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.

Network Licensees must publish the required Project Progress information on the Smarter Networks Portal by 31st July 2014 and each year thereafter. The Network Licensee(s) must publish Project Progress information for each NIA Project that has developed new learning in the preceding relevant year.

NIA Project Close Down Report Document

Date of Submission

Jul 2022

Project Reference Number

NIA2_NGESO010

Project Progress

Project Title

The Role for Hydrogen as an Electricity System Asset

Project Reference Number

NIA2_NGESO010

Funding Licensee(s)

NG ESO - National Grid ESO

Project Start Date

January 2022

Project Duration

1 year and 3 months

Nominated Project Contact(s)

Mark Perry

Scope

This project will provide National Grid ESO with:

- A more in depth understanding within / supplementing FES on the range of possible outcomes from a hydrogen transition.
- Identification of interactions of hydrogen with the electricity system and assessment of possible impacts, further work required to address these impacts, and gaps in current understanding.
- Evidence to support and refine the assumptions to allow modelling of hydrogen impacts (in particular electrolyser operation) into the existing NGESO market modelling environment (BID3) to understand their likely performance and contribution in the market.

Objectives

This project will follow a staged approach, based around an initial exploration stage followed by a more in-depth analysis stage. This will provide the opportunity to capture both the breadth of potential hydrogen interactions, and then focus more in-depth analysis on a sub-set of the impacts which are most pertinent to National Grid ESO in developing FES22 and supporting the modelling work going forward.

The final outputs will include:

- A list of Hydrogen value chains representing a broad range of potential future market uses of hydrogen
- Insight and feedback for the Future Energy Scenarios team to inform FES22 development and a short list of value chains mapped to the FES scenarios for subsequent analysis
- Report summarising the analysis, with recommendations on priority areas for stage 2 analysis
- Final summary report outlining the findings from each work package and the associated datasets
- Research report to support the development of the Redispatch module and the datasets and assumptions which drive it for the Network Options Assessment team

Success Criteria

The following will be considered when assessing whether the project is successful:

- Findings from the project can be used to increase the accuracy of the FES22 and NOA reports
- The project delivers against objectives, timescale and budgets as defined in the proposal
- ESO's in-house capability is improved for modelling and representing the impact of hydrogen on the future electricity system
- A greater understanding of how hydrogen can be most effectively deployed, taking into account the needs of National Grid ESO, alongside the competing use cases and demands on hydrogen across the electricity and heating sectors
- Implementable recommendations
- Knowledge and tools developed in this project can be replicated across network partners

Performance Compared to the Original Project Aims, Objectives and Success Criteria

Project Overview

The need to decarbonise energy networks, in both the gas and electricity sectors, has received an ever-increasing focus in recent years. This has led to a resurgence in innovation around low carbon gases, including hydrogen. There has been much discussion around the use of hydrogen as a heating fuel, but it has the potential to offer a range of uses, in industry, power generation and transport. Additionally, the generation and use of hydrogen has clear impacts on the electricity system and whilst it provides many opportunities to the broader energy system such as cross vector storage, it may also pose several challenges. National Grid ESO commissioned this project to better understand how the development of emerging hydrogen markets will interact with the electricity system. The findings from this work will feed into the thinking on hydrogen for FES 2022. This included the following considerations:

- Flexibility services from electrolysis – as more electrolysers come online, demand for electricity will increase but so too will flexibility potential. Electrolysers connected to the electricity network could provide balancing by 'turning down' for short periods of high demand, for the right price.
- Power generation – Combined Cycle Gas Turbines (CCGTs)/Open Cycle Gas Turbines (OCGTs),and potentially engines/fuel cells, which currently run-on natural gas could instead be powered by hydrogen. This could replace natural gas for peaking and mid merit power generation at times of high electricity demand.
- Inter-seasonal storage – long-term hydrogen storage capabilities will facilitate inter-seasonal storage of energy. This would involve using electrolysis to produce hydrogen and power generation using hydrogen, to bridge the seasonal mismatch in supply and demand.
- Location and co-location – how and when the hydrogen market develops will affect the siting of infrastructure. A key question is the potential for a hydrogen gas network, as this would enable hydrogen production to be located at greater distances from the end use.

Project Plan and Activities

The project consisted of eight work packages:

WP1: Mobilisation, including finalising scope

WP2: Desk based research and defining of key aspects of the hydrogen market to ensure a consistent approach throughout the project. The team refined a Value Chain (VCs) approach to ensure all aspects of production, distribution, storage and end use were considered. This included different infrastructure assets and use cases.

WP3: Interviews with external hydrogen experts and the development of long list of hydrogen VCs in Excel. Working collaboratively with NGESO, the team then short-listed the VCs down to a final list of 10. A workshop was held with the experts who had been interviewed at the end of WP3 to sense check the final short-list of VCs before moving to WP4.

WP4: Involved a thorough market sizing of the 10 VCs in terms of their potential scale, output and cost. An in-depth analysis of the VCs was completed, in terms of their potential to provide ancillary services and flexibility. This included the potential for electrolysers to turn up or down at times of low or high demand respectively. Additionally, the use of hydrogen as a fuel for power generation was also considered. A high-level mapping showed the possible geographical locations of different types of hydrogen infrastructure. This highlighted the challenge of co-location as the different requirements of the value chain are not always in the same place. The future of the gas networks, including scale, was also highlighted and the implications of the effect on how the hydrogen market can develop discussed. A critique of the assumptions regarding hydrogen with FES was also provided.

WP5: Internal modelling of the 10 VCs. This included a full impact analysis of the different VCs to determine costs, not only of production, but of distribution and storage. Sensitivity analysis provided a range of prices for the different VCs based on a number of variables. For VCs which generated electricity, the cost of producing electricity using hydrogen was also modelled.

WP6: The above WPs produced three reports; WP6 provided a Summary Report of all the key findings from the project.

WP7: Ongoing project management, including internal and external meetings

WP8: Following on from WP5, the team used the internally developed model to provide input to Redispatch. This included discussion with the Economics team at NGESO and their modelling contractor AFRY. This was a collaborative process whereby the team shared their thinking and assumptions about the hydrogen market and NGESO confirmed how hydrogen assumptions would be incorporated into BID3.

Required Modifications to the Planned Approach During the Course of the Project

Overall, the project followed the scope and approach as set out in the original proposal and as per the PEA.

This project was an iterative process, largely due to the high levels of uncertainty. For example, the key question regarding the future of the gas networks will not be decided by government until 2026, so the team provided a variety of Value Chains to cover alternative scenarios. Some would require a gas network to be feasible, while others were still feasible without a gas network but would face challenges.

The original project scope sought to determine the potential for electrolysers to reduce the curtailment of renewables. This proved challenging in practice due to the high number of variables associated with the question including:

- Where would the electrolyser be sited?
- How would the hydrogen be transported (if not being used on site)?
- How and where would the hydrogen be stored – either in the short term, long term or both?
- What price would be used for the electricity to generate the hydrogen be determined?

In addition to the challenge of the above questions, the expert opinion within Delta-EE regarding the wind industry, was that currently there would be minimal appetite from existing wind farms to install an electrolyser to reduce curtailment. This could change in the future and developers may develop business models where investing in an electrolyser could be profitable at a new site. However, until there is greater clarity on a significant number of variables, most notably regarding distribution and storage, it was not viable to provide a meaningful answer to this question.

Lessons Learnt for Future Projects

The project highlighted the significant amount of uncertainty regarding the emerging hydrogen market and the complex interactions of the hydrogen generation with the future electricity market and pricing.

Note: The following sections are only required for those projects which have been completed since 1st April 2013, or since the previous Project Progress information was reported.

The Outcomes of the Project

An important outcome was identifying the significant uncertainty based on the future direction of hydrogen infrastructure and networks.

The project highlighted the importance of a pure, hydrogen gas network for this low carbon gas to be a meaningful asset to the electricity network. We assume blending would only ever be a ‘stepping stone’ solution to pure hydrogen as blending alone would not achieve the required level of decarbonisation. This is less of an issue for blue hydrogen which can largely be produced and used at the same site. For green hydrogen, providing a means of transport from where it is produced e.g. at/near wind farm sites to where it is either stored or the final end use e.g. CCGTs will be key to creating a dynamic hydrogen market. The gas network may significantly reduce in size compared to today and be focused in a particular region. For example, the North of England, is has the potential to be an attractive location for all stages of the value chain (production, storage and end use). Without some level of distribution, including the gas network acting as 'off-taker of last resort', the business case for many hydrogen developers will be more challenging.

The use of hydrogen for power generation will be limited to mid-merit and peaking. This is based on the end of unabated natural gas by 2035. Existing power generation infrastructure (CCGTs/OCGTs/Gas engines) could be upgraded to burn hydrogen in place of natural gas, thereby reducing CAPEX costs. Initially, hydrogen for power generation would be minimal, for example during extreme cold weather but as the industry expands hydrogen's role could increase.

The project determined that long-term, inter-seasonal storage (salt caverns) cannot be considered separately from the distribution question; the two are fundamentally interlinked. Both transporting hydrogen from where it is produced and transporting it from the storage site to the end use. The likelihood of sites emerging that can generate, store and use hydrogen all in one place is slim and would significantly reduce the total size of the hydrogen market.

Based on our interviews with stakeholders and the workshop, the appetite for electrolysers to provide flexibility services through revenue stacking is currently low. One of the reasons relates to the uncertainty regarding distribution and storage options for electrolyser sites highlighted above. Our research shows that in the initial stages of the green hydrogen markets development, electrolyser plants will focus on producing as much hydrogen as possible to maximize profit. As the market matures and overall demand for electricity increases, there is potential for electrolyser plants to engage with ancillary and flex provision.

The importance of determining an accurate electricity price is crucial for any electrolyser business case as this is by far the biggest ongoing and overall cost. Any attempt to quantify the scale of the green hydrogen market in the future will require accurate electricity price forecasting.

The Delta team provided a range of possible Adders and Multipliers for electrolyser sites to be input into BID3.

A Summary Report of the project has also been published on the Smarter Networks Portal.

Data Access

Details on how network or consumption data arising in the course of a NIC or NIA funded project can be requested by interested parties, and the terms on which such data will be made available by National Grid can be found in our publicly available “Data sharing policy related to NIC/NIA projects” and www.nationalgrideso.com/innovation.

National Grid Electricity System Operator already publishes much of the data arising from our NIC/NIA projects at www.smarternetworks.org. You may wish to check this website before making an application under this policy, in case the data which you are seeking has already been published.

Foreground IPR

The following Foreground IPR will be generated from the project:

- Analysis of Hydrogen value chains and pathways
- Stage 1 Interactions analysis
- Stage 2 Impact analysis

Planned Implementation

A Summary report has been produced and a selection of the completed reports have been shared with Ofgem, at their request.

The bid and offer input values for hydrogen electrolysis are now being used in National Grid ESO's balancing mechanism simulations. This will ensure future Network Operability Assessments (NOA) better represent the behaviour of electrolysers connected to the electricity system.

Over the duration of this innovation project, the Energy Insights and Analysis team within National Grid ESO tried as much as possible to incorporate the findings shared by Delta-EE as the project progressed, into the development of the Future Energy Scenarios (FES) 2022.

This has included: 1) Validation of high-level assumptions made regarding hydrogen use, production, transportation, and storage in the four FES scenarios against the value chains examined in the report, 2) benchmarking datasets and technical data with industry standards identified by the literature review, interviews, and the expertise of Delta-EE and 3) consideration of the wider implications of a developing hydrogen market on the electricity system and its future operation.

Due to this project running in parallel with the FES 2022 modelling and analysis work, not all of the insights contained within the report were able to be included in this year's publication. The findings of this report will, however, form part of the foundation for the FES 2023 hydrogen assumptions and modelling analysis.

Given the potential for substantial disruption to the electricity system due to the increase in renewable electricity generation and the inherent challenges that brings with it, the analysis contained within this report will be used to help develop BID3 and Plexos modelling simulations to investigate electricity system constraints, and how hydrogen supply and demand flexibility can be configured and utilised to help operate the system more efficiently in the future.

Other Comments

The Project outcomes and results contain confidential information and intellectual property rights that cannot be disclosed in this Report due to their proprietary nature. Should the viewer of this Report ("Viewer") require further details this may be provided on a case by case basis following consultation of all Publishers. In the event such further information is provided each and any Publisher that owns such confidential information or intellectual property rights shall be entitled to request the Viewer enter into terms that govern the sharing of such confidential information and/ or intellectual property rights including where appropriate formal licence terms or confidentiality provisions. Dependent upon the nature of such request the Publishers may be entitled to request a fee from the Viewer in respect of such confidential information or intellectual property rights.

Standards Documents

Not applicable.