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

NIA Project Registration and PEA Document

Date of Submission

Aug 2024

Project Reference Number

NIA2_NGET0070

Project Registration

Project Title

EcoBuild 3D: Sustainable Substation Foundations

Project Reference Number

NIA2_NGET0070

Project Licensee(s)

National Grid Electricity Transmission

Project Start

September 2024

Project Duration

1 year and 1 month

Nominated Project Contact(s)

Muhammad Shaban

Project Budget

£556,964.00

Summary

The project aims to use a 3D printer to print substation foundations using low carbon concrete (Geo polymer mix) to reduce the construction driven carbon emissions. The supplier (Hyperion) has 3D printing mortar capable of resisting high forces with 50 years of design life. The project will optimize the design and will reduce the current material use by 50%. The foundations will be twice light as compared to the typical foundations. They will be transportable and can be precast near the site. The aim is to achieve the carbon emission reduction, concrete material reduction, weight reduction, labour reduction, and swiftness of the process. This project at first will explore the printability of lighting column foundation which is simple approach as compared to other foundations.

Nominated Contact Email Address(es)

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Problem Being Solved

Concrete industry produces 8% of global carbon dioxide emission making it the most polluting material used globally. Concrete accounts for 25% of the embodied carbon of construction in the UK. 90Mt/year concrete is being used in the UK with 10Mt CO2e/year equalling to 8 million additional cars on the road. In addition to emission issue, concrete has material inefficiencies and produces large amount of waste. Mixing and pouring of concrete is a labour-intensive process and has been a core of health and safety issues. There is a lack of labour in construction market and the problem will get severe when 40% of the existing labour will retire by 2030. National Grid (NG) has planned to do BIGWORK in the network in expanding and upgrading the existing network requiring more than ever construction opportunities. Use of concrete structures is reduced due to longer construction time required, but foundations are principally concrete in all substations. NG has challenge of how to use concrete when it is such a significant source of greenhouse gas emissions (GHG).

NG has commitments to Environmental Action Plan 2022 and net Zero targets to achieve by 2026. The above challenges increase the carbon footprint of the electricity transmission projects. The use of alternative materials has not been explored in detail due to availability of the steel, aluminium, and concrete so far, and there has been less focus on asset life cycle's environmental impact.

Method(s)

Phase 1: Design & engineering of structures

- Design of 3D printed foundations based on NG's specifications and construction drawings.
- Calculation of structure to Eurocodes (EN 1992, EN 1997, etc.).
- Planning of testing for certification for the UK market.
- Calculation report to be shared to NG for approval.

Phase 2: Production of full-scale foundations for inspection, testing and site monitoring.

- Production of foundations for inspection and site assembly.
- Production of foundations for testing.
- 3D printing production report.

Phase 3: Lab-scale and full testing of structures.

- Collaboration with accredited independent laboratory.
- Testing for serviceability and ultimate limit state of all specimens.
- Testing report to be delivered to NG.

Phase 4: Installation of units, monitoring and Micro-factory demo.

- Shipping of foundations and installation by National Grid for monitoring.
- Visit to site and inspection by Hyperion's engineering team.
- Demonstration event of Micro-factory and printing for NG's teams and relevant stakeholders.
- Delivery of final project report.

Scope

NG will specify the design requirements and the supplier will use their internal resources to optimise the designs. Optimised design foundations capable of resisting the same load will be modelled and approved by NG. Like the traditional foundation, the 3D printed one will incorporate standard reinforcement bars as per EN 1992-1. Supplier will produce an Engineering report based on all the calculations to local building codes and material properties along with the certified lab test results. Report will include relevant production steps, description of materials and technology used. Supplier will produce 3 different types of foundation units (75 in total) for testing and monitoring purposes. Lab and full-scale testing like mechanical and durability tests will be performed to verify the set standards. Foundations will then be delivered to Deeside for demonstration purposes. Site visits will be conducted during erection/construction, installation and reports will be published on the ease of installation and outcomes from civil contractor. Reports will also include laboratory/Site testing with findings for bolt pull-out and shear testing, crack control testing and recommendations of application of each. Micro-factory visits and 3D printing demonstration for National Grid's relevant teams will be arranged. Lighting column foundations are low risk profile assets and are non-critical in case the design fails hence will be the first choice of foundations to be printed. The next stage will explore other substation foundation options which will be decided based on results from first set of foundations.

Throughout the project, we will be monitoring the following KPIs and report them to wider NG teams. Main KPIs will measure sustainability, efficiency, and cost of the structures.

- eCO2: 40% reductions in CO2 emissions using 3D printed optimized foundations compared to traditional building technology. LCA detailed calculation to assess carbon savings.
- Time: 50% reduction in time for readiness of asset (production, shipment, excavation, and installation).
- Cost: 20% reduction in cost in comparison of entire value chain, from production to installation.
- Waste: 50% reduction of waste related to building material and reuse of excavated soil.
- Circularity: 20% recyclability/reusability of materials (as % of total weight).

Final report will be published with all the learning outcomes and will be shared with all the licensees. A dissemination event will present all the results to relevant stakeholders with the recommendations of certain technologies ready to use in business as usual (BAU).

Objective(s)

The work will be delivered in discrete work packages each with a focus on different objectives linked to the overall aim to explore low

carbon materials used in Civils. This project is planned to take 12 months with the following major objectives:

- Develop understanding of the possibility of integration of low carbon concrete and 3D concrete printing.
- Prove the specification requirements and design standards are achieved through 3D printing.
- Identify design requirements and changes in design compared to existing foundation designs.
- Like for like comparison of end foundation designs (weight, carbon footprint, ease of construction i.e., reduced asset management and decommissioning).
- Demonstration and testing of the foundations.
- Final recommendations to identify the potential benefits and implementation learning outcome.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

An assessment of distributional impacts (technical, financial and wellbeing related) for this project has been conducted using a bespoke assessment tool, which assesses the project as having a positive, negative, or neutral effect on consumers in vulnerable situations. To help inform the assessment, this tool considers the categories of consumers identified in the Priority Services Register. This project has been assessed as having an overall positive impact on consumers in vulnerable situations. The assessment has identified that this project will look to help NGET to invest on better construction structures and Civils which will reduce both cost and emissions for consumers.

This project ensures that NGET and the UK energy industry are at the forefront of global developments in asset management of transmission system, enabling the industry to make decisions that could reduce the carbon emissions and thus reduce OPEX expenditure and are supported by comprehensive research and experiments. The scale of substation development in terms of installation of assets requiring foundations is unprecedented and there is a concern that the understanding around low carbon concrete and its trials is not mature enough for future decisions. With the access to the latest development in the field, NGET will be able to manage the assets more efficiently and effectively which could deliver savings. Furthermore, the leveraged funding mechanism ensures that expensive research can be carried out at subsidised rates, thereby ensuring the best value for consumers' money. The project will not restrict benefits delivered to vulnerable consumers based on any vulnerability class.

Success Criteria

The project will be considered successful if the objectives are achieved, specifically:

- Successfully explore the low carbon concrete which can be utilised by NGET in near future especially T3.
- Understand the ability and value of design requirements compared to traditional foundations.
- Understand the potential impact of different factors like carbon footprint, weight, asset management, and decommissioning.
- Make clear recommendations regarding the availability and possible development of the materials to achieve net zero targets.

Sufficient knowledge would be gained for overall low carbon construction techniques like 3D printing that can be utilised to reduce the scope 3 emissions associated with the construction.

Project Partners and External Funding

The following project partners will be supporting the project:

Hyperion Robotics will design and manufacture the foundations.
NGET is providing all the funding for the project and is the lead network.

Potential for New Learning

There is very limited amount of work being done in this area and especially the existing one focus on theoretical research and not the live product development and trial. This work will provide the basis of our understanding of the capabilities of concrete 3D printing in substation environment and its associated impact. The work will be valuable resource for NG and have immediate application in subsequent projects in development. The sustainability opportunities register will be used to seek our new ideas and areas of focus; these will help shape conversations with future suppliers. In addition to potential for new learning outlined above, promotion of 3D printing of concrete using low carbon concrete like Geo polymer mix for substation foundations will aid in facilitating compliance with legislative requirements and achieving net zero targets by 2026.

The following will be new knowledge expected from carrying out the project:

- Development of new learning around low carbon construction techniques and their efficacy with 3D printing.

- Operational performance data obtained for various substation foundations.
- Like for like comparison of innovative designs and materials with existing ones.
- The outputs created from the project will be shared with the interested parties in energy sector especially the NGET construction working group.

Scale of Project

All work is strategically linked and designed to deliver the defined objectives. Therefore, the scale of the project is as specified, and the studies will be undertaken to demonstrate the testing of the foundations developed. There will be additional field work in this project that would be undertaken at Deeside Centre for Innovation (DCI), Wales, UK to establish some recommendations for final report.

Technology Readiness at Start

TRL6 Large Scale

Technology Readiness at End

TRL8 Active Commissioning

Geographical Area

Foundations will be designed and produced in Finland (Base location of Hyperion Robotics). The testing will be done at Sheffield University, UK and further field testing will be done at Deeside Centre for Innovation (DCI), Wales, UK.

Revenue Allowed for the RIIO Settlement

N/A

Indicative Total NIA Project Expenditure

£501,267

Project Eligibility Assessment Part 1

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

Requirement 1

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

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

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

National Grid has a commitment with Ofgem for carbon neutral construction by 2026 and current National Grid technical specifications does not allow alternative materials like Geo polymer mix hence an innovation trial like this will develop the case to change the specifications and permit other alternatives. Alternative material options ensure future upgrades to the network that avoid emissions while delivering an efficient and secure transmission system. This project is aligned with the National Grid climate transition plan which states, “We have also identified our material hotspots for construction activities and will continue to work with partners across the industry for lower carbon alternatives”.

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

Developing an understanding regarding low carbon construction is important to reduce the negative impact of carbon dioxide emissions arising from construction. Reduction in emissions, material volume, and concrete used has huge societal benefit.

Requirement 2 / 2b

Has the potential to deliver net benefits to consumers

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

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

N/A

Please provide a calculation of the expected benefits the Solution

The benefit of this project assumes that NGET will achieve low emission material performance. Low carbon concrete and 3D printing will reduce the capital investment and foundations can be printed easily with reduced time and waste. If this project is successful, over a 10-year period, £1.5M of Societal value will be created by saving 705 tons of concrete, and 323 tons of CO2. The overall financial benefit is £1.5M including a saving of £1.7M on capital costs. The benefit ratio obtained from the project is 1:3.

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

The developed methodology is of generic nature and would be applicable to all electricity network Licensees across GB, this would be inclusive of transmission and distribution owners. The outcome of the project will determine how much emissions can be reduced by the implementation of such materials. The success of the project will boost the confidence on the material reliability and safety practices.

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

If the project is successful, the method can be further developed to roll out across GB. The estimated cost will be reviewed at the completion of the project. Conservative estimates of costs have been made for the purposes of assessing the value of this project, they are based on the cost of polymer materials. There is some cost associated to changing the technical specification to allow the use of polymer materials in the business and across GB.

Requirement 3 / 1

Involve Research, Development or Demonstration

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

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

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

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

☐ A specific novel commercial arrangement

RIIO-2 Projects

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

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

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

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

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

☐ A specific novel commercial arrangement

Specific Requirements 4 / 2a

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

The learning will be used in the planning and designing of new substations and upgrading the existing infrastructure to reduce the carbon emissions. It is the learning that may be directly applied to other networks with similar assets at similar voltages. The disseminated results will be shared with all licensees so that the reasons for the conclusions may be understood. It will be the responsibility of others to determine to what extent it applies to other equipment types and different voltages but the underlying work from this project is likely to help.

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

N/A

Is the default IPR position being applied?

☑ Yes

Project Eligibility Assessment Part 2

Not lead to unnecessary duplication

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

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

This project explores new techniques which have not been explored or implemented before. The project intends to generate evidence to change the construction activities since the technical specifications do not allow such materials now hence, they are not utilised currently. There are no other projects in development looking at 3D printing that can help reduce the emissions. The risk of duplication will be addressed through dissemination of progress with other licensees and being open to co-operate with licensees working in this space.

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

N/A

Additional Governance And Document Upload

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

There are currently no NIA/SIF projects looking at Geo polymer mix and 3D printing of concrete with potential trials within the UK. As a responsible business, NG need to cover the knowledge gap to address the issue and manage the expectation to meet the commitments of reducing the scope 3 emissions. There is no overlap between this work focusing on foundations and the work currently under way in different trials and studies. NGET technical specifications do not allow use of any other materials now. To change the specifications, we need learning data to support the evidence of alternatives. The use of alternative materials has not been explored in detail so far, and less focus on asset life cycle's environmental impact. Polymer materials and innovative designs will directly address the risks and challenges NGET is facing.

Relevant Foreground IPR

The foreground IPR will be the knowledge gained about the testing and monitoring of 3D printed foundations. The learning will be brought together for like for like comparison and development of some of the materials to demonstrate at Deeside Centre for innovation and gather some data.

Data Access Details

Data for this project and all other projects funded under the Network Innovation Allowance (NIA), Network Innovation Competition (NIC) or the new Strategic Innovation Fund (SIF) can be found or requested in a number of ways:

- A request for information via the Smarter Networks Portal at https://smarter.energynetworks.org, to contact select a project and click 'Contact Lead Network'. National Grid already publishes much of the data arising from our innovation projects here so you may wish to check this website before making an application.
- Via our Innovation website at https://www.nationalgrid.com/uk/electricity-transmission/innovation
- Via our managed mailbox box.NG.ETInnovation@nationalgrid.com

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

There exists no data that supports the evidence of using Geo polymer mix and 3D printing in substation environment, especially in foundations. A strong test data along with validation data is required to change the technical specification to utilise such materials. There is a risk factor involved that may be the materials have supply chain issues or the availability is not well defined. The risk of materials not performing up to certain standards is also a possibility and that is why business as usual cannot fund such activities. This project aims to update the specification based on the data obtained through a series of testing. This is not a business-as-usual activity as there is considerable risk associated with the development and implementation.

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

Testing to date suggests that the work will be successful, but it cannot be guaranteed. If the laboratory and computational work proves unsuccessful, the project will not proceed to BAU and technical specifications will not be changed. The project is anticipated to generate sufficient benefit to justify the expenditure over 10 years. So, the success of the project will only become truly apparent over a longer period. During that time alternative, currently unforeseeable, solutions may arise that provide greater benefit.

There are technical risks associated with any innovation project as the proposed solution may not work. Replacing the existing materials like concrete has high risk requiring additional work like finding the unknowns about the material strength, exploring the supply chain, associated technical risks, validation, and verification of results, and identifying viable sources of relevant data and science. Therefore, considering the risks associated with the success of the project, NGET believes NIA funding is the best route for the project.

This project has been approved by a senior member of staff

☑ Yes