set up at Deeside and Eakring – see Section 2.3 for details. Subject to successful trials, the RICA solution will then be subjected to type-tests before it achieves its TRL8 ambition.

These trials are essential to establishing first time solutions to many of the factors which will enable RICAs to be a credible and repeatable investment option. This will help to ensure the specifications are to the right level of detail, and that key functionality required in the design of the RICAs is specified correctly. Furthermore, identification of best practice and design improvements are inevitable from the first network installation and project monitoring will ensure that these are captured and disseminated for future installations.

2.1.4. *The Solution(s) that will be enabled by solving the Problem*

RICA is a clean, conceptually straightforward innovation that will use improvements in ICAs over the last 10 years to deliver an innovative investment option, with multiple technical advantages as outlined in Figure 3.

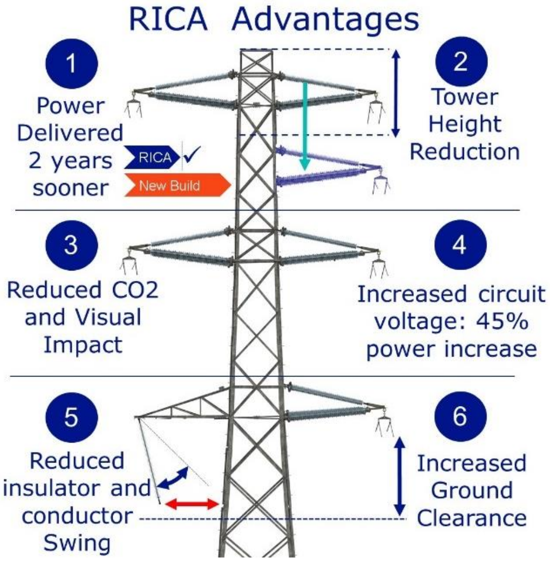


Figure 3 – Overview of the solution’s (RICA’s) potential advantages

RICA will provide a faster option to alleviate network constraints through uprating existing 275kV lines to 400kV, delivering significant savings to consumers. Our financial assessment of the benefits to consumers is given in Section 3.2, and demonstrates that uprating a single line could provide significant returns for consumers. Our Core scenario estimates £286m of savings can be delivered to consumers, as detailed in Appendix VI.5.

Uprating will increase the efficiency of transmission infrastructure through lower losses, saving energy and cost. In the near future where GB’s electricity supply still contains a significant carbon content, lower losses will reduce transmission network CO_2 emissions.

Using RICA will further decrease emissions through avoiding use of steel and concrete required for new OHL builds. Our Analysis of the CO_2 benefits is given in Section 4.1.3 and shows RICAs can deliver a 39kt reduction of net carbon emissions by 2050.

Additionally, using RICAs on existing towers to uprate OHLs will reduce the disruption to land and environment that would likely be required if new towers and new foundations were used instead along existing routes, and will prevent new routes being developed in greenfield or brownfield sites. The benefits to stakeholders and how this aligns with broader strategic objectives is provided in detail in Section 3.1, and shows that this project meets strategic objectives and stakeholder values directly.

As outlined in Section 2.1.2, the project will deliver type-registered RICA designs for use with key 275kV tower types that aren't inherently upgradable to 400kV on the NGET network - these represent 30% of all 275kV towers. Our analysis in Appendix II shows that there are multiple applications in England and Wales which relate to critical transmission boundaries and our engagement to date has shown that other licensees also see applications in their networks. This demonstrates this technology can be rolled out across the network to deliver value for consumers.

Extensive development and demonstration activities as outlined in Section 2.1.3 will take the technology out of the innovation phase and ready for BAU - providing a clear path for a competitive marketplace.

Project RICA will also make these other network investments more credible by:

1. Increasing current rating by providing additional clearances that allow for increased conductor sag at higher operating temperatures.
2. Providing experience and standards to enable Ultra High Voltage (UHV) networks – opening the door to UHV networks and associated capacity increases and reduced losses on 400kV routes throughout the GB network.
3. Providing an additional option for use on Visual Impact Provision (VIP) projects – enabling existing towers in Areas of Outstanding Natural Beauty (AONBs) to be reduced in height by around 25%. This will also reduce the disruption to the environment on such projects.

This project will provide significant risk mitigation for these additional investments to be considered by GB Network licensees, enabling RICAs to deliver more value to stakeholders.

2.2 Technical description of project

The project will be delivered in the following stages:

- Stage 1: Initialisation
- Stage 2a: Development
- Stage 2b: Building and testing
- Stage 3: Witness scheme delivery

Across these stages of the project are the following workstreams:

- **Procurement:** Enabling value for money to be delivered during the NIC project, de-risking the NIC project, and enabling investment line-of-sight.
- **Standards and specifications:** Establishing standards and specifications to enable the marketplace and adopting feedback from stakeholders.
- **Design and development:** Sizeable workstream, designing whole-life-value RICAs to meet UK and stakeholder requirements.

- **Investment Case:** Developing a clear justification for the use of RICAs and bringing critical whole-life design choices into financial terms.
- **Stakeholder Engagement:** Leveraging wider experience and knowledge to deliver better innovations, share outcomes and inform key stakeholders of what RICA can deliver for them.

The project's focus will shift between these workstreams as it progresses.

2.2.1. *Stage 1: Initialisation*

Stage 1 will be delivered internally by NGET and use experience of past projects and further investigation of real-world tower and route condition to prepare a concise set of work definitions, or 'knowledge gaps', to be completed by the supplier in stage 2.

Clear scope and guidance, to include detailed links to existing standards, will be prepared for potential suppliers. This information will be used to enable a competitive event. This part of the project is key to reducing technological and delivery risk on the project through consolidating the future design process. The procurement process will ensure value for money for consumers, and will ask suppliers to consider contributing to the project through several mechanisms; as outlined in section 6.1.8.

This stage will also produce a clear and agreed initial investment case, which will outline the benefits and areas of uncertainty from an investment perspective. This investment case will then be developed and improved as the project delivers key technical advances.

Table 1 provides a description of the workstreams contained in Stage 1; a description of key outcomes and the project's deliverables highlighted in bold.

Table 1: Stage 1 workstream descriptions

Workstream	Description	Key outputs
Procurement: *Pre-procurement*	Activities associated with engaging the market.	Expression of Interest published, Pre-Qualification Questionnaire begun, and **detailed design requirements finalised (D.S1.2)** – see Section 9.
Design and technology: *Preparation*	Outline of all design related tasks for completion at detailed design level by chosen supplier.	Reports containing preliminary design considerations, type-testing requirements and the development of design and development scope to drive supplier activities (D.S1.2).
Standards and specifications: *Review*	Review existing standards to identify gaps/conflicts. Quantify planning benefits. Assess condition of actual OHLs.	Documentation plan developed, and report informing planning and business decision factors.
Investment Case: *Initial case*	Understanding key metrics associated with the economic benefits of the RICAs to enable benchmarking against alternative solutions within optioneering activities.	**Drafting of the preliminary Investment Case (D.S1.1)** that sets out the break-even point between new towers and RICA solution through life-cycle analysis.
Stakeholder Engagement: *Involve*	Stakeholders engaged through Technical Advisory Board (TAB) and actively contributing to project work packages. Communications will begin around RICA through various media.	Stakeholders will directly input to the development and agreement of the detailed design requirements (D.S1.2) and (D.S1.1). Stakeholder input will be required to progress to Stage 2a.

2.2.2. *Stage 2: (a) Development & (b) Build and Test*

The purpose of Stage 2 is to establish the RICAs as a total lifecycle solution and it will resolve all remaining unknowns into a finished and documented solution. It will involve the development of a suite of RICA designs for a live operational route and establish a clear set of specifications for the future market.

This stage will be overseen by NGET and coordinated and delivered by the third-party supplier, whose selection will be the first key output to Stage 2, following on from earlier pre-qualification work completed in Stage 1. The supplier will be given clear deliverables for Stage 2 but it is expected that new solutions will be needed to ensure an optimised solution that is fit for purpose on the UK network.

Given the uncertainty in the specifications and design requirements, the supplier will need to be able to work flexibly to address challenges through innovation. This uncertainty in scope will be reflected in the contractual terms and procurement scoring methodology, to ensure that the project can proceed at reduced risk while identifying a sufficiently innovative supplier.

As with any research focused project, there is a risk that innovative discovery, or 'unknown-unknowns' will materialise as the project develops leading to schedule delays. This risk has been accounted for through planned iteration phases of load case specification, design, and testing to ensure that any final approval work is successfully completed on-schedule. This has been reflected in the project management plan by the split of Stage 2 into parts 2a and 2b, where 2a will have flexibility to innovate and iterate, and 2b will be focused on final testing and approval.

Table 2 and Table 3 provide a description of the workstreams contained in Stages 2a and 2b, with project deliverables highlighted in bold.

Table 2: Stage 2a workstream descriptions

Workstream	Description	Key outputs
Procurement: *Contract supplier*	Engage a supplier to deliver the technical aspects of the project. This workstream develops the work completed in stage 1 to completion of the chosen supplier on-boarding process.	Supplier contract awarded (through *Innovation Partnership* or equivalent).
Design and technology: *Development*	Detailed understanding of tower and RICA requirements through load cases, tower evaluations and initial insulator design. Trials will be performed across a range of sites including NGET's new outdoor test facility at Deeside, our training facility at Eakring, and within external labs as needed for RICA design validation tests - these need not be accredited labs at this stage. Iterative design and test cycles to allow learning to be implemented in updated prototypes and concepts with the final concepts being progressed to Stage 2b for validation. Design of the enhanced monitoring required for witnessing performance on a real network.	**Draft functional specification (D.S2a.1)** and **First generation product design portfolio (D.S2a.2).** Proof of principle and design testing at all levels, design improvements as required, culminating in a **report on detailed trial outcomes and lessons learned (D.S2a.3).**
Standards and specifications: *Development*	Ensure that any gaps in knowledge are filled and subsequently produce all required guidance notes, technical reports, NSIs, maintenance manuals and disposal strategies etc.	Draft of all NGET standards, specifications, processes and procedures in line with the documentation plan.

Workstream	Description	Key outputs
Investment Case: *Refine*	Develop the Investment Case with further insight as the project develops, e.g. information on the ease of installation or more precise hardware costs, to support economic decision-making. All new information will feed into decision tools such as NOA to conduct cost benefit analysis.	Investment guide documentation produced.
Stakeholder Engagement: *Seek support*	Stakeholders will be engaged through supporting deliverables, and be actively engaged in the trials to enable detailed feedback. Further stakeholder input based on the learning from other workstreams will also be incorporated into the investment case, standards and specifications.	Stakeholders will directly input to the functional specification **(D.S2a.1)**, detailed designs **(D.S2a.2),** and the lessons learned **(D.S2a.3)**. Agreement from stakeholders will be required to progress to Stage 2b.

Table 3: Stage 2b – Build and Test workstream descriptions

Workstream	Description	Key outputs
Procurement: *Supplier management*	The functional specification documentation will be refined throughout the project to ensure that, if necessary, the existing supplier could be supplemented or replaced by an alternative.	Functional specification updates.
Design and technology: *Validation*	By this stage, all concepts should have been fully worked through and this will now form the final validation testing in the form of type approval testing required for the type registration. Testing will be completed at Eakring and long term testing will be established at Deeside, to provide a benchmark for RICA performance that will have been running for several years prior to any mainstream network installation. External, accredited test labs will be engaged to perform any insulator testing needed for type registration.	Relevant type registration testing complete and type-approval achieved.
Standards and specifications: *Embed*	This is a follow on workstream from Stage 2a - NGET processes and procedures. During this stage all key documentation will be formalised and approved for adoption by the relevant NGET departments.	**High quality draft of all documentation (D.S2b.1)** approved into the business. **Full suite of documentation issued (D.S2b.3).**
Investment Case: *Adopt*	Following development of the investment guide, and proof of technology from the trials, we will conduct a major project review.	**Final Investment Case (D.S2b.2).**
Stakeholder Engagement: *Approval*	Stakeholders will be included in the design finalisation and be kept up-to-date on progress through the final stages of development. Input will be gathered for the final investment case and specifications.	Stakeholders will directly output into **(D.S2b.1) and (D.S2b.3).**

Stage 3 – Witness Scheme Delivery

The intention for this Project is that it will lead straight into **but not include** the roll-out of final RICA solutions within a real line refurbishment scheme. This Stage covers a period of enhanced monitoring of the performance of the route, over and above what would be carried out as BAU for a line uprating using a type registered technology. It also covers a final project report so that knowledge of live network implementation can be disseminated to our stakeholders.

Within the course of the project, it is anticipated that business drivers will support a full line up-rate to 400kV, returning value to the customer in the shortest possible timeframe. In this event, the scope of Stage 3 will remain the same[1].

The network installation will be determined based on an on-going assessment of business need and benefits provided, i.e. the Investment Case. This case will change over the lifetime of the project, but evaluation of all possible locations for 275kV to 400kV upgrades within the NGET network is already underway (see Appendix II).

2.3 Description of design of trials

Following extensive workshop-based RICA design development, ICA prototypes will be produced for testing the different system designs across the trial Stages (Stages 2a, 2b and 3). Throughout these three stages, stakeholders will be engaged throughout the process to enable feedback into the design, documentation and processes established.

Stage 2a

In Stage 2a, once a design has been agreed, prototypes will be produced, and constructability trials will be held at a field-based facility. The purpose of these trials will be to experiment with different techniques for modifying the towers to accept the new RICAs and subsequent operation and maintenance techniques. This work would be completed on new, bespoke structures, either identical to the family of L3 tower types, or as a minimum, containing the necessary features to allow comprehensive trialling to be completed.

These constructability trials are expected to culminate in a re-design of the cross arms, incorporating stakeholder feedback and lessons learnt. A key element of the design will be enabling ease of use on site and limiting the need for heavy lifting equipment to be taken to the OHL routes. This will address a significant proportion of the upfront and enduring costs from a RICA investment.

Testing will also be undertaken at Deeside, as this will have capabilities for testing insulators under network representative energised conditions with a high level of monitoring and for testing dynamic performance of conductors and RICAs using a long span variable tension rig with the ability to add vibrations through a hydraulic shaker unit. A range of RICAs in different configurations will be installed and tested at Deeside with the primary purpose of providing confidence in the network performance of the solution over a long time-frame. Testing of hardware from different manufacturers will ensure confidence in the security of supply, especially important, given NGET's first-hand inexperience with large composite insulators.

These Deeside trials will be ongoing for a minimum of a year as the design is refined, key technical risks are removed (or reduced to As Low As Reasonably Practicable) and uncertainties resolved.

Stage 2b

In Stage 2b, after lessons learned have been conducted from the first series of trials at Eakring and/or Deeside the designs will be finalised. The final RICA designs must then be type-tested.

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[1] If no route is available for on-line monitoring within the project timeframes, we will specify appropriate monitoring arrangements and return the monitoring costs to the consumer (more detail of mitigation actions provided against risk 12 in Appendix III)

Final constructability demonstrations will likely be performed at Eakring, and final electrical and dynamic assessment will likely be performed at Deeside, using a similar set up to that used in the Stage 2a demonstration. The difference being that in the Stage 2b demonstrations, a fully approved procedure will be presented and followed through to completion. Aside from minor amendments, the demonstrations are expected to be completed without departure from the procedure. Any departure will be considered a failure and the trials will need to be repeated following the implementation of the necessary changes. Successful completion of these demonstrations will be when the RICAs completed their installation and maintenance regime to the full satisfaction of all relevant operational stakeholders.

Additionally, for type-testing it is likely that testing of the insulators in an accredited laboratory will be required for design assurance. Examples of the specific set of tests to be carried out are given in Appendix V.4.

Stage 3

The purpose of the NIC project is to develop RICA technology to a point where it is considered as a tool for use in future network option assessments. Stage 3 completes the final milestone in this ambition by conducting enhanced monitoring and evaluation of performance, over and above what would normally be done as BAU for accepted design solutions.

The in-service monitoring will also allow feedback on the first few years of service experience to be disseminated to other utilities and provide clear validation of design assumptions. This data and learning will be critical to responding to concerns over the technology and the applicability of the specifications.

This data will also help remove conservative assumptions in the standards, further enabling the competitive market. The data will also be used to help improve accuracy of end-of-life predictions, which will directly impact the risk profile and investment case for RICA.

The project structure has been kept intentionally flexible to ensure spend is not over committed in any areas that won’t be applicable to any future network upgrade. Regarding the scope of the Stage 3 trials, various schemes will be considered from future NOAs, and the project will attempt to align with one of these.

2.4 Changes since the Initial Screening Process (ISP)

There has been no significant change to the scope since the ISP stage. The total project costs have decreased from £11.2m to £9.1m due to refinement of the project plan, revisiting prior assumptions and more granular cost modelling. We have used the FSP development period to mature and detail the RICA project, including:

- Undertaken a more detailed costing and cost-benefit analysis
- Characterised the technical detail of the technology development - revised the Start Date TRL from 7 to 6 and the Finish Date TRL from 9 to 8
- Developed a rigorous, implementable project plan
- Defined detailed deliverables against the project plan
- Conducted risk workshops to cover both technology development risks and project delivery risks
- Continued engagement with our project partners and potential suppliers

Section 3: Project business case

We have developed a robust business case for this NIC project case that presents:

- **The strategic case for change** - how this project aligns with electricity consumer priorities, government legislation, Ofgem guidance, and NGET business plans.
- **The economic case -** how this project delivers value for consumers and why now is the right time to bring this technology to a business-as-usual solution.
- **The commercial, financial and management cases** - how we have optimised the project's procurement strategy, funding and governance to deliver the best outcomes.

This breakdown follows the HM Treasury five case model for business case development. The following sections describe each case in further detail, while Appendix VI presents further detail on this model and the rationale behind using it.

3.1 The strategic case for change

RICA aligns with electricity consumer priorities outlined in our RIIO-2 business plan as illustrated in Figure 4.

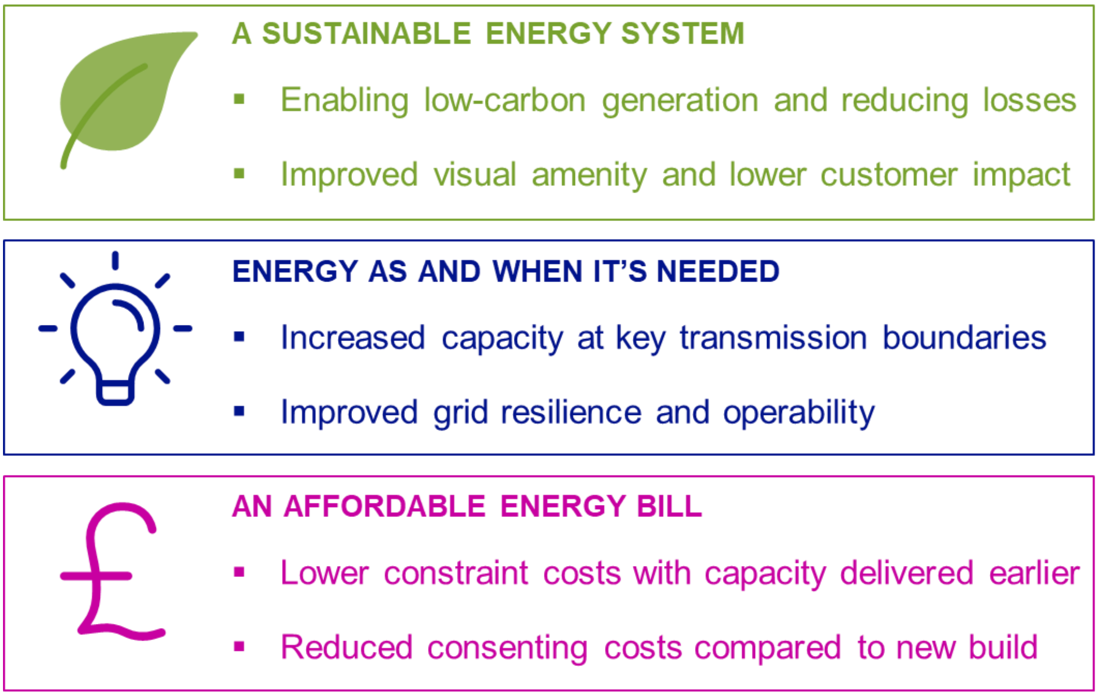

Figure 4 – Project alignment with electricity consumer priorities

First, the project supports and accelerates progress towards a more sustainable energy system - decarbonisation through connection of more low carbon generation to the transmission system and reduced electricity losses; while also enhancing the visual amenity of natural assets with lower tower heights compared with new build OHL.

Second, the new low-carbon generation will connect, thanks to increased capacity at key transmission boundaries, which in turn maintains a reliable and secure electricity supply - providing energy as and when it is needed.

Third, the project will help contribute to more affordable energy bill as it delivers a net present value of £286m relative to the baseline option of using new build OHLs under our Core assessment scenario (in 20/21 real terms). The optimistic value to consumers has also been estimated as £4bn – See Appendix VI.

The following subsections expand on these themes and demonstrate the project's alignment with government legislation, Ofgem guidance, and NGET's business plan for RIIO-2 and beyond.

3.1.1. *Enabling the transition to net zero*

The UK has legislated for a net-zero carbon emissions energy system by 2050[2]. In parallel to enacting this target in June 2019, the Committee on Climate Change (CCC) published guidance[3] stating that to deliver net-zero, transmission network capacity will need to keep pace with installation of new low-carbon generation to ensure a reliable network. This shows that delivering new transmission network capacity, at the lowest cost to consumers, is at the heart of the UK's road to net-zero. We have recognised this as a key area of focus in our sustainability strategy with a target to strengthen network capacity at a minimum-whole life cost[4]. RICA directly aligns with this ambition in providing additional capability to uprate existing lines at a lower whole-life cost to a new build OHL solution.

The project also aligns with the objectives of regulations and government plans developed in support of the legislated target, notably Ofgem's *Decarbonisation Action Plan.* The development of RICAs from a prototype technology to a business-as-usual solution supports the first two of the plan's actions: "designing cost-effective networks for net-zero" and "long-term planning and innovation". For the former, this project will expand the tool kit available to deliver network capacity increases for existing routes at a far lower cost than new infrastructure. It will do this while supporting the second action's aim to support innovative pathways to net-zero by developing the investment proposal where there is uncertainty. This is a key element of this project - to understand and improve the investment proposition for RICAs through de-risking the maturation of the technology.

The higher voltages RICA uprated towers can enable carbon emissions reductions through lower electricity losses. We have set a target, formalised in our RIIO-2 business plan, of net zero direct emissions by 2050. In the shorter term, we have also targeted a 20% reduction in controllable carbon footprint by 2021 vs 2012/13 levels in our NGET sustainability strategy. NGET's annual environmental statement describes our progress towards achieving these goals. This document shows that 81% of NGET's carbon footprint in 2018/19 came from losses - therefore any benefits that RICA have in reducing losses will be a significant contribution to lowering our total carbon footprint, alongside decarbonisation of the electricity itself.

3.1.2. *Improved visual amenity and lower customer impact*

The project helps to deliver on other elements of a sustainable energy system in improving visual amenity of uprated transmission infrastructure in National Parks and AONBs, while reducing impact of transmission works on customers. It will also build on

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[2] Enacted through an amendment to the *Climate Change Act 2008.*

[3] Committee on Climate Change. *Net Zero The UK's contribution to stopping global warming, May 2019. Retrieved from:* https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/

[4] NGET, *Delivering our environmental future - Our sustainability strategy,* March 2019

our efforts to recognise and enhance the value of natural assets, with 29 sites now being proactively enhanced using a Natural Capital approach against a target of 30 sites by 2021.

Our *Visual Impact Provision (VIP) Policy* sets out our approach to reducing the impact of existing infrastructure on important landscapes across England and Wales. A key intended outcome of this policy is feasible mitigation projects that have a tangible effect on landscape in National Parks and AONBs. Developing RICA to a BAU solution supports these aims by providing an option for network investment which may provide a stakeholder acceptable investment where ungrounding cables are not acceptable to all stakeholders (e.g. in areas of historical significance).

The reduction in construction timescales and volumes for RICA vs new OHL build also helps to deliver a sustainable energy system. Reducing impact on our customers and wildlife during construction is a key part of our Sustainability Strategy; RICA will result in fewer disruptions to communities and ecosystems.

3.1.3. *Energy as and when it is needed*

Maintaining a safe and reliable network is a key pillar of our RIIO-2 Business Plan and is consistently our stakeholders' number one priority, associated with 60% of our baseline costs for 2021-26 in our RIIO-2 submission. This focus aims to maintain our world-class service reliability of 99.9999% while allowing for future network requirements. A key component to delivering this reliability is flexibility in the delivery plan, allowing for multiple energy system development scenarios. Adding RICA as a low-cost network capacity solution will add another investment option to address network constraints going into the RIIO-3 price control. Maturing this technology will pay dividends when it is selected as part of cost-reflective investment decision making.

The majority of transmission built in NGET's network was installed in the 1960s as shown in Figure 5.

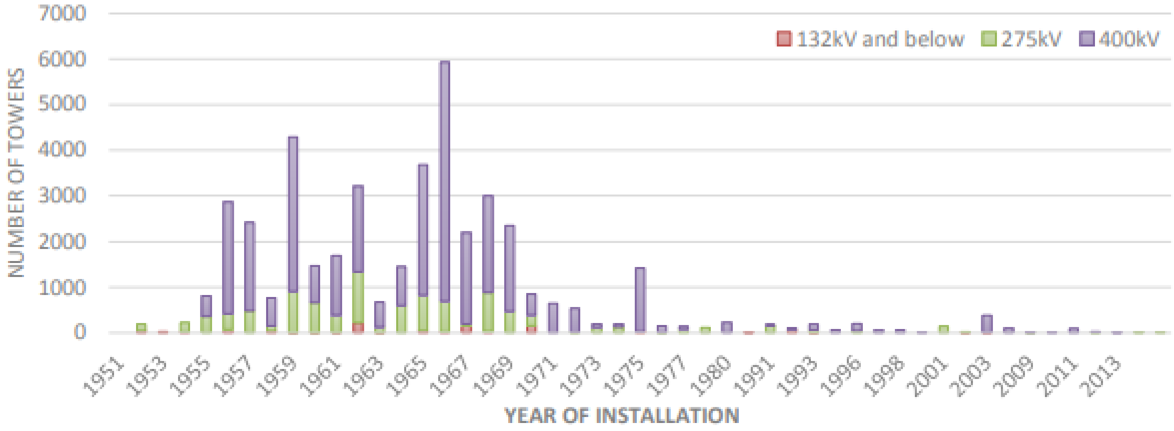

Figure 5 – NGET OHL tower installation years 1950-2017

Internationally, there have also been significant challenges to new OHL construction[5] due to many factors including more difficult consenting, and GB is no exception[6]. RICA

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[5] Transmission costs in the US rose by 80% between 1990 and 2007 (GDP growth adjusted):https://www.utc.wa.gov/_layouts/15/CasesPublicWebsite/GetDocument.ashx?docID=240&year=2007&docketNumber=072300

[6] This is supported by Shemar's letter of support in Appendix IV, which indicates UK planning timeframes of 6-9 years for new transmission.

provides an additional option to make the best use of the large existing fleet by offering an uprating capability for 275kV towers. This will help provide the network capacity we need to ensure energy is provided to consumers when they need it.

3.1.4. *An affordable energy bill*

A key electricity consumer priority and element of NGET's RIIO-2 Business Plan is to create an affordable energy bill for all.

Reduced underlying costs of Transmission network delivery and balancing services are ultimately reflected in consumer and customer tariffs. Therefore, RICA is well placed to reduce the pressure on consumer bills through reduced costs of managing constraints on the system and lower costs of delivering transmission infrastructure. Indeed as shown in the following section, delivering RICA will deliver a strong net present value (NPV) to consumers for the innovation funding requested.

3.2 The economic case - how does RICA deliver value to consumers

The project delivers good value to consumers and wider society as shown in Figure 6.

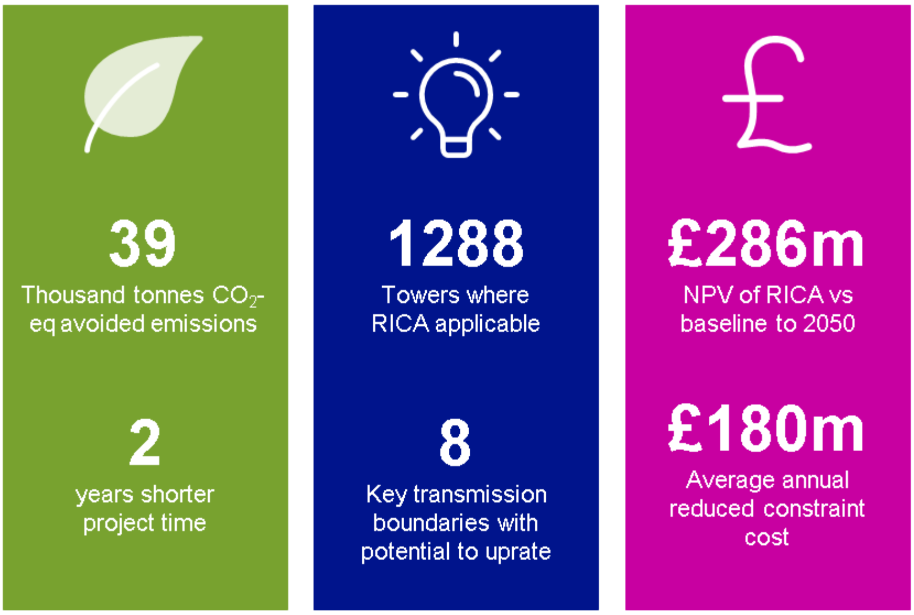

Figure 6 – Project value summary

We have appraised the development of RICA against a short list of options that includes the BAU approach. We have found that relative to BAU, RICA will deliver monetised benefits such as lower electricity losses, as well as lower costs to deliver transmission projects. RICA also delivers other non-monetised but equally important benefits relative to BAU such as improved visual amenity of GB's natural assets. Finally, there are benefits that are common to the BAU and RICA options including lower constraint costs and greater connection of low carbon energy sources. Our approach to NPV analysis aligns with that from the Network Options Assessment where possible to ensure a fair comparison with other transmission network investment. Further details on the outputs of our NPV analysis is summarised in Section 4 and the methodology followed is described in detail in Appendix VI.

3.2.1. *Defining the options shortlist*

We have defined a long-list of investment options and then down selected a reduced set to be investigated in further detail, as described in Appendix VI. We have included a credible do-minimum option in order to appraise the RICA option effectively.

Table 4: Shortlist options summary

Option name	Option description
BAU counterfactual	This comprises the **existing BAU toolset** to increase transmission capacity, covering: • Adapting current OHL routes: ○ Reconductoring with new higher capacity conductors ○ Adding circuits (from single to double) ○ Uprating voltage • Building new OHL • Non-network solutions (e.g. power control devices, battery storage)
BAU+RICA	• The set of BAU options. • Plus the RICA option for uprating lines from 275kV to 400kV for L3, L34, and L66 tower types.

3.2.2. *Assessing the options shortlist*

We have conducted a detailed NPV assessment of the shortlist as per the assumptions stated in Appendix VI. Table 5 shows that RICA has slightly higher present value costs than the BAU option due to costs being incurred earlier, but provides far higher present value benefits than the counterfactual due to faster capacity realisation.

Table 5: Shortlist appraisal summary

Options	Present Value Costs (£m)	Present Value Benefits (£m)	Benefit Cost Ratio
BAU counterfactual	[redacted]	[redacted]	2.2
BAU+RICA	[redacted]	[redacted]	2.4

In addition to the NPV benefits, RICA also delivers other non-monetised benefits relative to the counterfactual option, including enhanced visual amenity, less environmental disruption, and lower customer and community impact.

3.2.3. *Selecting the preferred option*

We have selected the RICA option due to its clear NPV advantage as well as additional stakeholder benefits. It also reflects a ‘least regrets’ option, as not implementing RICA would likely lead to more expensive capacity improvements costing hundreds of millions of pounds, while the worst regret of the RICA option is the £9.1m cost of the NIC project.

3.3 Putting it all together - commercial, financial and management considerations

The following subsections describe why this NIC project uses the right procurement strategy for RICA (the commercial case), why this project is affordable from a costs perspective (the financial case), and why it is delivered with the appropriate governance and delivery mechanisms (the management case). Further detail can be found throughout this submission document as referenced below.

3.3.1. *Making the commercial case - choosing the right procurement strategy*

NGET is in a strong position to bring RICA to BAU given our experience and leadership in GB over earlier stage ICA projects, described in Appendix VII. We have the technical expertise to provide suitable oversight of the planned R&D, as well as world class testing facilities at Deeside and Eakring to meet technology development and demonstration objectives. We will continue to collaborate with other licensees to fulfil our vision of a GB-wide RICA rollout.

Our intent is to follow an innovation partnership approach to delivery, detailed in Section 6.1.8 that provides the optimum level of collaboration between NGET and a supplier on this complex project, while ensuring a competitive method for reducing project costs and incentivising investment from the market. This is a successful model, validated though previous large innovation projects and has the support of suppliers as indicated in Appendix IV. The engagement we have done shows there is sufficient supplier capability to deliver RICA.

The project plan includes time to perform a clear and transparent process to identify a suitable supplier for the design, manufacture, and installation of the equipment. The procurement methods used will follow the EU Public Procurement Directive and the Public Contracts Regulations. This will enable the best supplier in terms of cost and technical capability to be identified, ensuring that the consumer obtains value for money during the NIC project’s delivery.

3.3.2. *Making the financial case - why is this project fundable*

This project reflects genuine innovation in developing the maturity of a technology, as explained in Section 4.3. Therefore, innovation funding is the appropriate mechanism to de-risk its delivery. Furthermore, the size and complexity of this project also means it is more appropriate for NIC funding rather than NIA funding and requires investment to deliver and accelerate the technology’s progress. The work completed during previous NIA projects referenced in Appendix VII is further evidence that now is the right time for NIC funding to bring RICA to BAU. Overall, we believe that RICA not being available constitutes a market deficiency; making it available would deliver consumer benefits. However, the current immaturity of RICA poses unpalatable risk to transmission licensees. The use of innovation funding is required to correct this market deficiency, maximise societal value, and accelerate our nation’s low carbon future.

3.3.3. *Making the management case - defining robust project governance and efficient delivery*

We have structured the project to ensure maximum efficiency of delivery while managing potential risks. We have used tried and tested governance arrangements used on the Deeside project, as well as successful methods and processes used on previous RICA innovation projects. Section 6 describes the management arrangements for this project, including our approach to risk management. These governance and management processes also include a wide range of stakeholders in decisions and delivery of the project.

Section 4: Benefits, timelines, and partners

4.1 (a) Accelerates the development of a low carbon energy sector and/or delivers environmental benefits whilst having the potential to deliver net financial benefits to future and/or existing Customers

4.1.1. *Accelerates the development of a low carbon energy sector*

In the problem statement, we described that additional transmission system constraints will arise due to the net zero transition, as more renewable generation is installed to meet an increase in demand in densely populated areas. For example, the ESO 2019 Electricity Ten Year Statement (ETYS) shows that as wind power in Scotland grows, the flows across all boundaries north of the Midlands (England) are set to double to meet demand arising in the Midlands (England) and in the London area.

As recognised in the ESO 2019-20 Network Options Assessment (NOA), thermal constraints are the most common constraints, which can be alleviated with the following actions: *1. Upgrade existing circuits through conductor replacement or increased operating voltage, 2. Develop new circuits, 3. Build new substations, usually to optimise the flows on a pair of OHL circuits, 4. Control power flow with compensating technologies.*

RICAs reduce the cost and therefore remove some of the financial risks associated with longer-term network reinforcement – meaning significant reinforcement becomes a 'least regrets' option. This accelerates the connection of low-cost, low-carbon generation.

This project addresses several aspects of the net zero transition involved with facilitating the connection of low carbon generation through capacity increases and facilitating the demand increase for heating and transport in the regions that need it most.

The project also opens the door for future operation beyond 400kV, exploring the use of RICA solutions to carry higher voltage lines on existing 400kV towers.

Furthermore, operating at higher voltages also contributes a small but important reduction to active power losses, and to associated monetary and carbon costs. There will be a reduced need for new steelwork and concrete bases compared with new build (and possibly traditionally reinforced OHL towers), helping to deliver investments with a low cost of carbon.

Crucially to the low-carbon transition, there is the possibility of accelerating project timescales from need identification to implementation compared with current reinforcement options. We anticipate that the reduced complexity around mechanical upgrades (as an uprating alternative) and reduced planning consents (as a new build alternative) could save significant time during the scheme's delivery. We expect a line uprating project with RICA to be at least two years faster than a new build 400kV OHL.

4.1.2. *Financial Benefits*

Details of how the financial benefits for RICA are calculated are found in Appendix VI.5. Where possible we have used monetised benefits for both avoided constraint costs and avoided emissions as described in VI.5.2. The net present value of RICA is presented alongside the baseline option in Figure 7. It can be seen that the roll out will break even by 2035, and move past the BAU option by 2032. The RICA option has a higher NPC because investment can be made sooner. However, this also results in significantly higher present value benefits and resulting NPV.

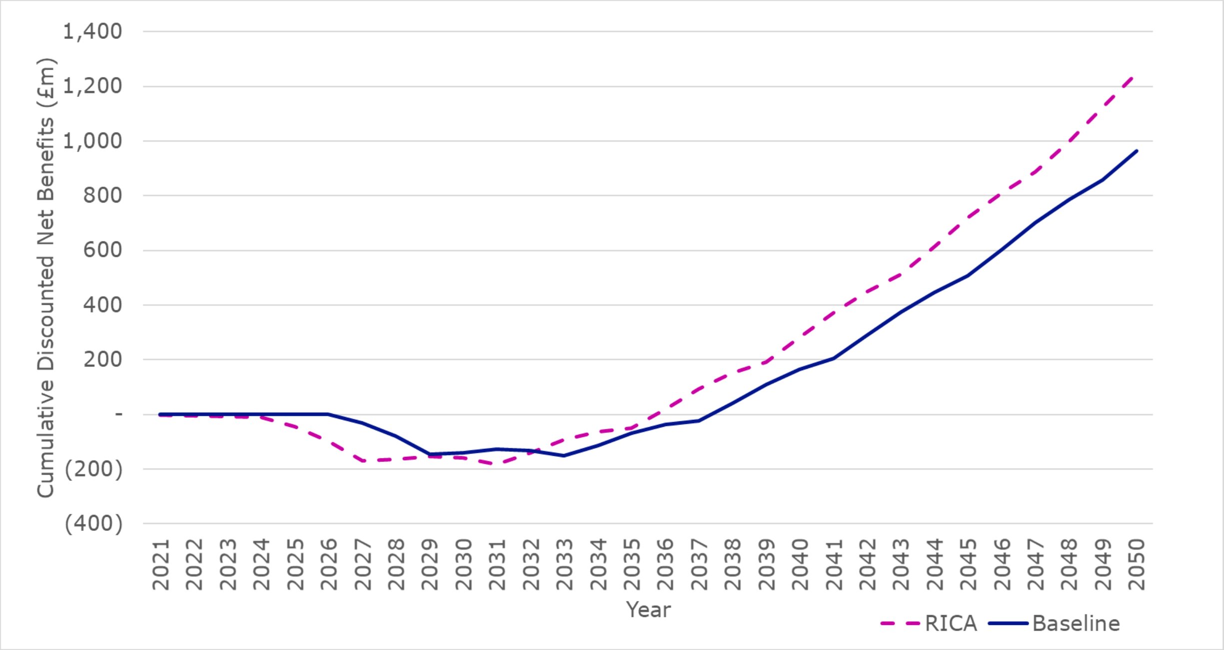

Figure 7 – Cumulative Discounted Net Benefits - Comparison Between Options

We have followed a single scenario of network development for our core RICA and Baseline options - the Future Energy Scenarios (FES) 2019 Two Degrees scenario - reflecting a high level of decarbonisation and transmission connection generation including offshore wind.

4.1.3. *Environmental Benefits*

The project provides a range of environmental benefits: improved visual amenity of transmission infrastructure relative to new build 400kV OHL, and lower emissions through reduced losses and decreased manufacturing embedded emissions.
A joint TO Willingness To Pay (WTP) study commissioned by NGET, SSEN and SPEN delivered in 2019[7] indicates that consumer preferences match well with the environmental benefits of RICA. Specifically, non-domestic consumer WTP for improving visual amenity of Transmission OHL is nearly 1% of the consumer bill - comparable to the amount for investing in infrastructure before a definite need to enable EV charging (0.90%) and connection of renewable generation (1.08%) - two other preferences that RICA will support. Domestic consumer preferences mirror this trend - additional visual impact work on OHL in National Parks and AONB merit a >£4 WTP (per household per year), along with c.£12 for investing to connect renewable generation and nearly £10 to enable EV adoption. Even allowing for the fact that willingness to pay studies often over-estimate consumer benefit for networks' actions, this means that delivering lower tower heights for uprated lines with RICA is a clear benefit to consumers, and one for which they are willing to pay.

We know from previous engagement, including as part of major projects consenting, that consumers in local communities are not supportive of the replacement of existing lines with larger towers, mainly from a visual amenity perspective. They are also negatively impacted by the disruption of construction works for as long as there is a

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[7] https://www.nationalgrid.com/uk/electricity-transmission/document/132056/download

presence on site. We see this project as an opportunity to deliver an Innovation that directly addresses concerns raised by stakeholders.

When assessing the environment impact of a technology on a location, we consider a range of impacts including effects on local archaeology, water, air quality, noise and vibration, and soils/geology. Uprating existing lines using RICA will result in reduced impacts of all of these parameters compared with a new OHL. For instance, using an existing route will have a reduced impact on soils, sites of archaeological significance and water resources relative to a new build line that requires excavation for new foundations. Additionally, shorter construction timescales will reduce the duration of changes to air quality and noise/vibration. During operation, existing lines uprated with RICA will have similar effects to a conventional new build OHL line for many of these parameters and therefore results in a net positive environmental impact.

To estimate the impact of RICA on carbon emissions we have conducted a losses study, which quantifies the emissions saved when compared to a new build OHL (the counterfactual). The benefits from RICA compared to a new build OHL from avoided losses alone are shown in Figure 8. This shows that RICA will enable significant emissions to be avoided. The benefits will only be decreased by an overall decarbonisation of the power sector (due to the predicted drop-off in generation carbon intensity towards 2050).

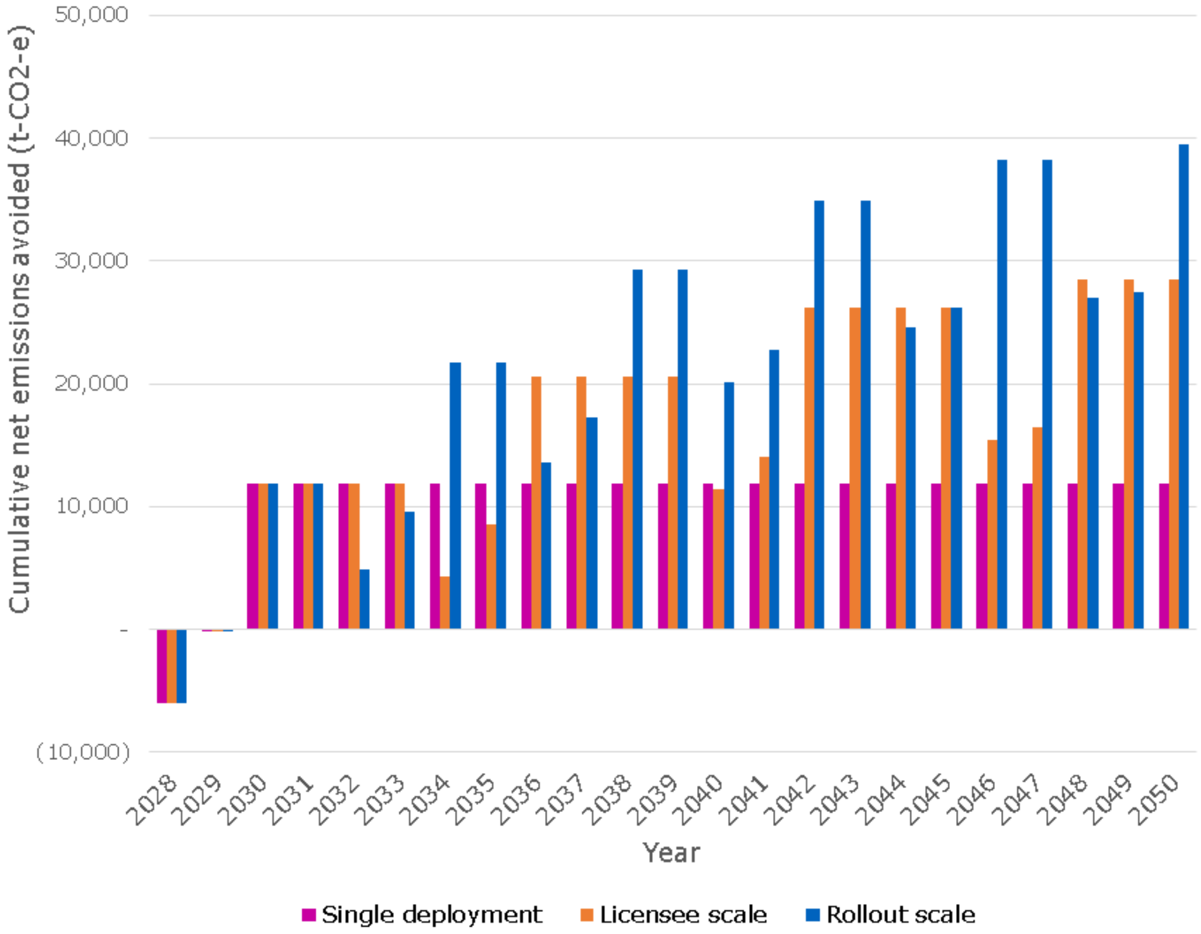

Figure 8 – AvoidedCO2 emissions delivered by RICA above the counterfactual

For this simplified analysis, we have conservatively assumed that RICA has the same capital emissions as a new OHL build, but these emissions are incurred earlier for RICA.

Details are provided in Appendix VI.5.1. However, this is a conservative approach as we believe that RICA will also deliver significant additional capital carbon savings. The carbon benefits table in Appendix I show RICA makes a significant contribution to reducing net carbon emissions even for a single route.

4.2 (b) Provides value for money to electricity distribution/transmission Customers

The use of RICAs will support the UK government's legislated net-zero carbon 2050 target while helping to maintain security of supply through increasing capacity of critical 275kV networks at minimum cost and disruption to customer and consumers. The direct impact of the project is realised in the short to medium term following the project, as the implementation of RICAs on a live operational route will realise improved flows over key transmission boundaries.

The right investment decision in any instance will require ongoing collaboration with ESO as the energy system evolves. However, even with conservative assumptions our NPV analysis shows that RICA is a very good investment option – delivering £286m of cumulative discounted net benefit.

In the longer term, this project will unlock further value as the RICA solution is rolled out across GB. We estimate that RICA could be used to increase capacity on 30% of the 275kV network. Further benefits from targeted interventions are more broadly applicable, and demonstration of the technology at 275kV would significantly de-risk use of RICAs on 400kV routes for UHV applications.

RICA would also allow network reconfiguration to occur more easily and without the need for entirely new routes to be built. This will allow existing assets used to feed demand centres to be better utilised to reconfigure the network; leveraging the existing asset base to deliver better overall transmission capacity. The ability to reconfigure the network more easily also opens the door to considering UHV networks for critical UK boundaries, establishing a pathway for large long-term benefits to consumers.

In addition to the direct positive impacts to decarbonisation and security of supply, additional value will be through: a lower visual impact, easier project consents and faster delivery of network projects; particularly for 275kV circuits which surround major demand centres (e.g. Midlands and the London area).

Lower capacity uplift costs will be realised due to these shorter duration projects with less onerous planning activities and reduction of the need for high capital cost, larger towers. Furthermore, there will be reduced system constraint costs due to curtailment of renewable generation and disconnection of demand during system events.

4.2.1. *Cost Breakdown*

Table 6: RICA Cost Summary provides a cost summary for project RICA. Internal labour costs have been estimated and reviewed internally to ensure minimum requirements for successful delivery. The project plan has been broken down by task, then a RACI (responsible, accountable, consulted, informed) was applied to each task to establish which teams need to be involved. This RACI has then guided a FTE estimate for each task.

The costs for the contractors have been estimated based on previous experience from the development of ICAs and ROM estimates from suppliers. The final costs for the suppliers will be determined through our competitive process. The same process has been followed for equipment budgets and disposal costs.

Legal fees have been estimated from previous innovation project costs and experience when patenting new technology. Travel costs have been estimated based on the activities outlined in the project plan. The stakeholder costs (referred to as Stage 4 in Table 6) have been estimated based on the dissemination plan outlined in Section 5.

Table 6: RICA Cost Summary in 20/21 Prices

[redacted]

4.3 (d) Is innovative (i.e. not business as usual) and has an unproven business case where the innovation risk warrants a limited Development or Demonstration Project to demonstrate its effectiveness

Outstanding technological and operational risks currently prevent adoption of RICA by Transmission licensees and suppliers. These risks persist because the end-to-end RICA solution is untested for full-scale implementation on a GB network. NIC funding is the appropriate mechanism to provide this innovation and deliver RICA as a crucial new investment option.

Innovation funding is required to mitigate risks from RICA to network reliability, personnel safety and stakeholder buy-in to bring RICA to BAU. A summary of risks is provided in Table 7, with reference to risk numbers in the project Risk Register (Appendix III) for more information.

Table 7: Project innovation to mitigate RICA risks

Risk	Innovation solutions	Risk #
The novelty of the RICA technology results in installation, maintenance and disposal challenges, reducing network reliability or affecting personnel safety	• Cutting edge design and manufacture of RICA to meet safety and reliability principles. • Development of new processes tailored to the RICA lifecycle. • Robust, de-risked testing of these processes at NGET facilities.	5, 8, 11, 16, 21

The technical characteristics of RICA are not understood, reducing network reliability or affecting personnel safety	• Apply latest modelling and testing techniques to establish RICA technical performance under operational conditions.	7, 15, 17
Stakeholders do not buy-in to RICA - preventing its successful implementation	• Community and stakeholder engagement plan designed for early and regular community group engagement and consultation.	3

These risks prevent NGET's and other Transmission Licensees' shareholders from speculatively funding RICA. Additionally, the uncertainty posed by these unresolved risks prevents suppliers from offering RICA. Based on our engagement with the market to date (detailed in the letters of support provided in Appendix IV) all suppliers have identified key technology gaps which prevent this application and require investment to overcome. The innovation partnership approach to working with a supplier enabled by this NIC project will address these gaps. Additionally, the project will develop innovative solutions to design, manufacture and install RICA that both address these risks and produce a low cost, rapid deployment method for delivering new network capacity.

While previous projects have provided the proof of concept for ICA implementation on an existing tower, no work previously has developed the design, manufacture, installation and disposal processes to a BAU level for GB 275kV only tower types. This is what is required for a true retrofit solution to meet GB network needs. Previous projects outlined in Appendix VII have examined the theoretical viability of 275kV to 400kV uprating using ICA and shown that ICA performance is reasonable when retrofitting to an existing tower. However, this previous work has not addressed the fundamental risks of RICA - the reliability, whole life value, and safety concerns due to the novel combination with NGET's L3, L34 and L66 tower types.

To support understanding of what needs to be done to deliver the innovative solutions, we have reviewed close-down reports for previous projects to identify outstanding issues that prevent RICA from being introduced:

- Further development work is required to deploy ICAs in retrofit applications, particularly whilst accommodating bundled conductors.
- A full assessment and design assurance is required for various mechanical/structural load conditions on tower types, as yet unconsidered.
- The appropriate methods of lightning shielding of the existing towers have not been assessed.
- The planning considerations associated with RICAs have not been explored, specifically with the voltage upgrade from 275kV to 400kV on existing routes.

The project will fill these gaps to allow NGET to deploy RICAs as BAU in its networks (as discussed in Section 2, along with other technology gaps not identified in these reports). NIC funding will accelerate the adoption of RICAs, leveraging the historic investments made in this area, to deliver an enabling technology for Zero 2050.

4.4 (e) Involvement of other partners and external funding

Our partnering strategy is based on two key requirements:

1. Identifying suitable suppliers from the market to deliver the technical outputs of the project at a reasonable cost to consumers
2. Ensuing we involve key stakeholders in the technology's development to increase the chances of success

These two requirements have led to two types of project supporters being identified, Suppliers and Stakeholders.

4.4.1. *Suppliers*

Suppliers will provide the delivery mechanism for the design, development and testing of the physical assets and the operational practices to be developed during this project. The suppliers involved in the project will be required to develop a solution to the point where it can be deployed in the network.

This requires two key capabilities from the suppliers. First, the ability to design and manufacture the range of assets required. Second, the ability to install the equipment in line with National Grid safety and operational requirements.

Given that several suppliers have demonstrated willingness to support the project, a competitive process is the best way to identify the supplier(s) who can deliver the best value for money to consumers. Identifying a project partner outside of transparent procurement process isn't seen as the best way to deliver value during the project.

The project plan includes time to perform a clear and transparent competitive event to identify a suitable supplier for the design, manufacture, and installation of the equipment. The procurement methods we will use will follow the Utilities Contract Regulations (2016). This will enable the best supplier in terms of cost and technical capability to be identified, ensuring that the consumer obtains value for money during the NIC project's delivery.

Given the opportunity this presents to the suppliers for a future lead in the marketplace, and the low risk route that the NIC offers them for the development of this stakeholder driven innovation, the suppliers must also be willing to contribute to the project. Our procurement process will ensure that consumers obtain protection from risk, and reward those suppliers who contribute funds to the project.

This could take several forms:

1. Developing an innovation partnership with the suppliers[8]
2. Asking suppliers to identify their contribution to the project during the procurement phase
3. Establishing contract terms which outline how costs from risk are shared

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[8] This mechanism is outlined in "*Public Procurement – The Utilities Contracts Regulations 2016*" – Section 49 page 35

Furthermore, NGET will ensure that a revenue sharing agreement is in place with the supplier to ensure that should the technology be used outside the UK, consumers are rewarded for their investment[9].

NGET has begun to engage the market regarding RICA, and have contacted insulator manufacturers, as well as EPC (Engineering, Procurement, Construction) contractors. Each company who has been receptive to the project has been invited to provide a letter of support for the project which can be found in Appendix IV. These letters also highlight the risks seen by the market place.

We also believe that our process for identifying the right supplier, will also help to accelerate the rollout of the technology, leading to benefits being realised sooner; accelerating the project's low carbon benefits.

4.4.2. *Stakeholder Supporters*

Stakeholder input is essential to ensure that the benefits from this project are rolled out across the network; developing further value to consumers. As there have been several NIA projects during T1 on ICAs, as well as projects seeking to develop new tower structure, there are clear opportunities to adopt lessons learnt and leverage the investments made by consumers to date.

The previous work on ICAs has also been heavily driven by UK academia, supported by utilities, and they have contributed to the technical advances which have taken us to the point where project RICA can now complete the process and deliver the beneficial outcomes for consumers.

To ensure that the project can leverage existing knowledge and disseminate new knowledge effectively, the project will be advised by a Technical Advisory Board (TAB) which will be made of members from:

1. ESO
2. SPEN
3. SSE
4. Cardiff University
5. University of Manchester

Other UK utilities have also been invited to attend all TAB meetings and help to govern the project.

Collaboration with the ESO will be important to understanding the cost benefit analysis , and how project learning impacts the assessments of options to uprate OHLs, particularly from 275kV to 400kV. This will ensure the learning delivered from the project is maximised such that all GB licensees will benefit - increasing the chance of success and accelerating the project's progression and implementation. The ESO fully support the project and have provided named individuals who will contribute to the project via the TAB.

As the majority of the Scottish transmission network is operated at 275kV, SPEN and SSE have provided support for the project and given named individuals who will support the project through the TAB.

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[9] As per "*Electricity NIC Governance Document V3.0*" Section 10

Furthermore, the TAB will report to other governance committees to ensure that we are sharing best practice and regular updates with relevant stakeholders. Our approach for report to other committees is outlined in Section 5.2.4.

4.5 (f) Relevance and timing

The recently legislated net zero target has driven a step change in the potential need for future onshore network reinforcement. This new paradigm makes faster methods to achieve network infrastructure capacity increases, such as RICA, highly relevant. The high quantities of renewable generation connecting will only grow in the next few decades, making now the appropriate time to provide Transmission Licensees all the tools they may require to help connect these low carbon sources.

This timing of this project also coincides with a convenient stage in the technology maturity process. Three NIA projects have demonstrated the technology concept and taken it as far as a short duration, specific objective project can achieve. It is now a suitable time for a NIC funded project to mature this technology to an appropriate level to unlock wider benefits. This project will build upon previous research and development, taking the RICA technology to the point where it can be applied to an entire existing route (and therefore achieve the sought-after benefits).

We have extensively reviewed previous UK transmission projects that have developed the technology and we believe now is the time to bring RICA to BAU. Previous projects include (detail in Appendix VII):

- Insulated Cross Arms – Lecht & St Fergus Trials (NIA_SHET_0006),
- Insulated Cross Arms – 132kV Trials (NIA_SHET_0007) and
- Composite Cross Arms Study (NIA_NGET0024).

It is also pertinent to be aware of SSE’s NIC project New Suite of Transmission Structures (NeSTS) for the wider benefits case, although this project focuses on new build solutions as opposed to retrofit. Our engagement with other Transmission Licensees demonstrates that this provides a complementary investment option to the new build transmission structures.

If successful, this NIC project will align well with the objectives of our RIIO-2 business plan as outlined in Section 3. As RIIO-2 draft determinations have now been published, we do not expect to update our RIIO-2 business plan specifically for RICA. However, we would include RICA options as part of our RIIO-3 business plans, assuming this project achieves the desired outcomes.

Section 5: Knowledge dissemination

We do not anticipate needing to deviate from the default IPR position.

The following subsections define the incremental learning expected to be provided by the project, how it is applicable to the efficient operation of the transmission system, and how it will be disseminated to other Network Licensees and wider stakeholders.

5.1 Learning generated

The learning generated from the project will take the following forms:

1. Technical designs of cross arms and supporting equipment which deliver whole life value
2. Installation guides and maintenance practices
3. Functional specifications and technical documentation for composite cross arms
4. Guidance for building the investment case and scheme delivery plan

The following subsections provides further detail on the knowledge gaps that will be filled by the learning generated during this project.

5.1.1. *Technical designs for whole life value*

There are several key considerations for the design of the cross arms:

1. The electrical and mechanical designs for different tower types
2. Ensuring that the towers can still be accessed, and the cross arms can be installed and maintained safely and without the need for changes to access
3. The necessary protection and operation and maintenance to retain the reliability of the circuit
4. Lifecycle analysis, including RICA carbon footprint

The design portfolio will provide an advanced starting point for other Network Licensees, and will reduce the technical development risks and barriers to use of RICAs in their own networks. Much of the whole-life design will be applicable to use of RICAs on different voltage levels, e.g. in 132kV in both transmission and distribution networks, and also greatly enabling further innovations to facilitate Ultra High Voltage (UHV) investments.

5.1.2. *Installation, maintenance and decommissioning guidance*

We will develop operational guidance to support operation of RICAs over the asset’s lifecycle. This includes supporting equipment for replacing RICA, without the need for additional investment in site access infrastructure. Rescue procedures and equipment will also be developed such that operational staff can be safely recovered in the event that an injury occurs.

We will develop the recommended Examination, Maintenance, Inspection and Testing (EMIT) processes that must be applied to RICAs to ensure circuit reliability remains as designed (as above). Decommissioning guidance will include how to recycle the RICAs at the end of their life.

These solutions will enable efficient operation of the transmission system and allow other Network Licensees to minimise whole of life costs for the RICA rollout while mitigating stakeholder impacts and safety risks to personnel.

5.1.3. *Functional specifications and technical documentation*

The learnings from above design and process development will be embedded in functional specifications, technical guidance documents, and technical reports – providing a clear guidance for the "What to do", "How to do it" and "Why it should be done this way".

These three critical document types will provide a basis for all future RICA projects and further developments across the industry.

5.1.4. *Investment guidance*

Project RICA will build a clear investment case to compete against the counterfactual options. This will generate two types of knowledge:

1. Specific information on how to perform investment calculations
2. Know-how to understand the specific scope of the RICA investment

The former may contain commercially sensitive information, but it is still essential to disseminate any general information on this topic to reduce barriers to investing in the new uprating methods as BAU.

Specific know-how regarding the scopes of work (hence providing an indication of cost/scale) and sequencing of the investment will also be integrated into this guidance documentation. This should help to provide confidence for those individuals who are asked to review RICA for future investment scenarios.

This guidance will include information on the options for minimising the CO_2 impact of the investment, and the experience gained from project RICA. The project costs and timescales for RICA will also be established through this project. This know-how can help all licensees consider a broader range of more sustainable solutions. Again, this is applicable to different voltage levels, so also relevant to DNOs, and in enabling further innovations that may seek to facilitate UHV investments. This will also be useful to ESO, who may wish to feed this back into the NOA process as an alternative investment option.

5.2 Learning dissemination

Sharing the learnings and making time for stakeholders to enable effective dissemination will be key for project RICA and the enduring success of the technology. The materials discussed in Section 5.1 are likely to be useful for technical users of the technology, but further activities will be required to gather feedback and opinions of a wider range of stakeholders. To deliver on this, we have developed a communications and stakeholder engagement plan, based on the following requirements:

1. To disseminate the project's learnings to all stakeholders
2. To provide further support for the RICA investment case from other utilities
3. To enable stakeholders to input into design and technology choices (this includes gathering requirements from customers as well as functional requirements from other network operators)
4. To develop internal and external stakeholder confidence with the technology (this includes customer confidence in the societal value of RICAs)
5. To accelerate and ease the adoption of the technology

5.2.1. *Stakeholder mapping*

The stakeholder map in Figure 9 shows a qualitative assessment of the knowledge and interest that key stakeholders have in project RICA, what their main priority is in relation to RICA, and where we want our stakeholder and communications plan to take these stakeholders over the project.

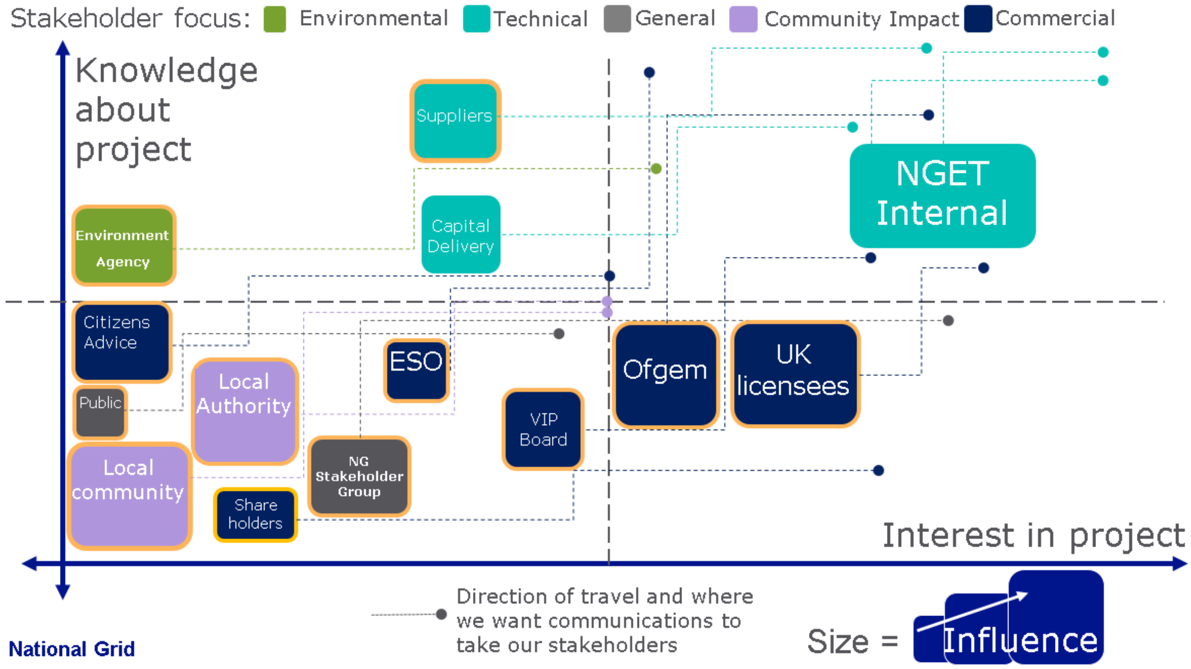


Figure 9 – Project RICA stakeholder map – Colours shows stakeholder's main area of interest

The general trend for most stakeholders is to increase their knowledge and interest in the technology over the project's delivery. Given the range of stakeholder interests, our communication strategy is tailored to meet the different focus areas for our stakeholders.

5.2.2. *Learning Dissemination materials and activities*

There are many different communication and engagement streams that we propose to use during the project to meet all stakeholder groups; each of our communication methods will help different individual stakeholders on their journey as outlined in Appendix X. These activities will be managed by a dedicated member of the NGET project team.

The materials generated will be posted publicly and made available for further use. It is envisaged that these materials will help consenting and community outreach activities during the delivery of RICA through the chosen scheme, as well as providing support for all further RICA projects in the future.

Materials on their own are not sufficient for dissemination, and a series of events will be held which will focus on different RICA stakeholders. The materials will help to provide all stakeholders with the right information, around which a collaborative and constructive conversation can be held.

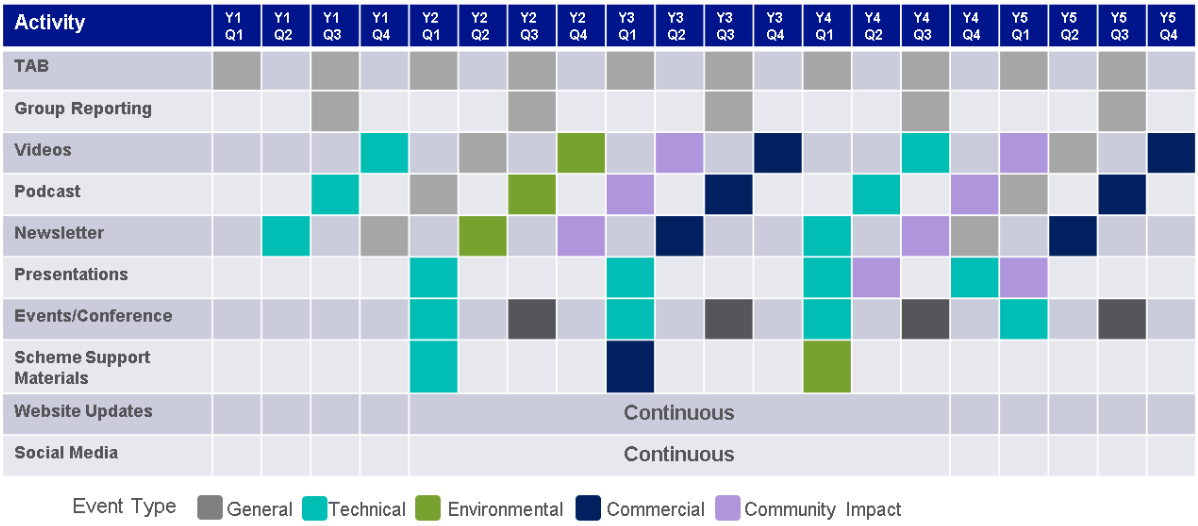
To ensure that designs, guidance and functional specifications outlined in Section 5.1 can be easily adopted by any UK network licensees – copies of these will be provided to support collaborative discussion while the NIC project endures. Being transparent in this way will enable further advancements to be made to the marketplace, building upon the corner stone laid down by project RICA.

5.2.3. *Stakeholder engagement strategy and plan*

We will maximise value from our stakeholder engagement strategy by:

1. Taking forward learning from the RIIO-2 Business Plan and engagement
2. Using AA1000 principles (Plan do check act) and the framework outlined in our RIIO-2 business plan
3. Leveraging existing websites and communication channels
4. Reporting to stakeholder groups across the industry
5. Aligning activities to maximise stakeholder value
6. Actively working with stakeholders to adopt learning

An overview of the proposed engagement and communications plan is shown in Figure 10. This plan will target different stakeholder focus areas through different engagement streams to help deliver the required outcomes which will support the success of the project.



Activity	Y1 Q1	Y1 Q2	Y1 Q3	Y1 Q4	Y2 Q1	Y2 Q2	Y2 Q3	Y2 Q4	Y3 Q1	Y3 Q2	Y3 Q3	Y3 Q4	Y4 Q1	Y4 Q2	Y4 Q3	Y4 Q4	Y5 Q1	Y5 Q2	Y5 Q3	Y5 Q4
TAB	▨		▨		▨		▨		▨		▨		▨		▨		▨		▨	
Group Reporting			▨				▨				▨				▨				▨	
Videos				🟦		▨		🟩		🟪		⬛			🟦		🟪	▨		⬛
Podcast			🟦		▨		🟩		🟪		⬛			🟦		🟪	▨		⬛	
Newsletter		🟦		▨		🟩		🟪		⬛			🟦		🟪	▨		⬛		
Presentations					🟦				🟦				🟦	🟪		🟦	🟪			
Events/Conference					🟦		▨		🟦		▨		🟦		▨		🟦		▨	
Scheme Support Materials					🟦				⬛				🟩							
Website Updates					Continuous															
Social Media					Continuous															

Event Type ▨ General 🟦 Technical 🟩 Environmental ⬛ Commercial 🟪 Community Impact

Figure 10 – Overview of our communication and stakeholder plan

5.2.4. *Project reporting*

To enable cross network collaboration, the RICA Technical Advisory Board (TAB) will be established, as shown in Figure 11. This will help to embed RICA as a concept throughout the UK value chain and help to foster future collaboration. The TAB will also have key oversight responsibilities as set out in Section 6.

To ensure the project is technically sound and open to challenge, UK universities will also be a part of the TAB. This will enable technical questions to be openly and honestly challenged.

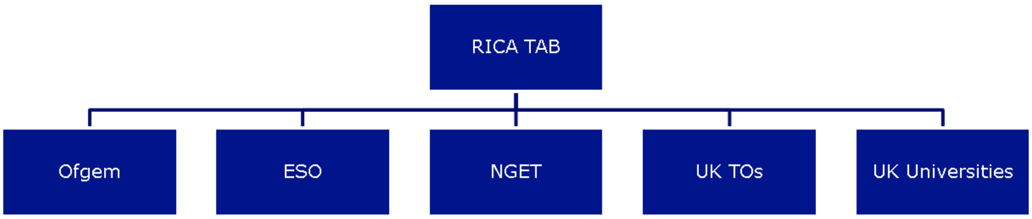


Figure 11 – Proposed RICA Technical Advisory Board (TAB).

Ofgem will also be invited to attend these meetings and provide guidance as they wish, and kept abreast of the project's development as well as of the regular innovation reporting methods.

RICAs will deliver values in different ways to different stakeholders: through load related investments, visual impact investment, accelerating the adoption of renewables, reducing community impact and reducing impact on customers (generators).

Given the range of possible applications and value cases where RICAs could be used, effective communications and reporting will be essential to make RICAs a common occurrence in the future. The TAB will increase the chance of project success by reporting into key stakeholder groups throughout the project's development as shown in Figure 12.

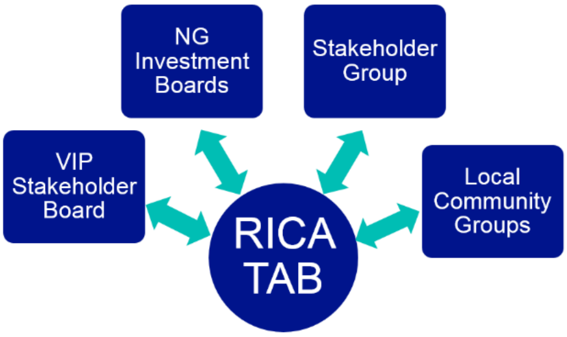


Figure 12 – Overview of the other committees and groups that RICA will send updates to on progress and actively seek input from

5.3 Intellectual Property Rights (IPR)

We do not anticipate needing to deviate from the default IPR position. However, should we find that through our procurement process with suppliers there are specific instances or elements where we need to deviate from the standard IPR position, we will consult with Ofgem directly to understand if this is acceptable.

The intellectual property generated from the project is seen to fall into the following three key categories: Manufacturer-specific RICA designs and test results; Functional specification, guidance documentation, and technical reports; Know-how.

The IPR terms will be agreed with the suppliers through our competitive procurement process and clearly outline how a supplier may use the foreground IP that they generate.

Given that this project will produce a tested design and methodology for installing RICAs into the network, it is likely that these designs could be leveraged across the globe. Our intent is to ensure that consumers obtain a return for their investment into this IP, through a royalty – under the terms outlined in the NIC governance.

The first version of the functional specifications, guidance documents and technical reports will be made freely available to UK network licensees, and be commercially available to other utilities through our IHS system; Subsequent revisions and updates will also be made available through this mechanism.

General know-how will be shared with utilities and stakeholders through our dissemination plan outlined in Section 5.2. All IP produced by the project will be actively recorded during the project's delivery.

Section 6: Project readiness

6.1 Evidence of why the Project can start in a timely manner

Project RICA is able to start in a timely manner, as the project has:

- High levels of project support across all levels of NGET
- A well-developed project structure and team, with identified key roles and responsibilities, and has communicated this information to the business
- A robust methodology and a detailed project plan to achieve it, which has been subject to appropriate challenge
- Experience from previous ICA projects and relevant links to industry and academia

Details are provided in the subsequent sub-sections.

6.1.1. *Project support*

An important objective of the project is to run alongside a real route uprating scheme, identified under NOA, such that the project transitions seamlessly into BAU implementation of the RICA technology – strong support from within the business is essential to meet this objective. To this end, the bid team has undertaken a considerable amount of engagement in defining this project and in FSP preparation.

[redacted]

NGET Executive are fully engaged with the RICA project, having been involved from project inception and throughout the bid process. The board fully supports the project aims and objectives, and NGET's contribution.

We have made a good start with market engagement, and have received letters of support for the project and technology from receptive parties (see Appendix IV).

6.1.2. *Project structure and team*

Careful consideration has been given to the make-up of the project team to ensure we have sufficient resources and the right capabilities within the team to ensure successful delivery. An overview of the proposed NGET RICA team is given in Figure 13 below, and key roles are in the process of being filled. As far as possible, key personnel of the NIC bid team will transfer into the project delivery phases, helping to maintain continuity and momentum, and to mitigate the risk of losing project knowledge and relationships that have been built with project partners gained through the bid process.

Responsibilities and accountabilities have been defined in detail for the project team members using a RACI matrix – this section provides a quick overview of how the team each contributes to meeting key project objectives.

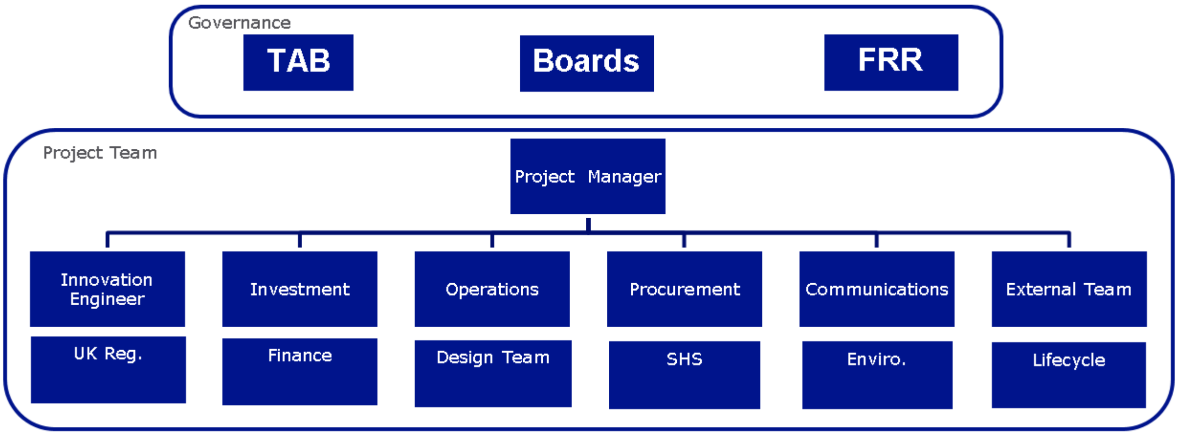


Figure 13 – RICA Core Project Team – including internal and external members. FRR is explained in Section 6.4.

As shown in the figure, some members of the team are expected to be required full-time, or close to full-time, for the majority of the project. This will include:

- The **Project Manager** will have overall responsibility for the delivery of RICA. This includes the management of the external suppliers, leading the rest of the team and reporting to the Technical Advisory Board and governance boards.
- **Operations** support will be required to help develop the required maintenance procedures, perform trials within NGET's existing training centre, and update documentation to ensure that key learning is embedded into the business.
- **Lifecycle Engineer** support will be required to establish the first versions of the RICA specifications enabling the suppliers to establish a testing plan for their technology with confidence. Further life cycle support will be required to review technical outcomes during the project and adopt the lessons learnt into our functional specifications and technical reports.
- The **Investment Engineer** will work to develop a credible investment plan for RICA on a suitable scheme and will lead the iterative updates to this plan as the project uncovers key learnings. For any chosen scheme, a base-case investment option will also be developed in parallel (paid for by BAU) as RICAs are not proven. The investment engineer will be responsible for keeping closest links with the scheme delivery team.
- **Innovation Engineer** will be the technical point of contact on the project and support through all aspects of design, development and trial. They will undertake much of the standards and specification development, and support the Project Manager in active sharing of knowledge, progress and lessons learnt.

Part time members of the team will include the following:

- **Procurement** resource will be required to help run procurement events at two key points in the project. During Stage 1 and early Stage 2a, the procurement team will lead the development and delivery of a competitive event to identify a supplier to deliver the innovation. Further procurement support will be required during Stage 2b to ensure that the RICA investment is presented in a way that makes it comparable to the costs from the base-case investment. Otherwise, light-touch support from procurement will be required to aid with supplier management.
- **Finance support** will be required to track costs and importantly provide an ongoing challenge and review function for all costs associated with the project.

- **Communications support** will ensure that we are updating all stakeholders regularly through the appropriate media. This will include the production of specific report, social media updates, videos and podcasts.
- **Stakeholder support** will also be required to collate the input of stakeholders on this new type of technology. Given that this technology could enable works to be carried out under permitted development, engaging with stakeholders will be essential to ensuring that RICA does not cause any unintentional consequences.
- The **Circuit Design Team** will review the detailed clearances and loading calculations for the routes for which we intend to prove Investment Cases.
- The **Environmental Team** will review the impact design choices on e-fields, acoustic and other environmental factors that can impact local communities, and that would form part of any EA assessment during an investment.
- Safety, Heath and Sustainability (**SHS**) will review the ongoing impact of the investment, including the cost of carbon during construction.

The structure of the design team (currently under ‘external’) will be developed upon appointing a supplier; as the exact levels of development required will depend on the individual supplier.

6.1.3. *Methodology and Project plan*

We have developed a comprehensive project plan, with interdependencies between tasks and responsibilities identified. A high-level overview is shown in Figure 14. This plan will be subject to continual review and refinement as the project progresses, and once the supplier is on board to undertake the RICA design and development. However, it has already been subjected to rigorous challenge by subject matter experts to ensure the assumptions we have made around task length and effort levels are appropriate.

Through two risk workshops we have developed and refined a risk register (more details on this below) that has also been through subject matter experts for approval. To ensure our methodology is robust, we have ensured that the activities in the project plan are sufficient to mitigate the technical risks we have identified, and similarly, we have reviewed the project plan and ensured any risks associated with its delivery are appropriately captured and mitigated.

6.1.4. *Previous project experience*

NGET have previous experience in the development of insulated cross arms from our previous innovation project on composite cross arms (NIA_NGET0024). Section 4.3 above outlines the previous research and development that this project will build upon, but in summary, the technology has been developed to TRL6 for the L3 suspension towers, and this presents a good starting point for design and development for the cross arms to fit other tower types and configurations.

We have extensively reviewed all previous UK transmission projects that have developed the technology to date and have sought expert input from industry technology specialists on the extant technology issues to be resolved. This has helped to identify that the concept is technically sound and that our approach to development will produce a reliable and importantly a validated solution.

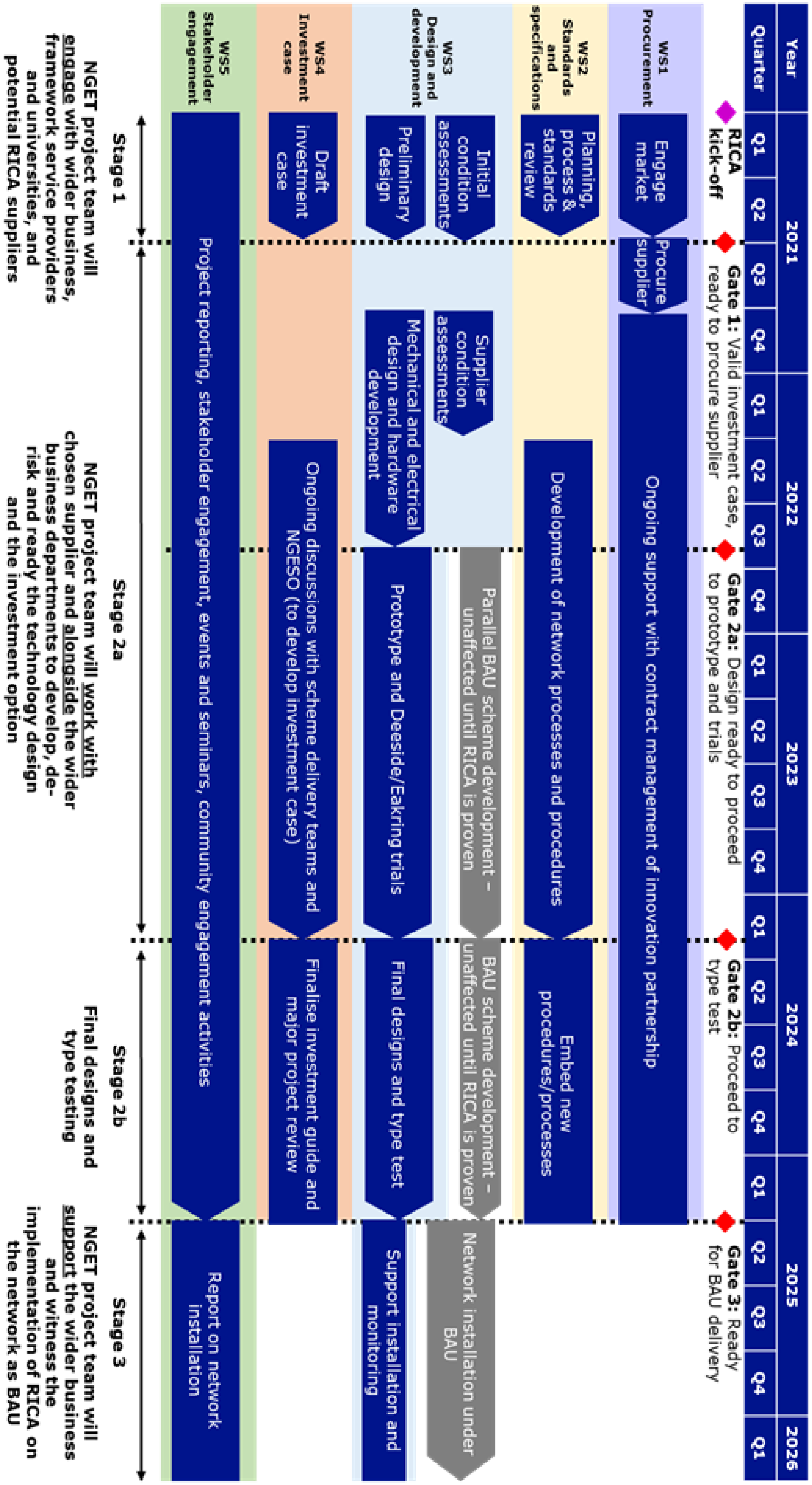


Figure 14 – RICA Project Plan overview

6.1.5. *Evidence of the measures that the Project will employ to minimise possible cost overruns and shortfalls in Direct Benefits*

We will ensure possible cost overruns are minimised by employing the following methods:

- Cost estimates and contingencies subject to scrutiny up front
- Robust governance processes
- Robust supply chain management and competitive procurement route
- Proactive risk identification and management

We have not quantified any 'Direct Benefits' in a financial sense, as the RICA technology cannot be implemented on our network until it is proven by the project. However, significant financial and environmental benefit is projected upon successful completion through future implementation (as set out in Section 4) and the above methods will also ensure that the project scope and timeliness remain under review to achieve this. The third phase of the project shall ensure that this focus is maintained.

Further details and evidence are provided in the sub-sections below.

6.1.6. *Cost estimates*

In the first instance, we have created an initial but detailed project costing breakdown using experience from previous ICA projects and other NGET technology development projects of similar length and complexity, including the previous NIA projects and the T-pylon project.

For the internal labour elements of this project we have used our fully absorbed costs. These rates have been developed under the International Financial Reporting Standards (IFRS), global standards and are benchmarked against present industry figures.

For the labour costs associated with site surveys we have used costs formulated by our specialised Construction Estimating Hub Team. These cost estimates have been ratified by our finance team, and we have sought external ROM (Rough Order of Magnitude) quotations to reduce uncertainty in the ICA production and delivery costs.

The cost estimates have been built with suitable but conservative contingencies where there are known areas of risk. This ensures, in the event of any risks being realised, that overspends do not occur and delivery of the project benefits is not affected.

6.1.7. *Governance process*

As well as providing learning dissemination, a key role of the Technical Advisory Board (TAB) (see Section 5.2.4) will be to provide project oversight. The TAB will comprise of representatives of the GB Network Operators, ESO, Ofgem, and academic representatives. Individuals will be asked to attend four meetings (or teleconferences) per annum.

Key TAB governance and oversight duties include:

- Provide strategic direction for the RICA project and its deliverables
- Challenge, review and approve/decline project proposals and associated deliverables
- Approve the continuation of the Project at key stage gates
- Approve any change in Project scope, direction or delivery
- Terminate a project
- Keep executive level stakeholders informed of the progress of the RICA method

- Help to resolve any risks that are escalated by the project manager or other governance
- Monitor the project risk spend and take action if necessary
- Ensure adequate resources are available
- Approve expenditure on any increases to project cost that is met by NGET or project partners

Project tolerances and key performance indicators will be confirmed at project initiation by the TAB, and agreed with Ofgem, to ensure that project progress and benefits are tracked effectively.

As mentioned above, a challenge and review process will be implemented with stage gates at pertinent stages of the project. These will determine whether to proceed to the next stage or activity, and if not, what remedial action is required (in the extreme, this would be a Material Change to the project or even suspension or the project, subject to Ofgem's agreement).

The project has developed the following key stage gates to ensure appropriate consideration is taken before undertaking key activities and releasing project funds:

- **Gate 1:** this gate occurs once the NGET investment case has been validated and accepted by the TAB, and suitable procurement documentation developed and agreed with procurement (see next section). After this point, a contract can be signed with a supplier for design and ongoing development of RICA.
- **Gate 2a:** this gate allows trials to proceed at Eakring and Deeside with the design at a sufficiently mature stage to influence this decision.
- **Gate 2b:** this reflects a decision following a major project review that commercial and technical risks have been suitably reduced by the trials. At this point, the only barrier to BAU implementation is to overcome the risks associated with passing the type testing required for network use. This gate allows type testing to proceed. This does not cover approval to deliver a real scheme using RICA.
- **Gate 3:** a decision is taken following type testing on whether or not the RICA method can be installed on an operational route, and if applicable will identify this route. (The cost of this implementation is of course, out of scope.) This gate allows reflection on whether RICA has achieved all that it set out to achieve.

6.1.8. *Management of suppliers*

Careful supply chain management will be key to ensure that strong financial controls are in place. Part of this is ensuring competitive quotes are received in the first instance; the procurement team use competitive processes and a series of framework arrangements to ensure value for money. The procurement team will help to ensure supplier performance is suitably managed, including adherence to our supplier Code of Conduct.

It is also key to ensure we select the most appropriate contracting method, and discussions are ongoing between the RICA team and procurement to identify this. The end goal is that our procurement approach should ensure we work in partnership with our suppliers and share project risk– this will, therefore, likely take the form of an Innovation Partnership.

The innovation partnership is an established procedure under the Public Procurement Directive and the Public Contracts Regulations 2015 *'where there is a need for the development of an innovative product or service or innovative works and the subsequent purchase of the resulting supplies, services or works cannot be met by solutions already* *available on the market.'* Its aim is to cover the development of an innovative product, service or works following by the subsequent purchase of the resulting supplies, services or works, provided that they correspond to the performance levels and maximum costs agreed between the contracting authority and the participants.

Due to the stage of design the RICA is in, it is appropriate to limit the partnership to just one supplier, as this will provide least project cost and shortest time to deliver.

The competitive phase will take place at the very beginning of the procedure only, when the most suitable partner will be selected on the basis of their skills, abilities, and price. The research and development phase can be divided into several stages, which crucially **allows us to flow down our governance process and project gates to our supplier**. It is a fair and robust process, that ensures the requirements and the award criteria shall be sufficiently met.

Additionally, cost overruns can often happen when the scope is poorly-defined. The first six-months (Stage 1) of the project involve working closely with procurement to ensure we have fully understood the capabilities of the marketplace through engagement and by launching an expression of interest. A key output of the first stage shall be to ensure the requirements are sufficiently precise to enable potential suppliers to identify the nature and scope of the required solution and decide whether to request to participate in the process. This will ensure optimum quality is achieved for the remainder of the project.

6.1.9. *Project risk assessment*

A structured project risk assessment process has been followed with a risk workshop conducted with stakeholders from Technical and Delivery areas. Participants identified key risks along with criticality (likelihood and consequence) and associated mitigation actions, with the Risk Register shown in Appendix III. As discussed above, suitable but conservative contingencies have then been applied to costs where there are known areas of risk. The risk fund will be tracked by the Project Manager and if this fund is spent faster than anticipated, the reporting at the TAB will determine options for de-scoping the work before project overspends occurs.

Project risks will be proactively and dynamically managed. We will regularly review risk to ensure any new risks are identified, and that all risks remain suitably mitigated and managed. The project will escalate any major new risks to the TAB, and if considered necessary by the group or by the Project Manager, an impromptu meeting will be held to resolve the risk or, in an extreme instance, whether any project changes are required (including Material Changes requiring Ofgem’s approval).

Key risks associated with cost overruns and/or benefits shortfalls, and their mitigations, are shown in Table 8:

Table 8: Key risks (with cost or benefits implications) and their mitigations (L= likelihood, C=consequence, S=Score)

Key risks	L	C	S	Mitigations
Currency fluctuation or tariff impacts on delivery or costs of key components, leading to project cost increases and delays.	M	M	8	We have allowed sensible conservatism for currency fluctuations and will review market activity at project stage gates.
A COVID-19 second wave or persistence affects personnel health, procurement events, or trials, leading to project cost increases (and delays).	M	M	8	Delivery plan developed to account for COVID-19 risk and distancing measures. We will engage with suppliers early to understand impacts on their operations.
RICA does not secure public support due to lack of engagement with communities, leading to project delays, cost increases, or barriers to post-project implementation.	M	M	8	Community and stakeholder engagement plan designed for early and regular community group engagement and consultation.
Stakeholder buy-in is not achieved due to lack of engagement with other utilities, government agencies and industry bodies, leading to project cost increases and delays.	M	M	8	Early engagement with letters of support. Clear plan with RACI, active dissemination of project materials. Ongoing engagement with stakeholders.

6.1.10. *Verification of all the information included in the proposal*

The project was widely reviewed at the ISP stage, mid-FSP development (mid-June), and again at final FSP issue. Rather than leave the review open ended and risk not getting the desired level of input, we set a list of questions with specific and measurable answers in their areas of specialty to guide their review, and proactively sought responses by an agreed deadline. We have run the submission past all relevant internal stakeholders and subject matter experts to verify the contents of the proposal. These include:

- Operations
- Finance
- Stakeholder Liaison
- Communications
- Life Cycle
- Investment
- Procurement
- Regulation
- Visual Impact Provision (VIP) team
- Safety, Health and Sustainability (SHS)

6.2 How the Project plan will still deliver learning in the event that the take up of low carbon technologies is lower than anticipated

In the event that the take up of low carbon technologies is lower than anticipated, project RICA will still deliver key learnings, as it will have shown:

1. A clear alternative for providing faster network reinforcement; enabling the renewable generation connected now to be used more effectively.
2. A stakeholder acceptable solution for VIP.
3. A technology suitable for targeted ground clearance issues.
4. Robust knowledge dissemination with other internal departments, as well as with other network operators (on the TAB), will maximise the options for future use of RICA.

Although timely and successful implementation on the network will have a positive impact on the speed of adoption of the RICA methods and potentially on the ultimate benefits case from RICA, it is not necessary for project success.

[redacted]

We have identified two relevant risks in our risk log:

Table 9: Risks associated take up of low carbon technologies (L= likelihood, C=consequence, S=Score)

Key risks	L	C	S	Mitigations
Due to any number of factors including emergence of other technologies or changing network needs, the Investment Case for RICA is not made. RICA funding is spent with no value delivered to consumers. *(Note - We believe the likelihood of this risk is actually 'very low' (but this isn't a category in our simplified risk register)*	L	H	6	As well as increased capacity and a potential option under the Visual Impact Provision, the technology can also be used in more specific areas where ground clearances have become an issue. The project will collaborate with stakeholders including ESO and internal NGET departments throughout the project to identify emerging network needs. Knowledge dissemination with other internal departments, and other network operators (on the TAB), will maximise the options for future RICA use.
Due to timing misalignment, RICA cannot be implemented on short-term delivery routes. Benefits are delivered later, with lower present value to consumer.	M	L	4	The project will collaborate with NGET departments to ensure required timeframes are met for good opportunities. As above, the RICA NIC project enables multiple use cases, as well as those required by NOA.

6.3 Processes to identify circumstances to suspend the Project

The governance procedures and project stage gate management set out above will provide a firm 'catch' for identifying if the project should be suspended for any reason. The project's stage gates have also been designed at key stages within the project, and the progression of the project beyond these gates will require governance approval.

However, project risks will be proactively and dynamically managed on an ongoing basis. We will regularly review risk to ensure any new risks are identified, and that all risks remain suitably mitigated and managed. The project will escalate any major new risks to the TAB, and if considered necessary by the group or by the Project Manager, an impromptu meeting will be held to resolve the risk or, in an extreme instance, whether any project changes are required (including Material Changes requiring Ofgem's approval).

6.4 Segregation with BAU activities

BAU rollout is **not** financeable through innovation. This is an important consideration for a project such as Project RICA, that is taking a high-level TRL project from innovation and development, and proving its use for BAU. By definition, at some point along its journey (in this Project, we expect by the end of Project stage 2b) the risks of adoption will have been sufficiently removed or mitigated that innovation spend is no longer appropriate. However, timely and successful implementation on the network, whilst outside of project scope and not necessary for project success, will have a positive impact on the speed of adoption of the RICA methods and potentially on the ultimate benefits case from RICA. We have therefore planned for the new RICA investment case to be developed in parallel to real network schemes. Because of the risks associated with innovation, this does not negate any development of real network schemes. However, it does result in staff working on both innovation and scheme delivery activities in parallel.

Use of entirely separate teams for the development of this technology would build knowledge barriers and increase overall costs to the consumer; this is against our ambition to change the way we work as a company. Placing project responsibilities on individuals who also have roles with normal investment process will help to embed this innovation into our business. Therefore, strong governance is particularly important to ensure that costs are appropriate and transparent.

We will employ clear governance over and above our standard project controls (though not unusual for NIC projects) to ensure the innovation funds are used only as intended.

For most projects, the finance and regulatory teams would review project costs at the beginning and end of a project; we plan to include an enhanced Finance and Regulatory Review (FRR) function for this project that provides a quarterly review. The FRR team will be tasked with reviewing the project's ongoing spend and activities in addition to the normal internal cost measures. They will critically challenge every line item in the schedule to ensure no overlap with roll-out or BAU activities, and identify cost savings measures. The FRR team will then directly report the status of their review to the RICA TAB, and can escalate any matters to this board for support.

The RICA project manager will ensure it is straightforward for the individuals delivering the project to accurately keep track of their cost reporting when working on both the RICA project and on internal investments.

Section 7: Regulatory issues

The project does not require any derogations or exemptions to current regulatory arrangements.

Section 8: Customer impact

A key benefit of RICA, and a fundamental objective of the project, is to minimise the impact on customers. Although land access for work on the towers will be required under any reinforcement option, the final solution avoids building taller towers traditionally used for 400kV lines. This would enable the voltage upgrading of circuits whilst minimising the disruption and visual impact to landowners.

Additionally, the disruption caused by the construction phase would be greatly reduced. This is also true when comparing with equivalent BAU network upgrades to existing towers, as the required structural work for tower strengthening would be less with the RICA due to reduced mechanical stresses. The development of a suitable outage programme for implementing the technology on a trial route is expected to be managed by BAU processes. In delivery of the technology's demonstration, we will undertake all tower reinforcement work possible without an outage, before moving on to the significant tower modifications. If RICAs are applied to a scheme at the end of the project, any impacts on customers would be managed through BAU.

The project will resolve and clarify the planning and permissioning arrangements required, and produce guidance, with a view to reducing the time and cost in the future. This guidance can be communicated with external stakeholders and customers. We believe that the outcome of this project will enable customers will be able to connect to our network sooner.

Additionally, we must consider the potential environmental benefits, as the RICA method will lead to minimum disruption of 'virgin' land compared with new towers or replacement towers. Additional environmental benefits are also expected from the accelerated delivery of onshore reinforcement schemes, which will enable more renewable generation on the network sooner.

Furthermore, on an equivalent voltage basis, RICAs would provide a solution for mitigating high levels of electrical field / clearance in a particular area due to the increased height and smaller spacing between phases. Research suggests that for voltage upgrades, this cancels out the increased field associated with the higher voltages. These EMF considerations will be confirmed by the project. Previous projects have also indicated that ICAs reduce operational noise levels. This can help to reduce complaints from stakeholders about customer related infrastructure.

During the NIC project delivery we are not expecting any impact on customer premises, and we will actively engage with customers to build interest and awareness in the technology and its benefits to customers.

Section 9: Project deliverables

A series of key deliverables have been set to ensure clear project reporting and that all tasks are satisfactorily completed. These deliverables have been carefully selected such that they have a wide range of dependencies to encapsulate all project tasks. I.e. successful completion of all project deliverables will mean that all work packages and sub-tasks have also been completed.

9.1 Deliverable summary table

Table 10: Project deliverables

Reference	Project Deliverable	Deadline	Evidence	NIC funding request (%, must add to 100%)
D.S1.1	Detailed requirement definition	July 2021	• Report consisting of all the information required for potential suppliers to accurately gauge the level of work that will be involved in Stage 2. • Shared with licensees through TAB	5%
D.S1.2	Preliminary investment case	July 2021	• Report on the preliminary investment case • Shared with licensees through TAB • Workshop with TAB members to review benefits from technology on their networks.	10%
D.S2a.1	Draft functional specification	September 2022	• Draft functional specification • Workshop with stakeholders to incorporate feedback into specifications • Disseminated through TAB	15%
D.S2a.2	First generation product design portfolio	December 2022	• RICA designs for first generation • Workshop with stakeholders to review impact of different design choices on investments and applications. • Disseminated through TAB	15%
D.S2a.3	Report detailing trial outcomes and lessons learned	July 2024	• Report on hardware trials of RICAs • Evidence of workshops and lessons learnt from trails • Non-confidential information disseminated through industrial conference or journal	10%

Reference	Project Deliverable	Deadline	Evidence	NIC funding request (%, must add to 100%)
			• Report disseminated to licensees through TAB	
D.S2b.1	NGET processes and procedures for RICA	August 2024	• Updated technical specifications • Guidance note on rational behind specification • Guidance on investment case development • Installation practices recorded in report • Disseminated to licensees through TAB, and non-confidential information through industrial conference or journal	10%
D.S2b.3	Full suite of documentation issued	February 2025	• Final technical specifications, published • Final guidance note on rational behind specification • Final Installation practices recorded in report • Materials disseminated through TAB	10%
D.S2b.2	Detailed uprate methodology (final investment case)	February 2025	• Report on scheme delivery plan and methodology • Disseminated through TAB to licensees • Final guidance on investment case development • Non-confidential learnings disseminated through industrial conference or journal paper	15%
D.S3.1	Enhanced stakeholder engagement	March 2025	• Record of RICA engagement with stakeholders • Materials for stakeholder engagement posted publicly	10%
Common	Comply with knowledge transfer requirements of the Governance Document.	End of Project	1. Annual Project Progress Reports which comply with the requirements of the Governance Document. 2. Completed Close Down Report which complies with the requirements of the Governance Document.	N/A

Reference	Project Deliverable	Deadline	Evidence	NIC funding request (%, must add to 100%)
			3. Evidence of attendance and participation in the Annual Conference as described in the Governance Document.	

9.2 Additional key milestones

The following milestones are not directly linked to deliverables, but will also be important to track project progress.

Stage 2a, Milestone 1 (M.S2.1): Supplier on board (December 2021)

The project is going to be completed in conjunction with a primary supplier who will perform all the relevant detailed design engineering tasks and procurement of equipment and testing necessary to satisfactorily demonstrate that the RICA solution is robust and technically fit for purpose. In addition to possessing all the necessary technical attributes needed to deliver the project, they will also need a proven track record of delivering innovative solutions. **This milestone will be completed once the key supplier has been chosen.**

Stage 2a, Milestone 2 (M.S2a.2): Demonstrate ICA prototype (June 2023)

This stage will be completed once an ICA has been delivered that includes all the essential features as defined in the functional specification. However, it is not necessary that the ICA is a finished design at this stage.

These are not the only milestones in the project plan, but are seen as two of the key milestones during the project’s delivery.

Section 10: List of Appendices

Appendix I - Benefits Tables

Table 11: Financial benefits

Scale	Method	Method cost (£m)	Base Case Cost (£m)	Benefit (£m)			Notes	Cross-references
				2030	2040	2050		
Post-trial solution (individual deployment)	RICA	199.9	180.5	66.2	66.1	66.1	Single route with capacity realised in 2028 (RICA) and 2030 (BAU). RICA option is slightly cheaper than baseline in absolute terms but incurs costs two years earlier. All NPV benefits quoted relative to the baseline option.	NPV analysis in Appendix VI.5.
Licensee scale (If applicable, indicate the number of relevant sites on the Licensees' network.)	RICA	607.0	544.1	59.4	63.3	194.9	4 routes on the NGET network Capacity realised in 2028, 2034, 2040, 2046 (RICA). Baseline capacity realised 2 years later for each route.	NPV analysis in Appendix VI.5.
GB rollout scale (If applicable, indicate the number of relevant sites on the GB network.)	RICA	877.1	789.3	-15.9	118.3	286.4	6 routes GB-wide. Capacity realised in 2028, 2032, 2036, 2040, 2044, 2048 (RICA). Baseline capacity realised 2 years later for each route.	NPV analysis for project in Appendix VI.5.

Table 12: Additional Capacity benefits

Scale	Method	Capacity released (MW)			Notes	Cross-references
		2030	2040	2050		
Post-trial solution (individual deployment)	RICA	0	0	0	All values are quoted relative to the counterfactual (new build OHL). Both RICA and the counterfactual contribute 6180MW per uprating.	Capacity explanation in Appendix V.1
Licensee scale (If applicable, indicate the number of relevant sites on the Licensees' network.)	RICA	0	6,180	0	Four routes, implemented in 2028, 2034, 2040, 2046.	Initial shortlisted routes presented in Appendix II.
GB rollout scale (If applicable, indicate the number of relevant sites on the GB network.)	RICA	0	6,180	0	Six routes, implemented in 2028, 2032, 2036, 2040, 2044, 2048. Comprise initial shortlisted routes plus two potential routes from SSEN/SPEN.	Engagement plan with SSEN/SPEN described in Section 5.2.

Table 13: Carbon and environmental benefits

Scale	Method	Benefit (ktC02e)			Notes	Cross-references
		2030	2040	2050		
Post-trial solution (individual deployment)	RICA	11.9	11.9	11.9	Single route in 2028. All values are net carbon benefits (avoided emissions from reduced losses less the expected capital emissions) above the counterfactual.	Emissions calculation methods described in Appendix VI.5.1.
Licensee scale (If applicable, indicate the number of relevant sites on the Licensees' network.)	RICA	11.9	11.5	28.5	Four routes, implemented in 2028, 2034, 2040, 2046.	
GB rollout scale (If applicable, indicate the number of relevant sites on the GB network.)	RICA	11.9	20.2	39.5	Six routes, implemented in 2028, 2032, 2036, 2040, 2044, 2048. Comprise initial shortlisted routes plus two potential routes from SSEN/SPEN.	Detailed emissions analysis in Section 4.1.3.

Appendix II - NGET Shortlisted Rollout Routes

II.1 NGET shortlisted rollout routes map

Figure 15 describes the shortlisted routes in the NGET network. Table 14 describes details of each route.

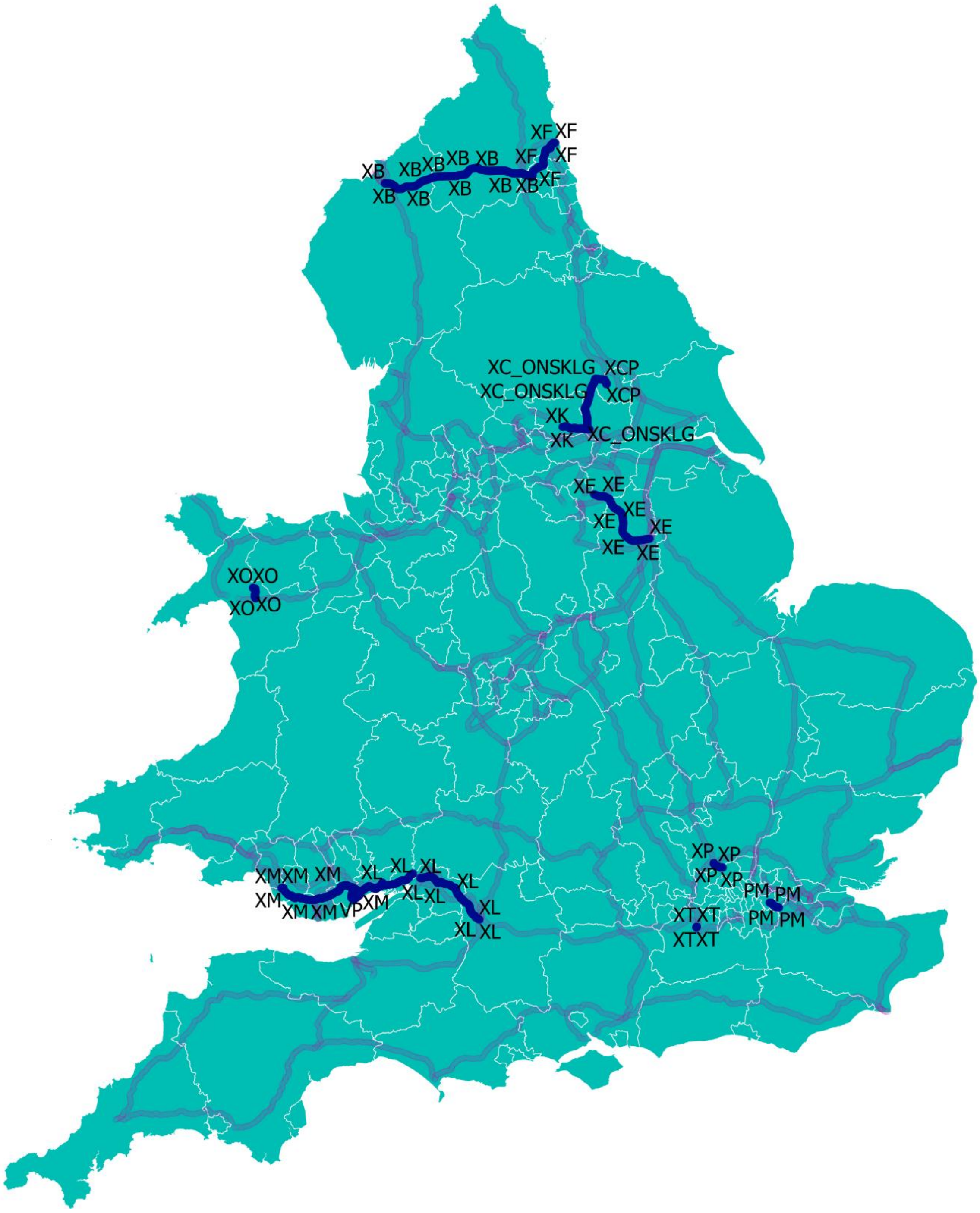


Figure 15 – RICA routes shortlist

Table 14: Shortlisted RICA routes parameters

[redacted]

Appendix III - Risk Register

An extract from the project register is found in Table 15, sorted by descending order of (mitigated) risk score.

Legend: Low (L), Medium (M), High (H), Likelihood (Li), Consequence (C), Number (#).

Table 15: Project Risk Register

#	Risk summary	Li	C	Score	Mitigation Actions	Category
1	Currency fluctuation or tariff impacts on delivery or costs of key components, leading to project cost increases and delays.	M	M	8	Allowing sensible conservatism for currency fluctuations. Review market activity at project stage gate.	Delivery
2	COVID-19 - second wave or persistence affects personnel health, procurement events, or trials, leading to project cost increases and delays.	M	M	8	Develop delivery plan to account for COVID-19 risk. Engage with suppliers early to understand impacts of COVID-19 on their operations.	Delivery
3	RICA does not secure public support due to lack of engagement with communities, leading to project delays, cost increases, or barriers to post-project implementation.	M	M	8	Community and stakeholder engagement plan designed for early and regular community group engagement and consultation.	Stakeholders
4	Project does not secure stakeholder buy-in due to lack of engagement with other utilities, government agencies or industry bodies, leading to project cost increases and delays.	M	M	8	Early engagement with letters of support. Clear plan with RACI, active dissemination of project materials. Ongoing engagement with stakeholders.	Stakeholders
5	Insulators are damaged while accessing due to unfamiliarity of personnel with novel technology, leading to outages.	M	M	8	Develop and testing of access and egress procedures. Knowledge dissemination to maintenance teams.	Technical
6	Due to any number of factors including emergence of other technologies or changing network needs, the investment case for RICA is not made. RICA funding is spent with no value delivered to consumers.	L	H	6	RICA NIC project enables multiple use cases (new capacity, visual impact, clearance). The project collaborates with stakeholders including the SO and NGET departments throughout the project steering committee to identify emerging network needs.	Outputs

7	Dynamic risks due to altered fixity of conductor compared to conventional cross arms leads to reduced asset life or safety risk to public.	L	H	6	PLSCAD modelling and testing to establish dynamic behaviour. Pivoted cross arms compared to fixed cross arms for instabilities.	Technical
8	RICAs increase risk of galloping clashes due to increased proximity of conductors, potentially leading to conductor damage and outages.	L	H	6	Cross arm spacing designed to increase conductor spacing.	Technical
9	Failure of type testing due to novel design aspects, leading to project cost increases and delays.	L	H	6	Work with more than one insulator supplier. Engage type registration engineer early on.	Technical
10	Supplier pulls out from project or becomes insolvent, leading to cost increases and delays to project.	L	H	6	Engage supplier early. Use approved suppliers with suitable financial background checks. Ensure insurance covers consumer for cost recovery. Allow new suppliers sufficient time to be approved.	Procurement
11	New earthing processes for RICA lead to physical strain on personnel to implement.	L	M	4	Develop earthing tools and trials (e.g. at Deeside/Eakring) during NIC project. Design for constructability. Develop and testing of access and egress procedures. Knowledge dissemination to maintenance teams.	Technical
12	Due to timing misalignment, RICA cannot be implemented on short-term delivery routes e.g. through NOA or VIP. Live monitoring cannot be delivered under stage 3 and benefits are delivered later with lower present value to consumer.	M	L	4	Explore the multiple use cases enabled by RICA which allow alternative routes. The project will collaborate with other NGET departments to ensure required timeframes are met for good opportunities.	Delivery
13	Access to test facilities and laboratories not secured due to unavailability, leading to project cost increases and delays.	L	M	4	Engage early with the facilities, require suppliers to identify alternative facilities.	Delivery
14	Faults with RICA are difficult to identify visually due to their composite materials - leading to longer time to identify faults, potentially leading to increases in outages.	L	M	4	Design for reliability during the feasibility study and detailed design stages of the NIC project.	Technical

15	More electrical faults (e.g. flashover/flashunder) possible due to the higher volume of insulators in RICA design, leading to potential increase in outages.	L	M	4	Conduct FMEA and other reliability analysis. Engage closely with insulator suppliers to develop detailed functional specification addressing material properties and failure risk.	Technical
16	Compression insulators are heavy - improper handling could lead to damage due to composite material properties, leading to outages.	L	M	4	Robust handling and commissioning techniques. Visual inspection prior to commissioning.	Technical
17	Increased mechanical loading on tower due to increased wind shear on conductors with height raised by RICA, leading to higher cost of investment case.	L	M	4	Structural assessment of RICA using PLSCAD.	Technical
18	No suitable supplier selected through initial procurement event, leading to project cost increases and delays.	L	M	4	Establish robust, pragmatic procurement process. Engage market early. Request CVs of suppliers or consortia.	Procurement
19	Additional scope items required/larger effort for design and trialling activities new to novel RICA technology, leading to project cost increases and delays.	L	M	4	Investigate risk sharing between supplier and NGET. Engage with technical consultants and other networks to understand potential costs at feasibility stage.	Technical
20	NGET does not have suitable internal resources or availability to deliver the NIC project due to other internal requirements, leading to project cost increases and delays.	L	M	4	Engage with senior managers and appropriate teams at FSP stage and continuously from start of project.	Delivery
21	Additional works for installing RICAs due to novel technology, leading to increased outage time.	L	M	4	Develop detailed installation procedures including new methods where possible in the Feasibility stage of the project. Estimate any additional time requirements for these new procedures and factor this into the Scheme delivery.	Technical
22	Suppliers indicate that documentation are already available for processes to be developed on NIC project due to previous work internationally, reducing work required on project.	M	L	4	This is an opportunity for the project. Adapt programme to ensure best use of NIC funds, including returning funds if possible.	Delivery

23	Conflicts of interest between members of the technical advisory board (TAB) and the chosen supplier for the innovation partnership, leading to an unfair procurement process and/or to project cost increases and delays due to re-procurement.	L	M	4	Mitigated by conflict of interest form at RFI/procurement stages.	Procurement
24	Sharing of information between supplier NG and project supporters leads to an information leak and potential legal issues.	L	M	4	NDA with suppliers and project supporters.	Delivery

Appendix IV - Letters of Support

The project has received the following letters of support, which are available upon request:

- *Transmission Licensees:*
  - ESO
- *Suppliers*
  - Babcock Networks
  - Balfour Beatty
  - Energyline
  - Nanjing Electric
  - PACE Networks
  - Allied Insulators
  - Shemar
  - Wood Group
  - ZTT
- *Academic Institutes*
  - Cardiff University
  - The University of Manchester

SSE and SPEN have also provided email confirmation that they are happy to support the project and have provided named individuals [redacted] have who will be a part of the TAB.

SSE have identified several routes where RICA could be applied in the near term, with other routes under consideration:

1. *275kV to 400kV:*
   [redacted]
2. *132kV*
   [redacted]
3. *132kV*
   [redacted]

Appendix V - RICA Technical Information

V.1 RICA technical gap analysis

A technical gap analysis has been undertaken for the RICA technology (see Appendix VII for details of previous trials) and used to inform the following areas of development:

1. **Mechanical design** – understand conflicts in established standards and the need for new guidance documents, and investigate an appropriate ICA form that suits different applications and dynamic system performance etc. For example, pivoted RICA vee vs. rigidly-fixed RICA.
2. **Tower modifications –** can development of new tower strengthening methodologies / procedures enable hard-to-strengthen areas to be resolved? Design new anchor points for access and temporary lifting equipment and platforms, and design modification for condition monitoring stations to collect data of RICA through life performance.
3. **Electrical design –** develop conductor specifications for optimal system performance, identify any dynamic related clearance issues from conductor galloping or similar, identify any electrical noise implications with RICA towers, and review electrical tracking (insulator condition) requirements.
4. **ICA hardware –** can maintenance be supported with new features, how will conductor jumpers be managed at angle and strain tower locations, and will the design of hardware meet structural and visual amenity requirements.
5. **Health and Safety** – can all tower climbing be done safely in consideration of new insulator proximity to the tower body, what is safe-climbing and working under single-circuit outage conditions with RICAs, what do safe earthing strategies look like etc.
6. **Lightning protection** – assess the impact of the changed phase orientation on lightning strike performance. Depending on the level of protection needed, can this be mitigated through implementation of a higher earth wire or a twin bundle shield wire set up.
7. **Installation methods –** understand the work that can be done energised vs. work that requires outages, develop temporary support structures to minimise outage requirements, and create load cases to ensure no risk of cascade failure from tower overloading during installation etc.
8. **Operation and maintenance** – define post installation visual inspection checks, access and egress solutions, and hardware replacement methodologies etc.
9. **Lifecycle analysis –** calculate embedded CO_2 for different insulator technology, comparison of predicted life vs embedded CO2 vs. reliability, recycling options, and development of on-going condition monitoring for advanced warning system etc.

V.2 RICA capacity delivered

We have conducted a short study to assess the capacity that can be delivered using RICA for rollout to the NGET network. The results are provided in Appendix II.

Firstly, for the shortlist of highly suitable routes for RICA we assembled OHL tower data, span data, geographical locations of OHL towers and ratings of the corresponding circuits. Further, we identified transmission boundaries close to these OHL towers, which could benefit from capacity increases on these routes.

We extracted the existing post fault summer ratings[10] for the circuits on the shortlisted routes. A key observation on this data is that ratings for all these circuits (except one) were limited by OHL assets, thereby highlighting the need for uprating these assets to unlock additional capacity.

For the purpose of this study, the conductor for reconductoring is assumed to be Curlew which is capable of maximum operating temperature of 190 deg C. Twin bundle was chosen to minimize noise issues that occur on operating single bundle conductors at high voltages.

We compared the existing ratings of the circuits on the shortlisted routes with those achievable through BAU option of reconductoring and found that it could provide an increase of approx. 2.5 times the existing capacity on average. Additionally, RICA can deliver 3-4 times the existing capacity for routes that would have limitations on operating temperature due to clearance limits. RICA provides the additional clearance that permits the conductor sag at maximum operating temperatures.

V.3 RICA Lightning Protection

Two key aspects that will be concluded within the project will be determining the overall system performance enabled by the increased RICA enabled clearances and the impact of the changed phase orientation on lightning strike performance Figure 16.

Overall system performance: along with voltage uprate, RICAs offer a range of system configuration options such as changing conductor type, thermal rating and moving from single to twin conductors. To illustrate, the increase from 275 to 400kV only requires a ground clearance increase of 0.7m, however the RICAs could enable several meters of mid span conductor height increase, which can be used to increase thermal rating.

Maintenance of required system lightning protection: Depending on the level of protection needed, this could be mitigated through implementation of a higher earth wire or a twin bundle shield wire set up. These options have different implications of tower loading and footprint etc., and the preferred solution will be considered in conjunction with a line specific study on lightning incidence.

Early studies have been carried out to examine the feasibility of upgrading an L3 tower from 275kV to 400kV. This is a challenging case as a twin conductor system is required at 400kV and this significantly increases the loads on the tower. Initial studies have shown that certain load cases cause overloads of the towers but only in the redundants. This would be straightforward to resolve through changing these members and studies

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[10] These are used as summer post fault condition is one of the worst for OHL spans considering conductor expansion and high ambient temperatures. We do acknowledge that heavy ice loading conditions also represent severe conditions for OHL spans, but for the sake of this high-level study, we’ve only considered the former.

have confirmed that this approach is valid. Using a novel conductor to reduce tension requirements is also thought to have a positive impact on the tower performance in the broken wire case. Alternatively, the additional conductor height enabled by the RICAs could be utilized to reduce conductor sag.

Based on these studies, this project will focus on validating towers for uprate by means of a full-scale network trial.

Lightning strike angle can be maintained through earth wire peak modifications

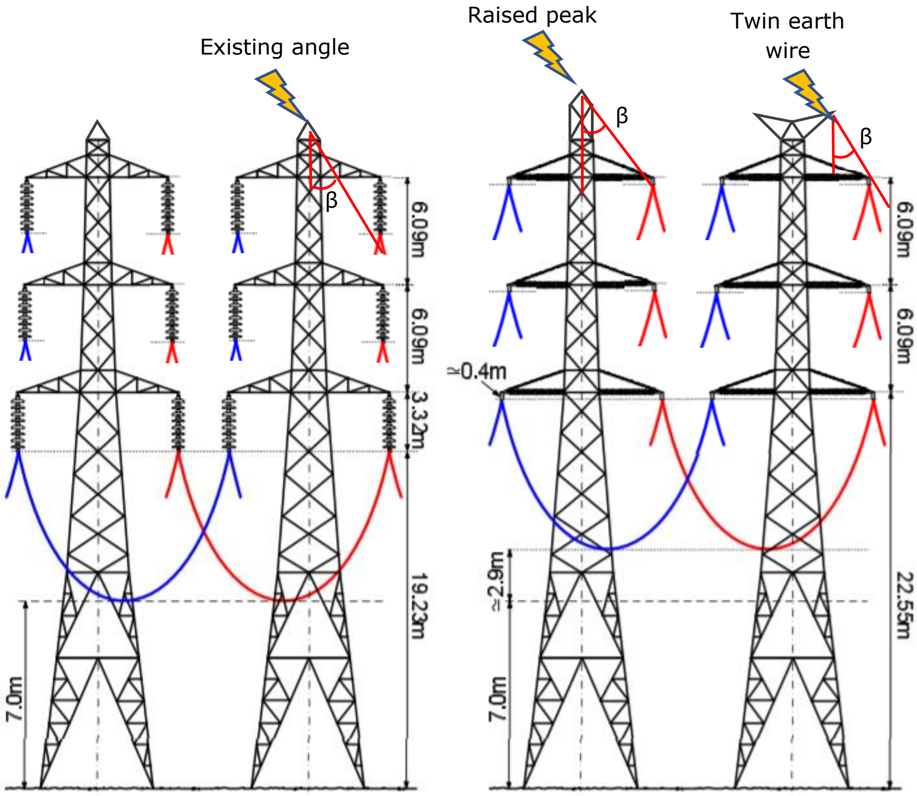

Figure 16 – RICA Clearance increase and effect on lightning strike

V.4 RICA Trials Details

The project has two stages of trials, aligning with Stages 2a and 2b of the project. These trials are as follows:

Stage 2a

In Stage 2a, trials of prototype designs will be conducted at test facilities such as Eakring and/or Deeside. We anticipate the Eakring trials will concentrate on aspects of the project such as:

- Installation methods
- Inspection methods (including access and egress)
- Safe earthing strategies
- Insulator and conductor replacement methodologies
- Development of an approved hardware list

We anticipate the Deeside trials will concentrate on aspects of the project such as:

- Energised testing of the RICA designs
- Dynamic system testing
- Testing the monitoring equipment

These trials will be ongoing for a minimum of a year as the design is refined, key technical risks are removed (or reduced to As Low As Reasonably Practicable) and uncertainties resolved.

Design of the trials is key to the project and will evolve over the course of the project.

Stage 2b

In stage 2b, after lessons learned from the first series of trials has been conducted at Eakring and/or Deeside trials, the designs will be finalised. The final designs must then be type tested. We anticipate this will be done by repeating the activities at Deeside and Eakring utilising the now finalised solutions. Additionally, laboratory testing of the insulators will be required for design assurance (type testing). Examples of the type testing that will be completed with examples of are shown below:

1 Electrical and mechanical testing of the new structural member end fittings. These tests involve applying a defined sequence of mechanical and electrical stresses to insulator end fittings to demonstrate manufacturing integrity. IEC 61109, IEC 62217, IEC 60060-1, IEC 60507, IEC 60815-1
    A Reference dry power frequency test
    B Sudden load release test
    C Thermal-mechanical test
    D Water immersion test
    E Steep-front impulse voltage test
    F Dry power frequency voltage test
2 Electrical testing of the full cross-arm assembly at 400 kV. The efficacy of the stress relief devices is contained within the electrical testing of the full cross-arm.
    A Radio interference test, TS 3.4.17, IEC 60437, BS EN55016-1-1 (CISPR 16-1-1), CISPR 18-2
    B Corona extinction test, S 3.4.17, IEC 61284
    C Dry Lightning impulse withstand voltage test, IEC 60383-1, IEC 60060-1
    D Wet power-frequency test, IEC 60383-1, IEC 60060-1
    E Wet Switching impulse withstand voltage test,
    F Electric field requirements, The conformance to the requirements stated below (wet or dry) is to be demonstrated through software including FEA simulation
        - Maximum electric field strength: 0.45 kV/mm
        - Maximum electric field magnitude of the housing: average 0.42 kV/mm per 10 mm section
        - Maximum electric field magnitude at the triple point: 0.35 kV/mm
3 Mechanical testing of new structural members. ICAs break with traditional OHL insulator testing as they're exposed to compression loads as well as tension loads. IEC 61109, IEC 62231
    A Specified Mechanical Tension load
    B Specified Mechanical Compression load
    C Specified Mechanical Torsion load
4 Mechanical testing of the full cross-arm assembly. The full ICA assembly is exposed to worst case load conditions, similar to tower type testing, IEC50349, IEC60652
    1.4.1 Load Testing

5 Material testing. These test validate the integrity of the materials and ensure integrity of weather protection. IEC 61109, IEC 62217

    1.5.1 Core Dye-Penetration Test
    1.5.2 Water Diffusion Test

Depending on the scale of change to the original tower designs, type testing may also be required on the refurbished tower structures. This would be performed at an established structural test facility capable of constructing a replica 'refurbished' tower and loading it to worst load case conditions. Tower testing will be according to IEC60652, loading tests on overhead line structures and other relevant NGET requirements and specifications. It's possible that the mechanical testing discussed in point 4 could be combined with the full scale tower testing.

Stage 3

In Stage 3 of the project, the project team will go on to support the installation of the now certified hardware on an operational route and begin to monitor their operation. The scope of the stage 3 network installation will be determined based on an on-going assessment of business need and benefits provided.

Appendix VI - Business Case Methodology

The project has followed the HM Treasury five case model in assembling the business case for RICA. We have chosen this model as it follows a structured approach to appraising an investment against alternative options, with a focus on strategic alignment and delivering social value. Many of the activities from the five case model also align well with the FSP proforma and provide a useful logical summary of the "why" for RICA.

However, unlike most business cases that use this model, we have spread each case over this document respecting the FSP proforma. We believe the content in this document is generally equivalent to an Outline Case[11] with some elements of the Full Business Case completed. We have summarised the information for each case against the relevant case requirements in Appendix VI.6.

VI.1 SMART objectives

The project has identified objectives described in Table 16 relevant to NGET's RIIO-2 Business Plan and electricity consumer priorities. These are specific, measurable, achievable, realistic and time-constrained (SMART).

Table 16: SMART objectives

Top level objective	SMART objective
Deliver transmission network capacity to enable the net zero transition	Increase capacity at key transmission boundaries from the ETYS (MW)
	Decrease constraint cost paid through the Balancing Mechanism (£m)
	Decrease project timings for transmission network reinforcement (years)
	Decrease capacity cost for transmission network reinforcement (£/MW)
Reduce losses on lines and associated emissions	Decrease transmission network losses (MWh)
	Decrease transmission network emissions (t-CO2-e)
Reduce visual impact of transmission	Decrease tower height for network reinforcement (# of routes, towers per route)

The main benefits of achieving the objectives are described in Section 4, while the main risks are documented in Appendix III.

VI.2 Critical success factors

We have defined the following critical success factors:

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[11] See for more details on each case: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/749086/Project_Business_Case_2018.pdf

Critical success factor	Description
Strategic fit	How well does it meet the spending objectives?
Potential value for money	How well does it optimise value to electricity consumer?
Supplier capacity and capability	How well does it match the ability of potential suppliers to deliver the required work?
Potential affordability	How well does it satisfy NIC innovation funding requirements?
Potential achievability	Does it match NGET's skillsets and abilities?

VI.3 Options Longlist`

We have developed a longlist of options that all meet at least the transmission network capacity objectives outlined in Appendix VI.1.

VI.3.1 BAU option

The current toolset for providing new network capacity comprises a range of different solutions including uprating existing lines, new build OHL and non-network solutions. The Network Options Assessment (NOA) process considers network reinforcement proposals by NGET, and other transmission operators (TOs). NG ESO facilitates the NOA process and makes recommendations for which investments should go ahead. The following subsections review the key components of BAU network reinforcement projects. Each of them may be used in isolation or as part of a single project depending on the particular network requirement and existing infrastructure.

Uprating existing lines

Either current or voltage uprating can be used for uprating existing lines. For suitable routes, both current and voltage uprating can be applied concurrently.

Current uprating consists of the range of solutions that increase the current carrying capacity (in Amps) of the route, primarily by increasing the thermal capacity of the assets. This could include installing newer High Temperature Low Sag (HTLS) conductors, more conductors per circuit or more circuits (where a circuit comprises three phases). It could also comprise upgrades to substations to allow increased thermal capacity or isolated tower improvements to improve clearances to allow higher temperature operation.

Voltage uprating covers upgrading assets to permit higher voltage operation. In the existing NGET network this is from 275kV to 400kV. Some tower types are capable of 400kV by design, such as L2 and L6, while others do not have required clearances to operate at 400kV without modification, for example L3 and L66. Voltage uprating also requires the installation of supporting infrastructure including transformers rated to 400kV.

New build OHL

New build OHL can be either in the footprint of an existing route or on greenfield/brownfield sites. Existing sites require significantly less planning processes than for new sites, however any works on an existing corridor will still be subject to planning approvals. Project details vary including different tower types, circuit configurations, and conductor types.

Non-network solutions

Non-network solutions cover any technology or process that provides network capacity without any additional network infrastructure. This could comprise smart power control devices, which control power flows to maximise the use of existing network assets. These could also include installation of battery storage to reduce flows in key regions.

VI.3.2 BAU + RICA 275kV tower types

The RICA option comprises the set of BAU options, plus the RICA option for uprating lines from 275kV to 400kV. This option considers NGET tower types that can only operate at 275kV due to clearance requirements - L3, L34, and L66. Section 2 provides more detail on this option.

VI.3.3 BAU + RICA expanded tower types

This option considers the RICA base option, plus inclusion of L2 and L6 tower types. This option does not uprate the voltage of existing towers, as L2 towers are already 400kV capable (possessing the required clearances). However, it does allow incremental capacity increases for spans where there is insufficient clearance to operate at the maximum current carrying capacity (due to insufficient clearances). It can also increase road and river clearances to meet stakeholder requirements.

VI.3.4 BAU + ICA new build

This option considers the RICA base option, plus development of compact ICA towers for NGET's network. These are 400kV capable towers that are shorter than conventional alternatives such as L2 and L6 and utilise the same cross arm technology as RICA.

VI.3.5 BAU + Dynamic Line Rating (DLR) option

This considers the BAU option plus deployment of a full-scale Dynamic Line Rating system. This would allow us to maximise the efficiency of using existing network capacity through better understanding of the dynamic thermal capability of assets. The option comprises a software system with associated processes and NGET internal resources.

VI.4 Longlist appraisal

We have appraised the longlist options above (other than the BAU option) in Table 17.

Table 17: Longlist appraisal

	+ RICA 275kV	+ RICA expanded	+ICA new build	+Dynamic Line Rating
Strategic fit	Very good - delivers network capacity with lower tower heights.	Moderate applies less to the network capacity objectives, better for visual impact.	Fair - only applies clearly to the visual impact objective.	Good for the network capacity objective - but applies to marginal gains on existing assets,
Potential value for money	Very good - reduced constraint cost.	Moderate - incremental reductions in constraint cost.	Fair - potentially equivalent to new OHL build costs	Good - but needs to be part of wider solution
Supplier capacity and capability	Very good	Very good - suppliers engaged are capable	Moderate - less risk to suppliers for new build option.	Moderate - new technology.
Potential affordability	Good	Good	Good	Very good (low cost)
Potential achievability	Very good	Very good	Good	Good
Outcome	Proceed	Proceed	Discard - doesn't' meet all spending objectives, not a good strategic fit.	Discard - doesn't meet all spending objectives, not a good strategic fit.

VI.5 NPV Analysis

The NPV analysis has followed HM Treasury Green Book practices to support the shortlist appraisal. In general, we have conducted a discounted NPV analysis in 2020/21 prices extended to 2050. The following subsections describe the details of the approach.

We have engaged with NG ESO and followed a common approach to benefit assessment as used in their Network Options Assessment (NOA) process. We have selected a single Future Energy Scenarios (FES) 2019 scenario for our core NPV projection in accordance with ESO advice and FSP guidance. This is the Two Degrees scenario, because it reflects the highest level of decarbonisation to 2050 for the FES 2019 along with the Community Renewables Scenario. Additionally, Two Degrees reflects a situation where a high amount of network capacity is required - reflecting an appropriate "worst regrets" candidate vs the worst regret of RICA being the NIC funding without any additional financial benefit.

[redacted] For this route, we have applied a 400kV uprating using RICA as well as a reconductoring which is typically completed in conjunction with voltage uprating. For the BAU option we have selected a new build OHL as this is the only way to deliver a new 400kV line in a region where there are no 400kV capable tower types. This therefore reflects the most efficient method to deliver capacity via voltage uprating and an appropriate Base Case method as per the NIC guidance. We have assumed capacity would be delivered 2 years earlier for the RICA option vs the baseline option due to the lower requirements for consenting and construction.

We have estimated 4 similar routes in the NGET network will be uprated to 400kV by 2050 based on a conservative assessment of the routes shortlisted in Appendix II. Furthermore, we have assumed 2 routes from the SSEN/SPEN network based on our engagement with these Transmission licensees and the makeup of their network being predominantly 275kV lines.

VI.5.1 Carbon emissions

Carbon emissions consist of both capital and losses components. We use Traded Carbon Prices in 2020/21 prices from the RIIO-2 template for our monetised emissions calculations. The capital emissions analysis is shown in Table 18 for the comparison route described in Appendix VI.5. This conservatively assumes that RICA has the same capital emissions as for a new OHL build due to uncertainties in materials, construction and transportation requirements at this time. We expect that in the long run RICA will have significantly lower capital emissions reflecting lower requirements for emissions-intensive steel towers with concrete foundations.

Table 18: Lifecycle emissions (non-losses) for RICA - per route

[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]

For losses, emissions intensity is based on the RIIO-2 assumption that there is a linear decarbonisation of the power sector from 2017/18 to 2050 levels of 10g/kWh.

VI.5.2 Monetised benefits

The key monetised benefit is the avoided constraint cost due to the additional network capacity.

For this route, NG ESO have provided the present value benefits of implementing [redacted] at its earliest in service date (EISD), with avoided constraint costs extended over 40 years from the EISD. These are discounted using the STPR of 3.5% for the first 30 years followed by 3.0% thereafter. Note that this includes the investment cost. This does not consider any impacts of follow on investments.

Table 19: [redacted] monetised benefit of avoided constraint costs

Constraint + Investment cost (£m, PV)	Consumer Evolution	Steady Progression	Two Degrees	Community Renewable
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

For the annual avoided constraint cost per route, we have added the investment cost of £283m to the "Net Benefit" and distributed the avoided constraint costs over 40 years starting from 2027 ([redacted] EISD). The ESO has also provided indicative figures for total additional constraint costs, including the knock on effects on other network reinforcement projects, if [redacted] is removed from the optimal path. These are presented in Table 20. The significant knock on effects show that key network capacity has important interdependent impacts. We have used the values above for avoided constraint costs, without any knock on effects, as this is conservative assessment of the value of network capacity.

Table 20: Additional total constraint costs without [redacted] including knock-on effects

	Optimal paths without [redacted] Constraint + Investment cost (£m, PV)
Two Degrees	[redacted]
Community Renewables	[redacted]
Consumer Evolution	[redacted]
Steady Progression	[redacted]

VI.5.3 Rollout costs

Costs for the baseline option are drawn from NGET costings for current scheme proposals for new build 400kV OHL, shown in Table 21. This is based on a route length of 38km which is consistent with the [redacted] data that the benefits are based off. It is assumed that a double circuit, Twin Curlew 400kV solution is implemented (see Appendix V.1 for details).

Table 21: Baseline option scheme costs per route

Activity	Cost per route (£m)
[redacted]	[redacted]

The RICA option comprises the elements expected to uprate a line of the same length as the baseline option to 400kV, as well as reconductoring to Twin Curlew double circuit. Costs for this option are described in Table 22.

Table 22: RICA option scheme costs per route

Activity	Cost per route (£m)
[redacted]	[redacted]

For the RICA option we have also included the costs of the NIC project, distributed over the project timeframe according to the FSP spreadsheet.

For both options, we have distributed all scheme costs according to the method used in our RIIO-2 business plan, outlined in Table 23.

Table 23: Cost allocation per expenditure year

Expenditure year (year 4 is delivery year)	1	2	3	4
Cost weighting factor	[redacted]	[redacted]	[redacted]	[redacted]

VI.5.4 Methodological considerations

We have applied the HM Green Book STPR rate of 3.5% to discount costs and benefits for the project as all costs fall within 30 years following 2020/21.

No weighted average cost of capital (WACC) is considered for the purchasing of the assets. VAT is excluded.

VI.5.5 Sensitivity analysis

We have conducted a sensitivity analysis for variation in key inputs to our NPV analysis. These are split in Table 24 into different potential outlooks for RICA - from pessimistic being the worst expected outcome to optimistic as the best outcome. The "core sensitivity" refers to the inputs used in Section 3 and Section 4 in the document.

Table 24: Sensitivity analysis input parameters

Parameter	Pessimistic	Core	Optimistic
Number of routes (GB-wide)	1	6	10
Number of years earlier constraint benefits delivered	1	2	5
FES scenario	Community Renewables	Two Degrees	Consumer Evolution
RICA costs	[redacted]	[redacted]	[redacted]

We present results of this sensitivity analysis in Table 25 and Figure 17. This shows the core scenario is a conservative assessment of the potential value of RICA based on the spectrum of potential outcomes. The pessimistic scenario is the only scenario that produces a negative NPV relative to the BAU option. However, this is primarily due to the Community Renewables FES scenario which has a lower avoided constraint cost than cost of uprating (Appendix VI.5.2). In this case, it is likely that the ESO's NOA process would recommend no project proceeds, due to negative NPV for both options (new 400kV OHL build and RICA). Therefore, the actual worst regrets outcome is still the cost of the RICA NIC project.

Table 25: Sensitivity analysis outputs

Output	Pessimistic	Core	Optimistic
Present Value Costs (£m)	[redacted]	[redacted]	[redacted]
Present Value Benefits (£m)	[redacted]	[redacted]	[redacted]
Benefit Cost Ratio	[redacted]	[redacted]	[redacted]
NPV total (£m)	[redacted]	[redacted]	[redacted]
NPV vs BAU option (£m)	[redacted]	[redacted]	[redacted]

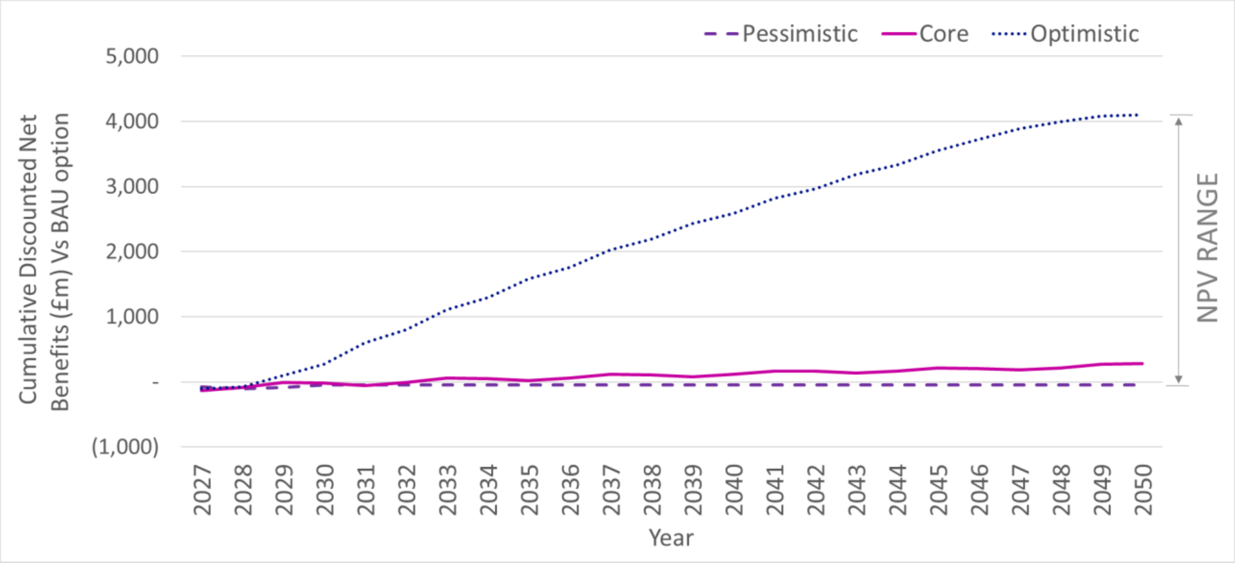


Figure 17 – NPV Sensitivity Analysis Results. Note: all values are relative to BAU option

VI.6 Business case alignment

We have compared the alignment between the sections specified in the HM Treasury templates for the project business case and the current document, presented in Table 26.

Table 26: HM Treasury Business Case Alignment

Case	Content	Section
Strategic Case	Business strategy and aims	Section 3.1
	Other relevant strategies	Section 3.1
	Spending objectives	Section 3.1 and Appendix VI.1
	Existing arrangements	Section 3.2.1 and
	Business needs – current and future	Section 3.1
	Main benefits and risks	Section 4 and Appendix III
	Constraints and dependencies	Section 3.2.1
Economic Case	Critical success factors (CSFs)	Appendix VI.4
	Long listed Options	Appendix VI.3
	Net Present Social Costs (NPSC)/ Net Present Social Value (NPSV)/ findings	Section 3.2.2, 4.1.2 and Appendix VI.5
	Shortlisted Options	Section 3.2.1
	Sensitivity Analysis	Appendix VI.5.1
	Risk Assessment	Appendix III
Commercial Case	Procurement strategy and route	Section 3.3.1
	Key contractual arrangements	Section 3.3.1
Financial Case	Capital and revenue requirements	FSP spreadsheet
	Overall affordability and funding	Section 3.3.2
Management Case	Project management & governance	Section 5, Section 6
	Use of specialist advisers	Section 6
	Change and contract management arrangements	Section 6
	Benefits realisation arrangements	Section 5, Section 6
	Risk management arrangements	Section 6
	Project assurance	Section 9
	Contingency plans	Appendix III

Appendix VII - Previous ICA development

Table 27 below summarises the work completed to date which is then described in more detail in the following sub-sections. These projects were run in cooperation with SSE:

Table 27: summary of previous IFI / NIA trials

Details	Primary Purpose	Outcome
2008 (2 yrs) -Concept initiation (phase 1) and Technical validation (phase 2)	Confirming theoretical viability of uprating 275kV towers to >400kV. Validation of mechanical feasibility Validation of electrical feasibility	This project resulted in the generation of the core enabling IP for existing cross arms to be replaced with insulating cross arms with like-for-like geometry.
2010 (2yrs) Dead Section of Decommissioned 132kV Line Scotland, UK (Lecht, Cairngorms)	Confirming mechanical performance and capabilities in extreme wind and snow conditions, as well as to show among other features the relative ease with which this can be achieved – highly instrumented	Non-cylindrical geometry of the horizontal members is unlikely to affect the environmental performance of the cross-arm
2012 (6yrs) Coastal Substation. 400kV Scotland, UK (St Fergus)	Observing the electrical behaviour of all insulators within the cross-arm arrangement and any changes through variable environmental conditions – highly instrumented	Trial successfully completed. Extensive learning into environmental performance of composite insulators No adverse behaviours detected
2013 (4 yrs) 132kV Transmission network. Scotland, UK Aberdeen	Installation and monitoring of cross arms to demonstrate a new capability to retrofit existing towers with insulating cross arms operating at 132kV which provides system operators with a range of new system design options – not instrumented	Successfully validated bespoke access equipment and demonstrated timely cross arm retro-fit installation process

VII.1 Concept Initiation - Phase 1: NGET Feasibility Study (NIA_NGET0024)

While there had been a small number of examples of insulated cross arms, at the time of the project, there were no known case studies of utilities replacing existing steel cross arms with polymeric insulators to achieve voltage uprating.

The project involved looking at the feasibility of uprating a 275kV L2U and L3 tower to 400kV and focused on the key areas of the mechanical uprating of the tower, the electrical requirements and the possibility for using composite materials to support the very high compression loads associated with the cross arm members which are traditionally managed through the use of diagonal and redundant bracing members as shown in Figure 18.

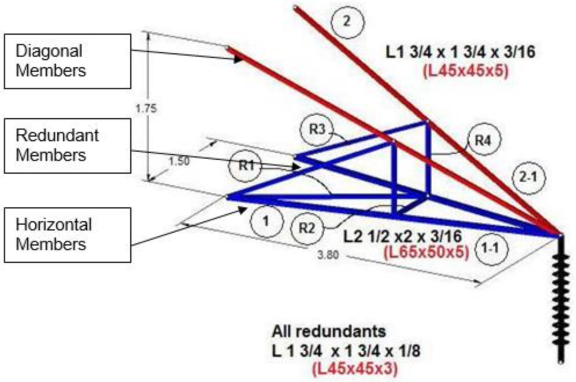


Figure 18 – PLS-tower model of the benchmark steel cross arm

Initially, the concept only considered replicating the geometry and bracing arrangement of the steel cross arms like-for-like to see if this approach may be feasible, as there were no composite insulators available on the market that could have withstood the very high compression loads without incorporating mid span bracing members to prevent buckling failure.

This concept was validated during the project through the construction of a full-scale test rig designed to apply full mechanical loading to a traditional steel cross arm and a prototype cross arm fabricated from pultruded angle sections.

This full-scale composite cross arm trial demonstrated the viability of using glass reinforced plastic pultruded sections as structural members for transmission tower cross arms.

As well as demonstrating the mechanical viability, considerable work was undertaken by the University of Manchester to fully understand the range of electrical benefits that could be offered by the composite technology.

The potential issues to be overcome were presented in the project conclusions along with key project findings:

- The use of composite cross arms will significantly reduce the likelihood of infringing clearances during windy conditions improving the reliability of overhead line circuits.
- A L2 tower could be uprated to operate at 500kV using a composite cross-arm technology
- The use of composite cross arms could allow significant increases in current rating and would be much more beneficial in terms of power transfer than an increase in voltage rating. Furthermore, it could allow the full utilisation of novel composite conductors.
- Electric fields are reduced by a composite cross-arm technology and this even allows up-rating in voltage without exceeding base case electric field levels.
- Magnetic fields are reduced by a composite cross-arm technology.

- Lightning flashover rates would be increased by the use of composite cross-arm technology. This may not be a risk in the UK but could be a risk in other countries.
- Composite cross arms have no impact on the corona performance of an overhead line.

While this first project was at the very early stage of the RICA development, it proved the viability of using composite materials as a replacement to steel within a transmission tower cross arm.

VII.1.1 Concept Initiation Project achevements:

- Problem statement clearly defined
- Demonstrated technical feasiblity of RICAs at a network level to uprate 275kV to up to 500kV
- Developed mechanical understanding of the solutions required through benchmark testing of a representative L3 steel and pultruded cross arm

VII.1.2 Gap Analysis:

- Solution was required to eliminate the diagonal and redundant members needed to prevent the composite cross arm from buckling failure.

A subsequent innovation of developing the non-circular compression insulator led to the instation of phase 2 of the project which is detailed below.

VII.2 Technical Validation - Phase 2 (NIA_NGET0024)

Following the conclusion of the feasibility study, it became clear that while the technology offered benefits, but hurdles remained, preventing technology from becoming a viable network tool. The largest of these challenges was how to achieve the electrical coordination insulation, while maintaining the buckling resistance and achieving the necessary electrical tracking within the crossarm length, and without diagonal or redundant members.

The answer was that the compression members would need to withstand the buckling load on their own, without the use of any bracing members, as illustrated in Figure 19.

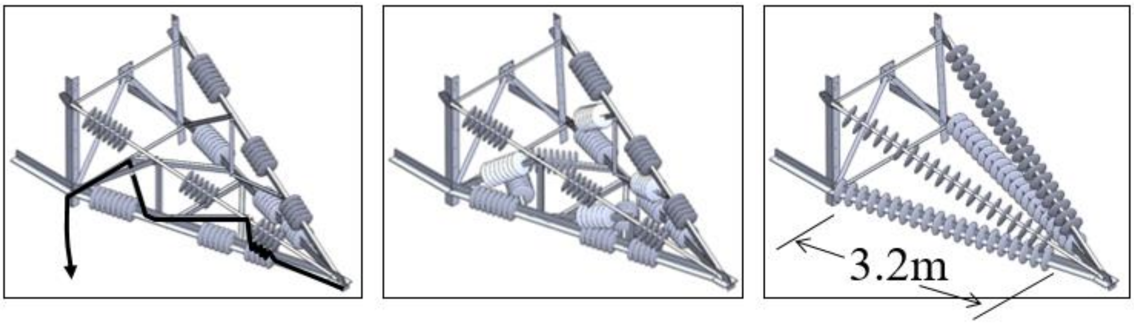


Figure 19 - electrical requirements of RICAs

Preliminary research into existing composite line post insulators concluded that there were no products available on the market that could achieve these requirements. This led the project team to investigate novel shape options that were a move away from a solid circular profile, which is not very efficient at withstanding compression loads (Figure 20).

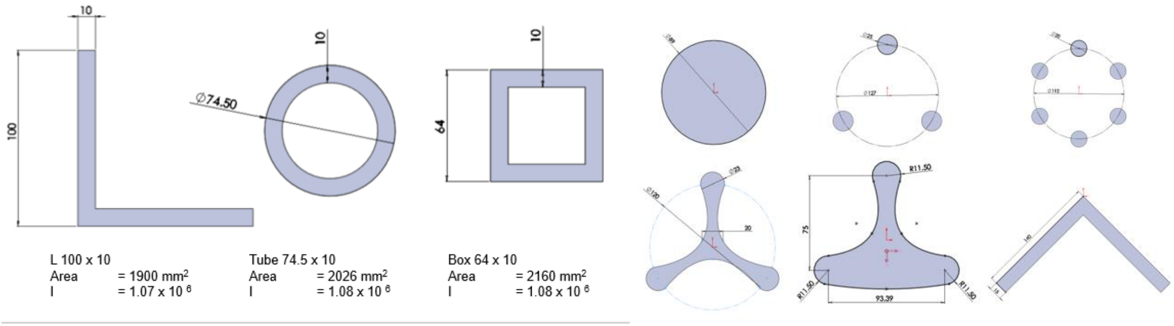


Figure 20 – novel shape options for RICA insulator profiles

Ultimately, this line of investigation led to the core enabling IP generated to overcome the problem, being the non-circular composite profile. This IP was initially filed by the University of Manchester and subsequently transferred into a spin off company that was tasked with continuing its evolution through to market readiness. The non-circular concept was validated during phase 2 through further mechanical and electrical testing.

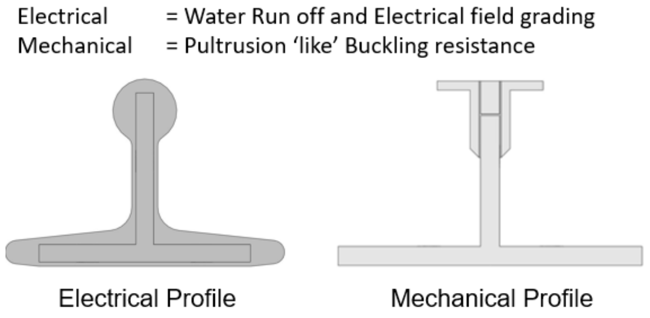


Figure 21 – Novel high compression strength insulator profiles

To save on tooling costs at this early stage in the project, the composite profile was initially manufactured by using off-the-shelf composite 'pultrusions', bonded together using high strength adhesive. For the electrical trial, these pultrusions were then over moulded to create the smooth shape and then over moulded with silicone sheds that were cast by hand and individually applied to the composite profile. While not suitable for long term use, this was sufficient to demonstrate the electrical coordination potential of the solution at 400kV; these are shown in Figure 22.

Mould split leaving final part with bare ends for attachment plates

Figure 22 - The electrical prototype fabrication which shows how the fabricated pultrusion member was encased in a fibreglass mould and cast with resin

Finally, silicone sheds were individually cast and adhered to the composite profile using a silicone adhesive (Figure 23).

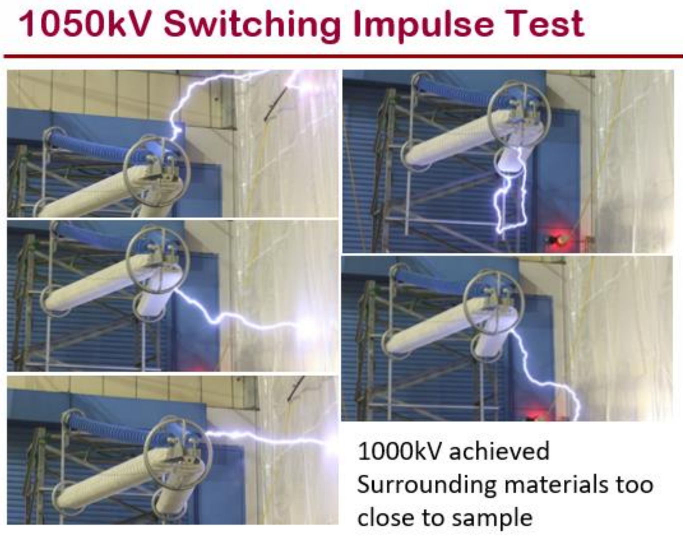
Sheds are slid down over the horizontal profile and sealed with silicone

Sheds are alternated large and small to maximise the creepage ratio (IEC 60815)

Figure 23 – Silicone sheds provided representative electrical insulation characteristics

The insulator assembly was then spray coated in a 'Sylgard' (Dow Corning) silicone insulation product to provide the necessary electrical hydrophobic and weather resistant properties.

The electrical assembly was tested in the high voltage lab at the University of Manchester where it was subjected to representative design validation testing such as switching and lightning impulse in both wet and dry conditions (Figure 24).



1050kV Switching Impulse Test

1000kV achieved
Surrounding materials too close to sample

Figure 24 – RICA electrical coordination testing at UoM HV labs

VII.2.1 Technical validation Project achevements:

- Validated non-circular insulator concept under full L3 mechanical load conditions
- Validated electrically representative non-circular based RICA under high voltage conditions

VII.2.2 Gap Analysis:

- Optimisation of both the mechanical and electrical design
- Requirement for long term aging under energised conditions

- Better understanding of environmental performance in terms of snow and ice build up and the effect of the semi-rigid support of the conductor.
- Understanding of erection and maintenance techniques

VII.3 Lecht (NIA_SHET_0006):

Introduction

The Lecht trial was completed on a de-energised section of PL16 Line that was being de-commissioned in the Cairngorms National Park as a planning condition related to the new 400kV Beauly-Denny line construction. The project aims were to demonstrate mechanical feasibility, constructability and environmental performance of the composite cross arms.

The non-circular insulators incorporated in the cross arms have a relative compression strength of twice a comparable circular profile as shown in Figure 25. Therefore, for the same compressive load capacity, a profile will only weigh half a solid circular profile and therefore be easier to handle, have less material cost and therefore less embedded CO2.

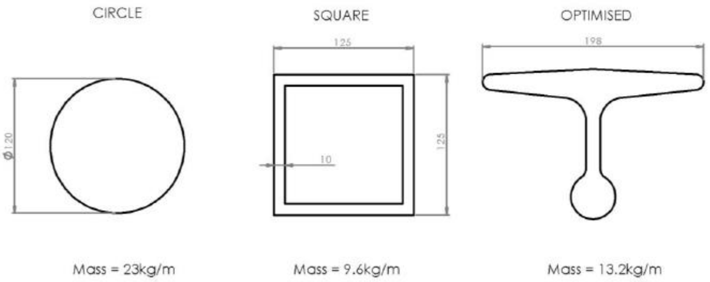


Figure 25 – Relative structural performance of the Arago profile to circular and square hollow sections.

However, the move to non-circular as associated uncertainty due to the unconventional shape[12]. Part of the Lecht project was to investigate these impacts in a high-altitude location known for snow accretion. A project conclusion was that the non-circular members would accrete less snow and ice if they were rotated around their horizontal axis by 184 degrees. Other changes to the geometry was to specify that the horizontal raking members should be inclined by 6 degrees to the horizontal plane to further improve water run off (Figure 26).

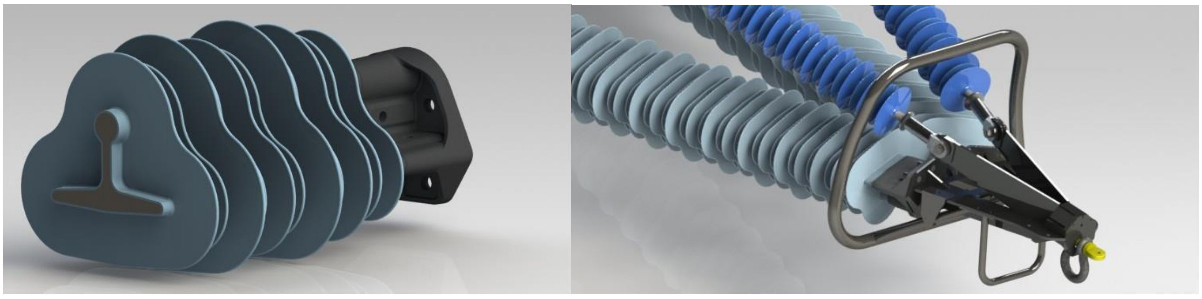


Figure 26 – Rendering of non-circular profile

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[12] Both of utilising insulators in a horizontal orientation and the relatively flat surfaces of the insulator profile.

Other work completed ahead of the Lecht installation was a thorough structural analysis of the ICAs including FEA simulations and full testing of normal and broken wire load conditions (Figure 27).

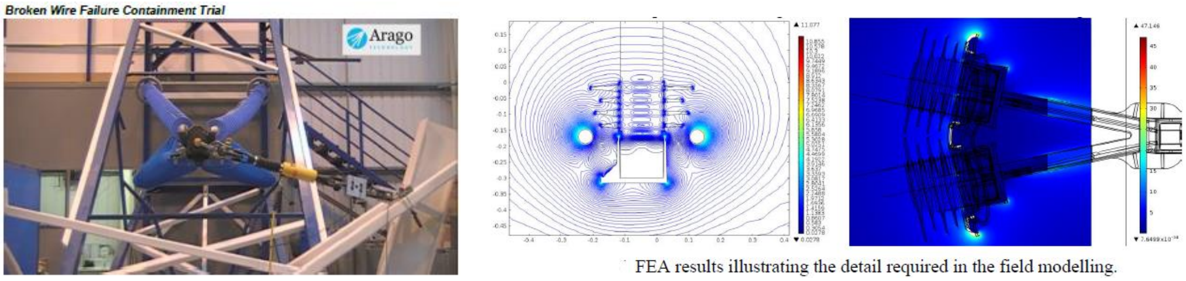

Figure 27 – Testing and computer simulations to validate performance

The photos below provide a view of the final Lecht installation process (Figure 28).

Figure 28 – Photos of Lecht installation

VII.3.1 Structural Validation Project achievements:

- Understanding of snow and ice performance relative to traditional insulators
- Improvements to the non-circular insulator geometry and ICA arrangement
- Validation of structural performance of 400kV insulator on traditional crossarm footprint
- Improved undertanding of construction related procedures

VII.3.2 Gap Analysis:

- Only retro-fitted the middle phase insulators so didn’t develop method for top phase replacement
- No conductor change so no tower strengthening required

VII.4 St. Fergus (NIA_SHET_0006):

VII.4.1 Introduction

The St. Fergus trial involved the long term evaluation of 2 ICAs under 400kV electrical loading in an off grid coastal environment. Data from this trial was highly monitored and collected over a 6 year period focusing on electrical leakage currents over all 8 insulating members (4 No. non-circular compression members and 4 No. Traditional circular polymeric tension insulators).

The project represented a step change in prototype quality as it incorporated all the of the improvements identified from the Lecht trials with production quality manufacturing techniques to make the novel compression insulators.

The site was inspected at 6 monthly intervals over the with observations made relating to the surface condition of the insulators relative to data collected on wind speed, humidity, precipitation and ambient temperature changes etc.

The trial was de-commissioned in line with the project closure and at the time all insulators were still performing well. As expected for the coastal location, strong seasonal variation was seen in leakage currents and this is associated with wind direction and resulting weather variations. Large areas of algae growth were seen on upward-facing surfaces of all the insulators and this related to an associated loss of hydrophobicity on some surfaces.

The project conclusion was that satisfactory performance was maintained during the trial period and that the algae growth that occurred at around year 3 of the trial could have been exaserbated by the proximity of local vegitation. However, it is noted that some level of algae growth should be expected in temperate climates.

The insulators from this trial have been transferred down to the NGET Deeside test facility so that they can be re-installed there for continued long term testing and monitoring under the current project, if needed. This will provide valuable insight into the performance in a second coastal location and will serve as an important early warning system should further performance related factors start to show in the future.

Further detailed information on the results of this trial are available in a paper published by the University of Mancehster Titled: Six-year Trial of an HV overhead line Wide Bodied Composite Insulator which is due to be published in TDEI in a December 2020 special issue on condition monitoring.

VII.4.2 Manufacturing

A milestone for this project was the transition from manual manufacturing to production quality manufacturing processes where products were produced for use at St. Fergus and for electrical and mechanical design validation testing in the lab (Figure 29).

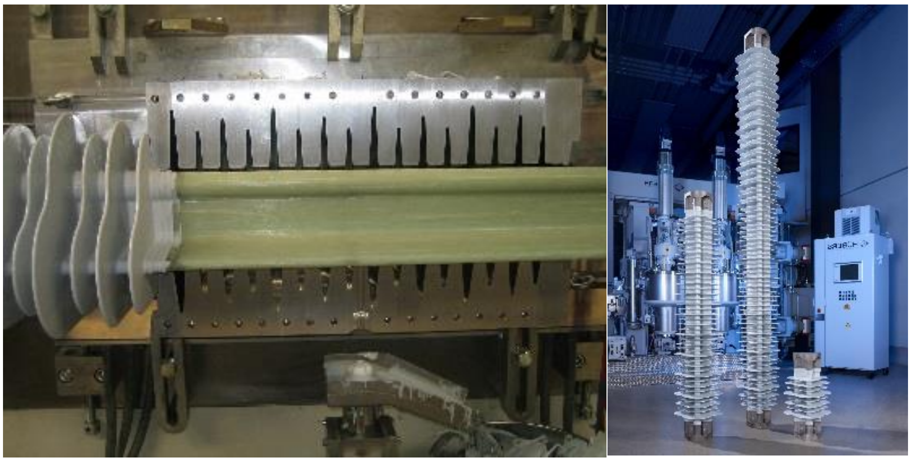

Figure 29 – Production of insulators for St. Fergus trials

Before the insulators were installed in the field, they were subjected to tests that would be required for type approval to demonstrate that they were sufficiently robust for the trial. Examples of the testing completed are listed below:

VII.4.3 Testing completed in project

- 2D test rig developed for end fitting tension tests

- Boiling water test rig to perform 100h boiling test on short samples
- End fitting attachment assembly jig
- Electrical testing at UoM (tracking / erosion / HV with bespoke water spray kit etc)

VII.4.4 St Fergus description

The Figure 30 below shows the ICAs installed on the bespoke support structure and the surrounding trees. The level of vegetation growth experienced between the start and the end of the project is seen between the two photos.

Figure 30 – Test tower with ICAs at St. Fergus.

Figure 31 shows how the leakage current varied over the course of the experimental period. It can be seen that the compression members and tension members performed in a similar fashion, serving to validate the concept. The variation on leakage currents was due to different levels of induced currents in the system resulting to the relative orientation of each insulating member relative to each other and the feed conductor.

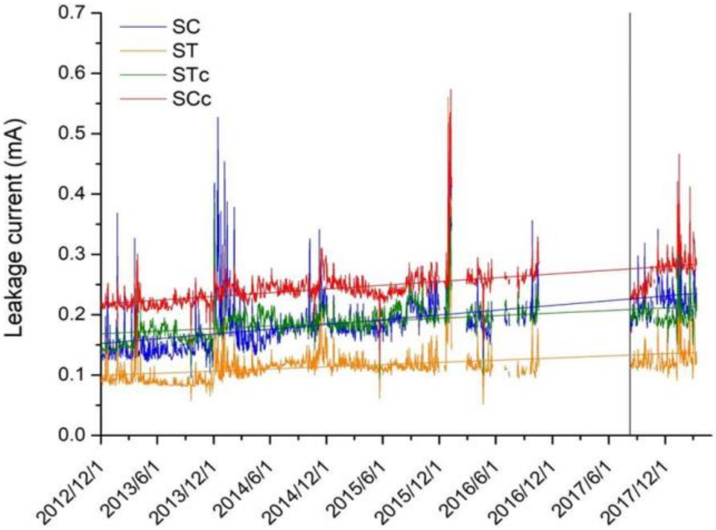

Figure 31 – The daily average rms value of current measured on all four of the elements of the south-pointing cross-arm. The missing data in 2017 was due to an outage in instrumentation communications.

A point of interest within the project was the algae growth that occurred on all of the insulator members. It was reasoned that this growth is more severe due to the proximity to the local low level vegetation. Similaraly the growth was experienced on both the traditional insulators and the compression members.

Figure 32 – Images showing the level of algae growth after 35 months in service.

VII.4.5 Electrical validation project achievments

- Manufactured production quality prototypes
- Completed lab testing according to industry standards to validate quality
- Designed and installed bespoke test tower to mount insulators and commissioned test site and 11kV to 400kV transformer
- Established condition monitoring equipment to allow remote monitoring of all environmental factors and leakage current through a 4G mobile network
- Monitored and reported on outcomes regularly over the full 6 month trial period.

VII.4.6 Gap Analysis

- Some improvements needed to increase the reliability of the monitoring equipment
- This project didn’t include any work on installation or O&M under standard network conditions as all work was under taken from a Mobile Elevating Work Platform (MEWP).
- The trial would have benefited from being undertaken for a longer time frame

VII.5 132kV Aberdeen network installation (NIA_SHET_0007)

VII.5.1 Introduction

Following the long-term operation of the insulators at St. Fergus, the Aberdeen network installation was the first trial that involved installing the compression insulators on the energised Network. A pair of PL16-D2 towers linking Cragiebuckler with Kintore (Aberdeenshire) was chosen for the RICA trial based on ease of access.

The key objectives of this project were to drive the type approval testing to a level that SHETL engineers would accept them. This involved completing all the necessary quality assurance documentation and procedures, as well as undertaking the necessary formal testing. The other key objective was to develop the required installation techniques to install them under outage conditions with the associated time constraints.

A total of six RICAs were installed for operation at 132kV. These demonstrated a new capability to retrofit existing towers with insulating cross arms which provides system operators with a range of new system design options. Namely:

1. Doubling capacity with existing towers through voltage and current upgrade when using novel conductors.
2. Simple solution to discrete ground clearance issues.
3. Up to 30% height reduction against conventional towers when considering new build.

4. Considerable reduction in tower and foundation costs when considering new build (important in hard to reach locations)
5. Whilst subjective, many consider the elimination of the suspension insulators improves the look of the towers. This could have particular benefit again when contending with planning objections for new lines.

VII.5.2 Installation, access and egress

A crane was employed for the study, the exercise provided a useful opportunity to assess the viability of removing the existing steel cross arms, making the required modifications to the attachment points[13] and re-installing the RICAs.

The photos below show key stages of the installation process, including a light weight platform that was designed to enable the linemen to walk on top of the insulating sheds without causing damage.

Figure 33 – Installation of RICAs on SHETL network

VII.5.3 Network installation project achievements

- Completed type approval to SHETL requirements
- Operated RICAs on UK transmission network with no issues for more than 2 years before the trial was completed
- Positive responses from local residents suggested that they preferred the look of the RICAs over the traditional insulators strung on the opposite circuit.

VII.5.4 Gap Analysis

- The cross arms were not validated on the network at 400kV geometry of operation
- A crane was used for installation, leaving many installations questions unanswered – particularly how to install the top RICA.
- Only suspension towers were modified leaving solutions required for angle and termination towers.

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[13] Additional Steel work was required to maintain the phase spacing arrangement and also to provide a min. 300mm electrical standoff between the tower body and the RICAs.

- Potentially more efficient designs such as pivoting Vee type RICAs could be installed offering further savings to the consumer and improving the RICA business case.

VII.5.5 Market Progression

The previous sections have highlighted the UK development of this technology. There have also been other developments driven by the market place, which are now allowing new build towers to include ICAs. The development in the UK has shown strong potential for further application, but the developments aboard should also not be ignored as there are many other designs which may offer advantages.

VII.5.6 Technical References

[1] Kopsidas, K., Rowland, S. M., Baharom, M. N. R. and Cotton, I. (2010) Power transfer capacity improvements of existing overhead line systems. IEEE International Symposium on Electrical Insulation, San Diego, CA, 2010, pp. 1-5, doi: 10.1109/ELINSL.2010.5549755.

Appendix VIII - Abbreviations

Acronym	Description	Acronym	Description
BS	British Standard	NGET	National Grid Electricity Transmission
CAD	Computer Aided Design	NIA	Network Innovation Allowance
CISPR	Comité International Spécial des Perturbations Radioélectriques	NIC	Network Innovation Competition
CO2	Carbon Dioxide	NOA	Network Options Assessment
COVID	Coronavirus Disease	NPSC	Net Present Social Cost
CSF	Critical Success Factor	NPSV	Net Present Social Value
CV	Curriculum Vitae	NPV	Net Present Value
DLR	Dynamic Line Rating	NSI	National Safety Instruction
DNO	Distribution Network Operator	OHL	Overhead Line
EMF	Electromotive Force	PLS	Power Line Systems
EPC	Engineering Procurement Construction	PLSCAD	Power Line Systems Computer Aided Design
ESO	Electricity System Operator	RACI	Responsibility Accountability Consultation Information
ETYS	Electricity Ten Year Statement	RFI	Request for Information
EU	European Union	RICA	Retrofit Insulated Cross-arm
EV	Electric Vehicle	RIIO	Revenue Incentives Innovation Outputs
FEA	Finite Element Analysis	*SF*	Safety Factor
FMEA	Failure Modes Effects Analysis	SHET	Scottish Hydro Electric Transmission
FRR	Finance and Regulatory Review	SHETL	Scottish Hydro Electric Transmission Limited
FSP	Full Submission Process	SHS	Safety, Heath and Sustainability
HM	Her Majesty's	SMART	Specific Measurable Achievable Realistic Time-constrained
HTLS	High Temperature Low Sag	*SML*	Specified Mechanical Loads
HV	High Voltage	SO	System Operator
I2I	Innovation 2 Industry Ltd	SPEN	Scottish Power Energy Networks
ICA	Insulated Cross-arm	SSE	Scottish and Southern Energy
IEC	International Electrochemical Commission	SSEN	Scottish and Southern Electricity Networks
IFI	Innovation Funding Incentive (replaced by NIA)	NeSTS	New Suite of Transmission Structures
IFRS	International Financial Reporting Standards	TAB	Technical Advisory Board
IHS	Information Handling Services [IHS Markit is NGET’s information management tool]	TDEI	Transactions on Dielectrics and Electrical Insulation
IP	Intellectual Property	TIRSC	Transmission Investment and Review Sanction Committee
IPR	Intellectual Property Rights	TO	Transmission Operator
ISP	Initial Submission Process	TRL	Technological Readiness Level

MDTol	MDToL	TS	Technical Specifications
MEWP	Mobile Elevating Work Platform	UHV	Ultra High Voltage
MW	Megawatt	VIP	Visual Impact Provision
NDA	Non Disclosure Agreement	WTP	Willingness to Pay

Appendix IX - List of Figures and Tables

IX.1 Figures

IX.2 Tables

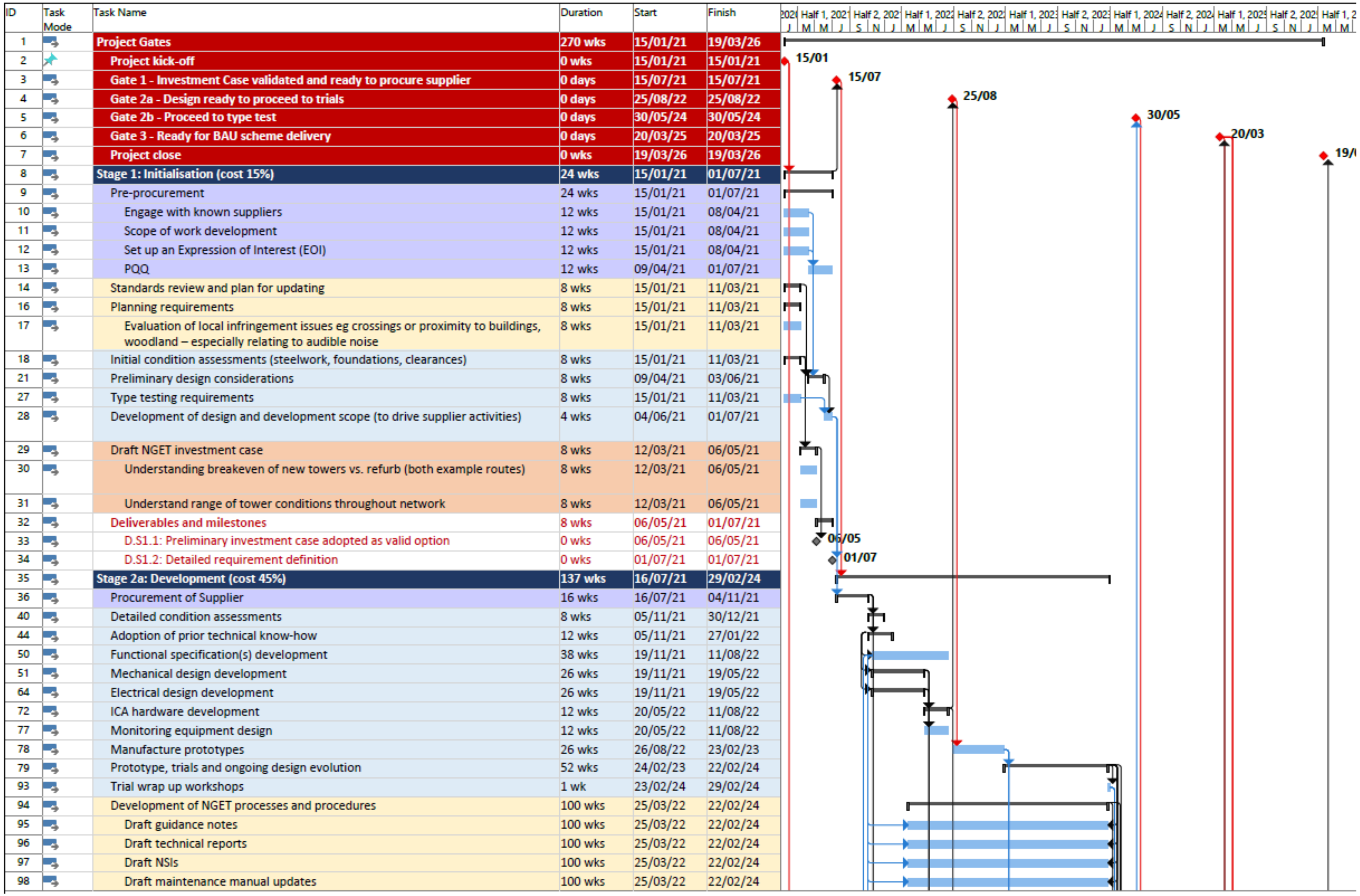
Appendix X - Project communications methods

A summary of the engagement streams we intend to use is given in Table 28.

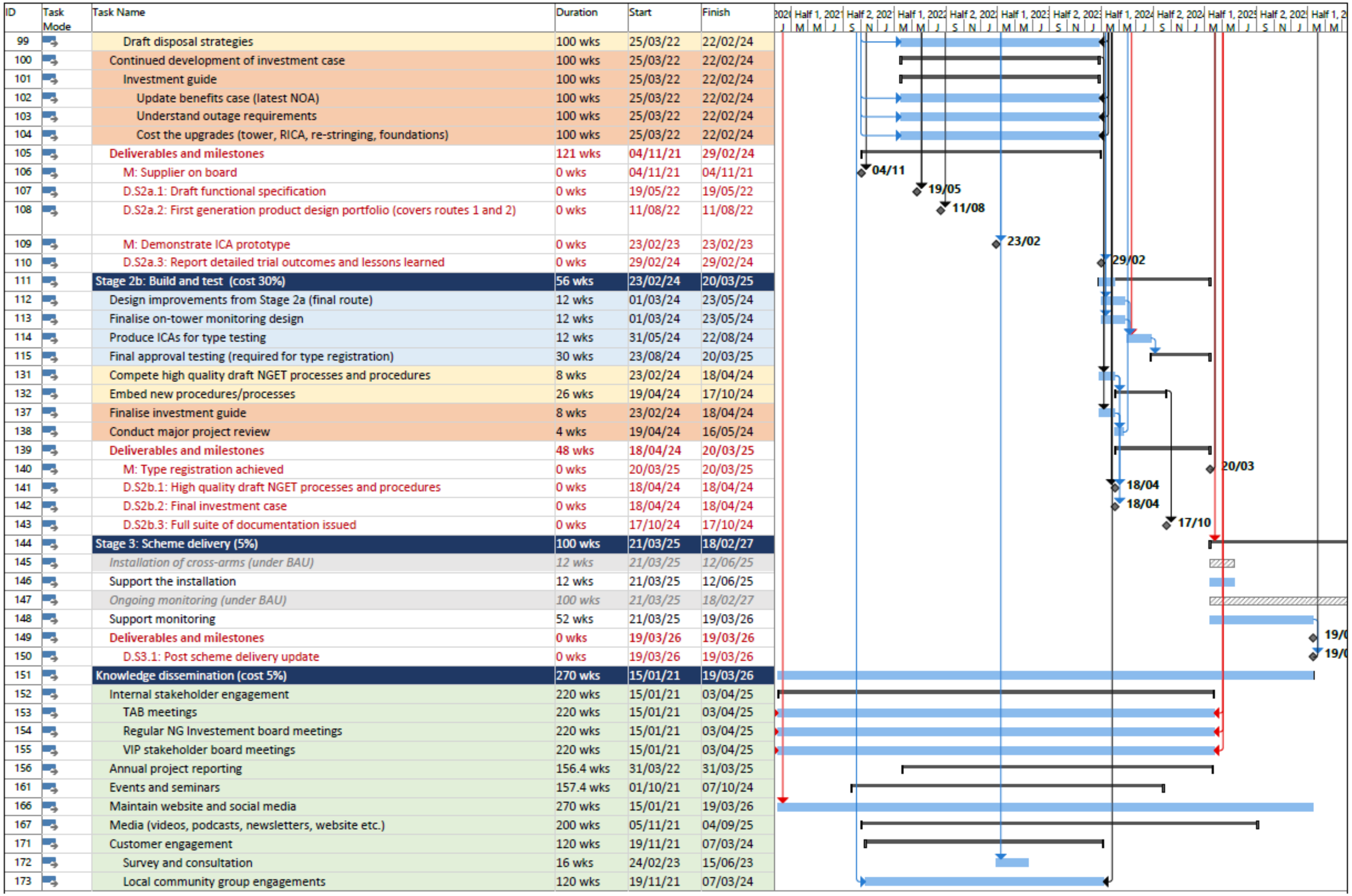
Table 28: Engagement streams we propose to use.

Streams	Description
TAB & Approval gates	Technical Advisory board (TAB) – Attended by UK utilities, universities and other industry stakeholders. These meeting will encourage active engagement between the utilities and seek active input into the project and help provide governance at key decision gates using stakeholder input.
Group Reporting	This involves reporting updates and outcomes to other governance committees: Transmission Investment and Review Sanction Committee (TIRSC), Visual Impact Provision (VIP) project, and other stakeholder groups. This will help to ensure senior stakeholders can be informed and support the project.
Web Videos	Videos will be used to provide easily digestible information as a 'gateway' communication
Podcast	Podcasts will be used to provide more detail on specific questions and allow the detail around specific issues to be discussed transparently.
Newsletter	Regular progress updates will be provided, which provide stakeholders the options of reading in their own time. These will be posted through existing communication channels to include stakeholders.
Presentations	Presentations will be given to different key stakeholder groups and will be used to promote the concepts and share information with the wider industry.
Events	The project will attend specific events and support the low carbon narrative through industry events.
Scheme Support Materials	Further communication materials will be produced to help future schemes with disseminating information to stakeholders – where their community will be impacted by RICAs
Website Updates	Information will be stored and shared via the National Grid's website – leveraging existing communications channels
Social Media	Successes and updates will be provided through social media to deleverage existing communication channels

Appendix XI - Project Plan



ID	Task Mode	Task Name	Duration	Start	Finish
1		**Project Gates**	**270 wks**	**15/01/21**	**19/03/26**
2		**Project kick-off**	**0 wks**	**15/01/21**	**15/01/21**
3		**Gate 1 - Investment Case validated and ready to procure supplier**	**0 days**	**15/07/21**	**15/07/21**
4		**Gate 2a - Design ready to proceed to trials**	**0 days**	**25/08/22**	**25/08/22**
5		**Gate 2b - Proceed to type test**	**0 days**	**30/05/24**	**30/05/24**
6		**Gate 3 - Ready for BAU scheme delivery**	**0 days**	**20/03/25**	**20/03/25**
7		**Project close**	**0 wks**	**19/03/26**	**19/03/26**
8		**Stage 1: Initialisation (cost 15%)**	**24 wks**	**15/01/21**	**01/07/21**
9		Pre-procurement	24 wks	15/01/21	01/07/21
10		Engage with known suppliers	12 wks	15/01/21	08/04/21
11		Scope of work development	12 wks	15/01/21	08/04/21
12		Set up an Expression of Interest (EOI)	12 wks	15/01/21	08/04/21
13		PQQ	12 wks	09/04/21	01/07/21
14		Standards review and plan for updating	8 wks	15/01/21	11/03/21
16		Planning requirements	8 wks	15/01/21	11/03/21
17		Evaluation of local infringement issues eg crossings or proximity to buildings, woodland – especially relating to audible noise	8 wks	15/01/21	11/03/21
18		Initial condition assessments (steelwork, foundations, clearances)	8 wks	15/01/21	11/03/21
21		Preliminary design considerations	8 wks	09/04/21	03/06/21
27		Type testing requirements	8 wks	15/01/21	11/03/21
28		Development of design and development scope (to drive supplier activities)	4 wks	04/06/21	01/07/21
29		Draft NGET investment case	8 wks	12/03/21	06/05/21
30		Understanding breakeven of new towers vs. refurb (both example routes)	8 wks	12/03/21	06/05/21
31		Understand range of tower conditions throughout network	8 wks	12/03/21	06/05/21
32		Deliverables and milestones	8 wks	06/05/21	01/07/21
33		D.S1.1: Preliminary investment case adopted as valid option	0 wks	06/05/21	06/05/21
34		D.S1.2: Detailed requirement definition	0 wks	01/07/21	01/07/21
35		**Stage 2a: Development (cost 45%)**	**137 wks**	**16/07/21**	**29/02/24**
36		Procurement of Supplier	16 wks	16/07/21	04/11/21
40		Detailed condition assessments	8 wks	05/11/21	30/12/21
44		Adoption of prior technical know-how	12 wks	05/11/21	27/01/22
50		Functional specification(s) development	38 wks	19/11/21	11/08/22
51		Mechanical design development	26 wks	19/11/21	19/05/22
64		Electrical design development	26 wks	19/11/21	19/05/22
72		ICA hardware development	12 wks	20/05/22	11/08/22
77		Monitoring equipment design	12 wks	20/05/22	11/08/22
78		Manufacture prototypes	26 wks	26/08/22	23/02/23
79		Prototype, trials and ongoing design evolution	52 wks	24/02/23	22/02/24
93		Trial wrap up workshops	1 wk	23/02/24	29/02/24
94		Development of NGET processes and procedures	100 wks	25/03/22	22/02/24
95		Draft guidance notes	100 wks	25/03/22	22/02/24
96		Draft technical reports	100 wks	25/03/22	22/02/24
97		Draft NSIs	100 wks	25/03/22	22/02/24
98		Draft maintenance manual updates	100 wks	25/03/22	22/02/24



ID	Task Mode	Task Name	Duration	Start	Finish
99		Draft disposal strategies	100 wks	25/03/22	22/02/24
100		Continued development of investment case	100 wks	25/03/22	22/02/24
101		Investment guide	100 wks	25/03/22	22/02/24
102		Update benefits case (latest NOA)	100 wks	25/03/22	22/02/24
103		Understand outage requirements	100 wks	25/03/22	22/02/24
104		Cost the upgrades (tower, RICA, re-stringing, foundations)	100 wks	25/03/22	22/02/24
105		Deliverables and milestones	121 wks	04/11/21	29/02/24
106		M: Supplier on board	0 wks	04/11/21	04/11/21
107		D.S2a.1: Draft functional specification	0 wks	19/05/22	19/05/22
108		D.S2a.2: First generation product design portfolio (covers routes 1 and 2)	0 wks	11/08/22	11/08/22
109		M: Demonstrate ICA prototype	0 wks	23/02/23	23/02/23
110		D.S2a.3: Report detailed trial outcomes and lessons learned	0 wks	29/02/24	29/02/24
111		Stage 2b: Build and test (cost 30%)	56 wks	23/02/24	20/03/25
112		Design improvements from Stage 2a (final route)	12 wks	01/03/24	23/05/24
113		Finalise on-tower monitoring design	12 wks	01/03/24	23/05/24
114		Produce ICAs for type testing	12 wks	31/05/24	22/08/24
115		Final approval testing (required for type registration)	30 wks	23/08/24	20/03/25
131		Compete high quality draft NGET processes and procedures	8 wks	23/02/24	18/04/24
132		Embed new procedures/processes	26 wks	19/04/24	17/10/24
137		Finalise investment guide	8 wks	23/02/24	18/04/24
138		Conduct major project review	4 wks	19/04/24	16/05/24
139		Deliverables and milestones	48 wks	18/04/24	20/03/25
140		M: Type registration achieved	0 wks	20/03/25	20/03/25
141		D.S2b.1: High quality draft NGET processes and procedures	0 wks	18/04/24	18/04/24
142		D.S2b.2: Final investment case	0 wks	18/04/24	18/04/24
143		D.S2b.3: Full suite of documentation issued	0 wks	17/10/24	17/10/24
144		Stage 3: Scheme delivery (5%)	100 wks	21/03/25	18/02/27
145		*Installation of cross-arms (under BAU)*	*12 wks*	*21/03/25*	*12/06/25*
146		Support the installation	12 wks	21/03/25	12/06/25
147		*Ongoing monitoring (under BAU)*	*100 wks*	*21/03/25*	*18/02/27*
148		Support monitoring	52 wks	21/03/25	19/03/26
149		Deliverables and milestones	0 wks	19/03/26	19/03/26
150		D.S3.1: Post scheme delivery update	0 wks	19/03/26	19/03/26
151		Knowledge dissemination (cost 5%)	270 wks	15/01/21	19/03/26
152		Internal stakeholder engagement	220 wks	15/01/21	03/04/25
153		TAB meetings	220 wks	15/01/21	03/04/25
154		Regular NG Investement board meetings	220 wks	15/01/21	03/04/25
155		VIP stakeholder board meetings	220 wks	15/01/21	03/04/25
156		Annual project reporting	156.4 wks	31/03/22	31/03/25
161		Events and seminars	157.4 wks	01/10/21	07/10/24
166		Maintain website and social media	270 wks	15/01/21	19/03/26
167		Media (videos, podcasts, newsletters, website etc.)	200 wks	05/11/21	04/09/25
171		Customer engagement	120 wks	19/11/21	07/03/24
172		Survey and consultation	16 wks	24/02/23	15/06/23
173		Local community group engagements	120 wks	19/11/21	07/03/24