

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

Apr 2017

### Project Reference Number

NIA\_NGN\_206

## Project Registration

### Project Title

H21 – Alternative hydrogen production and Network storage technologies

### Project Reference Number

NIA\_NGN\_206

### Project Licensee(s)

Northern Gas Networks

### Project Start

April 2017

### Project Duration

1 year and 11 months

### Nominated Project Contact(s)

NGN - Dan Sadler, NGGD - Lorna Millinton

### Project Budget

£374,000.00

## Summary

The study will consider three scenarios which will be used for design purposes for an alternative low carbon hydrogen production system utilising ATR/Ammonia and CCS and the associated impacts on the UK gas networks system for large scale roll out.

**Scenario 1:** 1 x Leeds approximately 1 GW hydrogen (average annual production 678MW) and 1.5 million tonnes of CO2 per year developed in 2025.

**Scenario 2:** 10 x Leeds approximately 10 GW hydrogen and 15 million tonnes of CO2 per year developed between 2025-2035 @ 1 GW additional hydrogen production generation per annum and 1.5 million tonnes additional CO2 sequestration requirements per year.

**Scenario 3:** 50 x Leeds approximately 50 GW hydrogen and 75 million tonnes CO2 per year developed between 2025-2045 @ 2.5 GW additional hydrogen production generation per annum and 3.75 million tonnes of additional CO2 sequestration per year.

The study will also be used to support the H21 – Strategic modelling – Major Urban Areas NIA which is due to be registered in April 2017.

## Preceding Projects

NIA\_NGN\_207 - H21 –Domestic and Commercial Metering

## Third Party Collaborators

Statoil

## Nominated Contact Email Address(es)

innovation@northerngas.co.uk

## Problem Being Solved

The H21 – Leeds City Gate Project assessed the feasibility of converting a major city's gas network from natural gas to hydrogen. The project demonstrated the feasibility of the hydrogen conversion concept, developed detailed cost estimates for the conversion of the Leeds area and an estimate of the costs for an incremental roll out of hydrogen conversion nationwide.

The H21 Leeds city gate project identified (Section 10) the next steps required to move this concept towards a policy decision through a series of strategic projects aimed at filling critical evidence gaps, this was referred to as the 'H21 roadmap'.

To execute this H21 roadmap will require a combination of large scale NIC type projects, a government led program of research and a suite of smaller NIA projects. These projects will ensure the UK gas networks will understand the impact of hydrogen conversion in four key areas:

1. Application and impact of new equipment within the network. This will ensure a future conversion to hydrogen comprises the optimised selection of assets utilising the best technologies from around the world in the interests of gas customers.
2. Transportation of a different form of gas, i.e. 100% hydrogen on existing licensee assets
3. Operation of the network and its configuration when transporting 100% hydrogen.
4. The commercial impact of a hydrogen conversion and the alterations required to current commercial practices across the gas industry e.g energy efficiency losses across hydrogen production assets, different leakage model impacts etc.

This work will support the requirement for government to make firm energy policy decisions by the early 2020s. Without this suite of projects the opportunity for 100% hydrogen to play a significant role in future decarbonisation pathways may not be realistically considered. This could have a significant impact on UK gas customers if alternative non-optimized policy decisions are subsequently put into force. This NIA project will focus on section 12, 16 and 14.3 of the H21 roadmap.

The H21 project was predicted on a hydrogen supply chain consisting of hydrogen production utilising SMR (steam methane reformation) technology, intraday and inter-seasonal storage utilising salt cavity storage facilities and CO2 sequestration through pre-established CCS (carbon capture & storage) infrastructure. However, through extensive stakeholder engagement since release of the H21 project report, it is clear that the upstream hydrogen generation (including CCS) and downstream storage options could be provided by alternative solutions and be further optimised. This could lead to significant savings for gas customers as well as the option for accelerated conversion of the UK below seven bar gas networks should conversion take place. Understanding the technical and economic differences on the UK gas networks assets, and the customer bill impact of such an alternative system is essential to the long term strategy of the UK gas industry and UK government policy. Additionally Work package 14.3 requires investigation into the feasibility of hydrogen power generation. Understanding the potential for power generation from either new build or converted CCGTs and the associated costs and viability are critical to understanding the size and compression requirements associated with the new hydrogen transmission system. Conversion of large end users, such as power stations, could have a significant impact on storage and production requirements and therefore need to be accurately modeled and understood to develop a holistic view of the UK gas network impact both technically and commercially.

The Three fundamental components of the hydrogen supply system are;

- Hydrogen production
- Hydrogen storage
- CO2 sequestration

In the H21 roadmap package 12 and 16 identifies the need to fully assess the different options for UK wide deployment, including hydrogen network storage requirements, alternative hydrogen production technologies and CO2 sequestration options. All these elements have the potential to impact across the UK gas transmission and distribution systems and its operations which grow in scale with an incremental UK roll out of a hydrogen conversion. It is critical that impacts of alternative hydrogen production system methodologies be understood and realistically modeled and assessed against their respective impact on the UK gas industries system and assets.

Statoil, in collaboration with Northern Gas Networks has committed to undertake a study to assess the feasibility of alternative hydrogen supply chain technologies. The study will assess the technical feasibility, commercial impacts and scalability in respect of a UK wide deployment of the following technologies;

- Hydrogen production utilising Auto Thermal Reforming (ATR) technology as an alternative to Steam Methane Reforming (SMR)
- Hydrogen Storage in Ammonia for intraday and inter-seasonal storage capacity as an alternative to salt cavity storage
- CO2 sequestration utilising existing Statoil assets and infrastructure
- Conversion of existing CCGT power generation to operate on hydrogen

Statoil has committed to fund the research work required to deliver this project (circa. £600k - £800k), however they will need support

from the UK gas network operators to understand the operations of distribution networks, impacts of different hydrogen supply chain technologies on network operations and provide network modelling and analysis to support the feasibility study. This NIA project will provide the UK gas distribution network operator support required to deliver the project.

## Method(s)

In collaboration between NGN and Statoil this project has been developed to address the problem and enhance the UK gas industries understanding of the opportunities, technical considerations and economics associated with alternative technologies for UK hydrogen conversion. Statoil will lead the project which has a total cost of £1m, the UK gas industry involvement of £240K is to provide input and assessment of the different options developed and their specific impact on the UK gas system as well as disseminating the knowledge across the industry and to local and national stakeholders.

The study will consider three scenarios which will be used for system design purposes these include.

**Scenario 1:** 1 x Leeds approximately 1 GW hydrogen (average annual production 678MW) and 1.5 million tonnes of CO<sub>2</sub> per year developed in 2025.

**Scenario 2:** 10 x Leeds approximately 10 GW hydrogen and 15 million tonnes of CO<sub>2</sub> per year developed between 2025-2035 @ 1 GW additional hydrogen production generation per annum and 1.5 million tonnes additional CO<sub>2</sub> sequestration requirements per year.

**Scenario 3:** 50 x Leeds approximately 50 GW hydrogen and 75 million tonnes CO<sub>2</sub> per year developed between 2025-2045 @ 2.5 GW additional hydrogen production generation per annum and 3.75 million tonnes of additional CO<sub>2</sub> sequestration per year.

Based on this work it would be possible to determine optimum development, i.e. how many GW of low carbon hydrogen capacity to be installed per year, the associated investment and decision points and the development requirements and impact on the existing UK gas system (transmission and distribution). For each scenario the following assessments will be undertaken.

1. **Ammonia Storage:** Alternative methods of intraday and inter-seasonal storage in both the upstream and downstream UK gas network using ammonia.
2. **H<sub>2</sub> production technologies:** Whole life impact of ATR (Autothermal Reforming) for hydrogen production Vs SMR as per the original H<sub>2</sub> study.
3. **CO<sub>2</sub> Storage Capacity:** Long term and large scale potential of CO<sub>2</sub> storage capacity, i.e. how can UK and Norwegian CO<sub>2</sub> transport and storage infrastructure be developed for accommodating linear bulk scaling amounts of CO<sub>2</sub>, e.g. for 50 Leeds this would be circa 75 million tonnes/year. This assessment will also consider long term storage reserves for CCS in the North Sea considering key geological formations. .
4. **Rate of hydrogen deployment (UK & Norwegian based):** Development of UK based low carbon hydrogen production and potential synergies with Norwegian based production. Schedule, cost, experience in developing mega scale projects and execution risk will be addressed.

The project delivery will be split into four phases.

**Phase 1:** Technical system assessment and development of the concept for 1, 10 and 50 'Leeds' Equivalents. Including rate of production and storage (ammonia) deployment.

**Phase 2:** UK gas network impact consideration for storage locations, scaling production and conversion/ HTS requirement

**Phase 3:** Impact of large user power generation.

**Phase 4:** Final report and knowledge dissemination.

## Scope

The study will consider three scenarios which will be used for design purposes for an alternative low carbon hydrogen production system utilising ATR/Ammonia and CCS and the associated impacts on the UK gas networks system for large scale roll out.

**Scenario 1:** 1 x Leeds approximately 1 GW hydrogen (average annual production 678MW) and 1.5 million tonnes of CO<sub>2</sub> per year developed in 2025.

**Scenario 2:** 10 x Leeds approximately 10 GW hydrogen and 15 million tonnes of CO<sub>2</sub> per year developed between 2025-2035 @ 1

GW additional hydrogen production generation per annum and 1.5 million tonnes additional CO2 sequestration requirements per year.

**Scenario 3:** 50 x Leeds approximately 50 GW hydrogen and 75 million tonnes CO2 per year developed between 2025-2045 @ 2.5 GW additional hydrogen production generation per annum and 3.75 million tonnes of additional CO2 sequestration per year.

The study will also be used to support the H21 – Strategic modelling – Major Urban Areas NIA which is due to be registered in April 2017.

## Objective(s)

The project scope has been developed to deliver the following objectives;

1. **Hydrogen Production** - Enhance the technical knowledge database for the utilisation of Auto Thermal Reformation as an alternative method to Steam Methane Reforming for hydrogen production, including an economic assessment of the relative Capex and Opex costs. This will address part of Work Package 16 in the H21 roadmap and inform the UK gas sector on the potential impacts of this technology on the gas distribution network future configuration, operations and regulatory implications.
2. **Ammonia for Hydrogen Storage** – Establish the technical and economic feasibility of utilising ammonia as a viable technology for the storage and transportation of hydrogen. This will address an element of Work Package 16 in the H21 roadmap. It is critical in understanding how intraday and inter-seasonal storage could be addressed in the UK distribution networks
3. **CO2 Sequestration** – Establish a technical and economic model for CO2 sequestration from hydrogen production utilising existing Statoil assets and infrastructure. This will address an element of Work Package 12 in the H21 roadmap. Understanding the economic and technical options for CO2 sequestration from hydrogen production is a critical component of the hydrogen supply chain and is imperative in demonstrating the overall viability of converting the UK gas grid to hydrogen. The H21 project assumes the development of associated CCS infrastructure to align with the anticipated H21 UK roll out programme. This project will provide a technical and economic model, based on hydrogen production base load to ascertain the economic viability of bespoke CCS infrastructure to support the hydrogen conversion programme. Furthermore it will consider the opportunities for the UK offshore asset redeployment to ensure minimal costs and therefore minimize the impact in UK gas customer's bills.
4. **Power Generation from Hydrogen** - Provide a technical assessment of the feasibility and costs of converting existing CCGT power generation to hydrogen. The retrofit of existing CCGT power generation plants and the potential for new power generation from hydrogen has the potential to substantially decarbonise the UK power generation sector. Understanding the impact on future hydrogen demand and the impact on the future network configuration, network operations and hydrogen storage requirements is essential in modeling the hydrogen supply chain to ensure the optimum solutions are identified and adopted..

## Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

n/a

## Success Criteria

In considering the success of the project we would consider the following success criteria as a minimum output from the project;

1. Provide an assessment of the technical and economic opportunities for hydrogen production utilising Auto Thermal Reformation, ammonia storage and CCS deployment rates to allow an assessment of the relative merits of ATR vs. SMR hydrogen production in the context of the three identified scenarios
2. Provide an assessment of the technical and economic opportunities for hydrogen in ammonia transport and storage, to allow an assessment of the relative merits of hydrogen in ammonia vs. salt cavity storage in the context of the three identified scenarios
3. Provide a technical assessment of the feasibility and costs of converting existing CCGT power generation to hydrogen.
4. Provide a feasibility report, including a high level economic assessment for CO2 storage options against the three identified scenarios utilising existing Statoil pipelines and storage infrastructure.
5. Understand the technical impact of this system on the UK gas network including transmission and distribution networks
6. Provide critical rates of conversion data for 1, 10 and 50 'Leeds equivalents' to inform the H21 – Strategic modelling – Major Urban Areas NIA which is due to be registered in April 2017.

## Project Partners and External Funding

Statoil will lead this project supported strategically by NGN. Statoil's element of the work is estimated at £800k, NGN & NNGD will use £120K each from their NIA funding to support the work, gain access to this critical strategic knowledge and understand the impact on the UK gas network from an operational, technical and cost point of view.

## Potential for New Learning

This project will build significantly on the knowledge base developed in the H21 Leeds City gate Project in respect of hydrogen production, hydrogen storage options (as ammonia), the impact on large loads, specifically hydrogen used for power generation, on storage requirements and CO2 sequestration and transport.

It will provide realistic deployment rates for a UK conversion to 100% hydrogen which can be considered against a UK conversion strategy. These will consider both UK and Norwegian based hydrogen production, storage and CCS.

The learning from this project will significantly increase the knowledge base for Auto Thermal Reforming hydrogen production and its relative technical and economic merits vs. SMR hydrogen production, this will help inform the optimum strategy for hydrogen production in the context of various UK roll out scenarios.

This project will also provide technical and commercial comparisons between ammonia and salt cavern storage and the respective impact on the UK gas system.

### Scale of Project

This project will provide critical information applicable to the entire UK gas system when considering conversion to 100% hydrogen incrementally over time.

### Technology Readiness at Start

TRL2 Invention and Research

### Technology Readiness at End

TRL5 Pilot Scale

### Geographical Area

The NGN project support will be based out of the H21 project office in Leeds. The research programme will cover the Leeds area in scenario one and the wider UK GDN network areas for scenarios two and three (10 Leeds and 50 Leeds respectively).

The studies will also assess various potential hydrogen production facilities and existing infrastructure in Norway and potential CO2 sequestration locations in the North sea.

### Revenue Allowed for the RIIO Settlement

None

### Indicative Total NIA Project Expenditure

Max Internal costs: £94k

NGN - £46,667

NGGD - £46,667

External Costs; £280,000

NGN - £140,000

NGGD - £140,000

**Total project costs - £373,333k**

## Project Eligibility Assessment Part 1

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

### Requirement 1

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

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

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

n/a

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

n/a

### 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)

This project is one of a suite of projects to enable a conversion of the UK gas grid to hydrogen. Repurposing the UK gas networks with hydrogen to support the challenge of the climate change act has the potential to save £100s billions with minimal gas customer disruption verses alternative decarbonisation solutions.

#### Please provide a calculation of the expected benefits the Solution

Not required as this is a research project

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

The research undertaken by this project is applicable to all of the Network Licensees

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

The research undertaken by this project is applicable to all of the Network Licensees

### 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 generated will be undertaken directly across all GDNs making the knowledge transferable and assisting with knowledge dissemination of the original H21 Leeds City Gate project.

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

This project sits centrally to NGNs future of the gas network strategic requirements

- Has the Potential to Develop Learning That Can be Applied by all Relevant Network Licensees

### 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 will inform the economic models for UK wide hydrogen conversion scenarios

### 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

.

### Relevant Foreground IPR

n/a

### Data Access Details

n/a

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

.

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

**This project has been approved by a senior member of staff**

Yes