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Acorn Hydrogen Project Summary Report (HSC-2)

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1.0 Executive Summary

This report concludes the Concept Evaluation Study for Acorn Hydrogen which commenced on the 12th of December 2019.

Over the past seventeen months, the project team have completed sixteen Deliverable Reports and their associated Outputs on time in full and within approved budget. This is despite COVID-19 restrictions resulting in over 80% of the project being delivered through remote working by a multi-party project team, many of whom have yet to meet in person.

A parallel Alternative Reformer Technology Study has also been completed. The Project Assurance Review (PAR) for both studies has endorsed the progression of the Acorn Hydrogen Project from Concept Evaluation into Concept Definition. The PAR process confirmed that the project has been well managed and transparent, with no direct challenge of output produced whilst providing useful builds through recommended actions for the next stage of project development.

Funding has been secured to deliver the next stages of project development through to Final Investment Decision, currently planned to be held early 2024.

With the submission of this Project Summary, the Acorn Team have now concluded the BEIS Hydrogen Supply Competition Phase 2 (HSC-2) supported Concept Evaluation stage of project development for Acorn Hydrogen. A separate Alternative Reformer Technology (ART) Study, funded by Acorn Partners has been completed in parallel. This report provides:

- An overview of the Concept Select Journey outlining the project development stages and the performance against budget and schedule in delivering the HSC-2 Acorn Hydrogen Concept Evaluation project.
- An Executive Summary of each of the sixteen Deliverable reports produced.
- A precis of the Project Assurance Review (PAR) process.
- The way forward for the Acorn Hydrogen Project.

The output of both the HSC-2 and ART studies has established the input for a Call for Tender to select the reformer technology solution to progress into Front End Engineering Design (FEED). In parallel non-technical aspects of project development, i.e., permits and consents, route to market, business model, financing, stakeholder engagement etc., will also be completed in the next stages of project development, Concept Definition and Define. Together the Technical and Non-Technical work scopes provide the evidence upon which a Final Investment Decision (FID) can be made, which upon approval enables the project to proceed into Execute (final design, installation and commissioning) ahead of Operation. FEED is projected to commence on or before the 3rd December 2021 on the finalised Concept. The current target date for FID, subject to numerous aspects, is early 2024.

The approach to Acorn Hydrogen Phase 1 has been revised to reflect the accelerated deployment both required and achievable to meet the stated

Scottish and UK Government statements for hydrogen deployment of 1GW by 2025 and 5GW by 2030. For St Fergus, Build Out to 10GW of hydrogen capacity, and the associated infrastructure for the transportation and sequestration of the arising 20Mt/yr of CO_2, is required in a relatively short timeframe to meet legislated Net Zero targets of 2045 (Scotland) and 2050 (UK).

Phase 1 of Acorn CCS enables at least 5Mt/yr of offshore transport infrastructure for CO_2 sequestration through the repurpose of the Goldeneye Pipeline. The 400kt/yr of CO_2 associated with the Acorn Hydrogen Phase 1 200MW Unit utilises only 8% of Goldeneye's capacity. Thus, in preparation for the Scottish Cluster Plan, and to further optimise the Levelised Cost of Hydrogen (LCOH) for Acorn Hydrogen Phase 1, the approach to deploying the initial reformer capacity has been revised to three Units, a Unit 1 of 200MW with a 300MW Unit 2 and 300MW Unit 3, each staged to be 18-24 months apart. Exact details will be finalised within Define ahead of FID. This will include the review of pre-investment for Units 2 and 3 alongside Unit 1. Hydrogen blending into the National Transmission System (NTS) will need to increase to 5% to support full operation of Unit 2 without turndown and 10% to support Unit 3 at full output. Ongoing conversations with National Grid Gas have confirmed that they are directionally aligned to these % steps and their respective timelines, i.e., approval of at least a 10% hydrogen blend into the NTS at the St Fergus Gas Terminal by 2030. The associated CO_2 for Phase 1 now increases from 400kt/yr from the end of 2026 to the latter now being 1.6Mt/yr by the close of 2030.

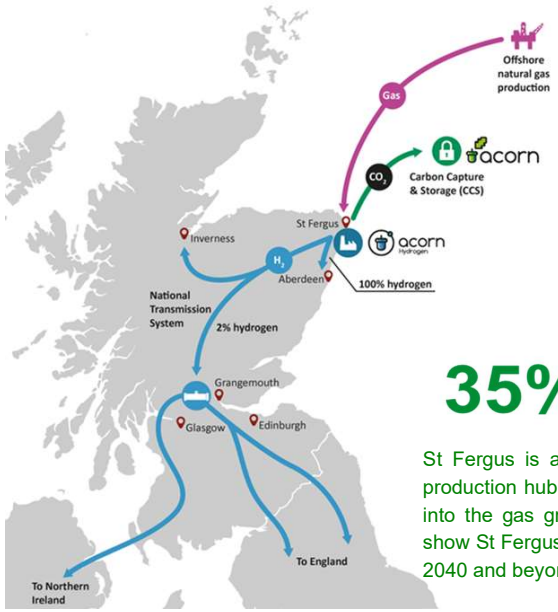
The above is subject to review during Define prior to or at FID, particularly with respect to the conditions required for and timing of deployment for Units 2 and 3 but also the subsequent development plan that gets Acorn Hydrogen to 3.5-4Mt/yr with the first Phase of Build Out and then subsequent Acorn Hydrogen Phases of 1GW+ Build Outs until all carbon emissions associated with the natural gas flow through St Fergus are fully mitigated at St Fergus or beyond.

If the relevant parties, i.e., BEIS, IGEM, HSE, National Grid Gas etc. can work with Acorn Hydrogen to further expedite the approval of the Safety Case and Hydrogen Standard for the initial 2% hydrogen blend by volume but more so 5%, 10% and ideally 20% blending within the NTS to match that planned by several of the low pressure Gas Distribution Network operators, then Acorn Hydrogen can be deployed faster with larger reformer capacities. The 200MW capacity for Acorn Hydrogen Unit 1 is considered small in the context of the average reformer size being deployed globally for industrial applications which are more in the region of 300-700MW per reformer train. The replicability of modular reformer trains closer to the current global experience will lead to a major reduction in LCOH and a cyclical effect of increased CO_2 volumes leading to a reduced Levelised Cost of Carbon that further improves LCOH leading to further investment in the next Build Out Phase, etc.

Ultimately the aim must be to optimise value for money for UK Taxpayers with the view, backed by investor support, that "if we build it, they will come". The demand is already there in the form of natural gas off-takers from the NTS. To achieve Net Zero, the carbon emissions associated with this demand needs to be mitigated through energy efficiency, electrification, hydrogen or most likely a combination of all pathways. Blue hydrogen will play a prominent role and where better to deliver this at scale than at St Fergus where a third of the UK's natural gas is currently landed and where three existing, but unused gas pipelines have the capacity to convey over 20Mt/yr of CO_2 to well appraised world class offshore CO_2 storage capacity within short reach of those pipelines.

2.0 Introduction

This work was completed as part of the BEIS Hydrogen Supply Competition Phase 2, from which the project received £2.7million. The Acorn Hydrogen Project, located in North East Scotland, Figure 2-1, is looking to establish hydrogen generation from North Sea Natural Gas at the St Fergus Gas Terminal. The project aims to use a leading hydrogen reformation process to deliver an energy and cost-efficient process for hydrogen production with the project carbon dioxide (CO_2) emissions being captured and permanently stored using the Acorn Carbon Capture and Storage (CCS) infrastructure. Clean hydrogen will be blended into the National Transmission System (NTS) or used in the region for decarbonising heat and industry.



35% of natural gas used in the UK currently comes on shore at St Fergus.

St Fergus is an ideal site for a major hydrogen production hub. Hydrogen can be directly blended into the gas grid to decarbonise gas. Forecasts show St Fergus continuing to play a key role out to 2040 and beyond.

Figure 2-1: Acorn Hydrogen location at St Fergus Gas Terminal

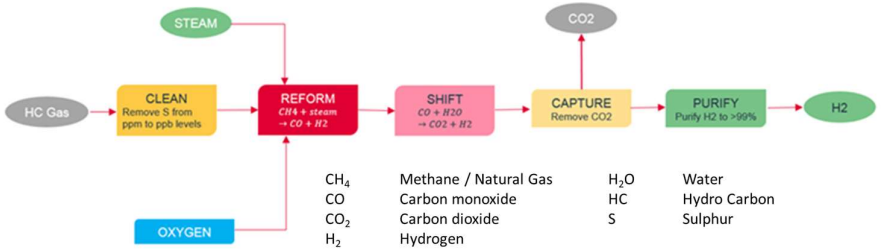


Figure 2-2: Base case hydrogen generation process (from natural gas to hydrogen and CO_2)

Figure 2-2 provides an overview of the base case hydrogen generation process. The project aims to create a full scale reforming hydrogen production plant with efficiencies above 80%, and integrating the CO_2 capture process in an energy efficient manner, to provide the lowest hydrogen production costs compared to existing reformation systems.

Acorn Hydrogen will be a significant contributor to the requirements of the Scottish and UK Governments to deploy 1GW of hydrogen production by 2025 and 5GW by 2030. If current timescales are met, the Acorn Hydrogen reformer could be one of the first operational large scale clean hydrogen plants in Europe. The aim is to have an operational project by the end of 2026, taking advantage of the availability of the Acorn CCS Project which is under development at the same location. St Fergus Gas Terminal is identified as an ideal location for developing clean hydrogen as depicted in Figure 2-3.

St Fergus gas Terminal also offers potential for a massive build out of hydrogen production using the large scale gas import facilities to enable decarbonisation of the UK's gas system, supporting heat decarbonisation and enabling the UK's

Net Zero obligations. The Phase 1 of the project starts with a 200MW Unit 1 reformer with an annual energy output of approximately 1.75TWh/yr, to enable an initial 2% blend by volume in the NTS system, and to meet the initial Aberdeen Vision demand through a 20% blend by volume into the regional Gas Distribution Network (GDN). Phase 1 is also assessing the operation of a 300MW Unit 2 by mid 2028 and a 300MW Unit 3 by early 2030. Units 2 and 3 would support increased NTS blending to 5% and 10% respectively and initial conversion of end users within the Aberdeen Region to 100% hydrogen. Subsequent Acorn Hydrogen buildouts could see hydrogen generation capacity rising to 10,000 MW, 60TWh/yr by 2045 to fully utilise the forecasted natural gas flow at the St Fergus Gas Terminal.

This will offer widespread decarbonisation opportunities to the UK, initially greatly reducing and ultimately fully addressing the carbon intensity of the natural gas flowing through the St Fergus Gas Terminal. Unit 1 will reduce CO_2 emissions in the UK by 400,000t/yr. Phase 1 could reduce CO_2 emission by 1.6Mt/yr with full build out removing up to 20Mt/yr and thus place Scotland as a global leader in the decarbonisation of heat and industry.

Building on the Hydrogen Supply Competition Phase 2 (HSC-2) funded Concept Evaluation Study completed in May 2021, the subsequent UK Government Industrial Strategy Challenge Fund (ISCF) and Acorn Development Agreement (ADA) funded stage of project development will progress the Acorn Hydrogen Project through to Final Investment Decision (FID). This will see parallel completion of Technical, including Front End Engineering Design (FEED), and Non-Technical work scope to enable FID within the first quarter of 2024.

This stage of project development will complete the Concept Select project development stage ahead of progressing FEED to develop Acorn Hydrogen's specific engineering design. In parallel the necessary consents, commercial model development, transfer of hydrogen and CO_2, and stakeholder engagement that enable the project to reach a Final Investment Decision (FID) will be developed. A successful FID outcome, including the securing of funding will enable the project to move into detailed design, construction and operation.

Figure 2-3: Benefits of St Fergus Gas Terminal as a hydrogen production location

Acorn Hydrogen Phase 1 will create new material of relevance for other significant hydrogen projects in the UK and will continue to build upon work already conducted through projects such as Aberdeen Vision, FutureGrid, H21, H100, Hy4Heat, HyDeploy, HyNet, Union etc. and provide a clear governmental signal on the potential future use of the gas grid.

3.0 The Concept Select Journey

3.1 The Concept Select Stage

The Acorn Hydrogen Project, supported by BEIS and private investment match funding, now has an established pathway through to Final Investment Decision, Figure 3-1. In 2019 the BEIS Hydrogen Supply Competition (HSC) Phase 1 supported the Project's Feasibility Study.

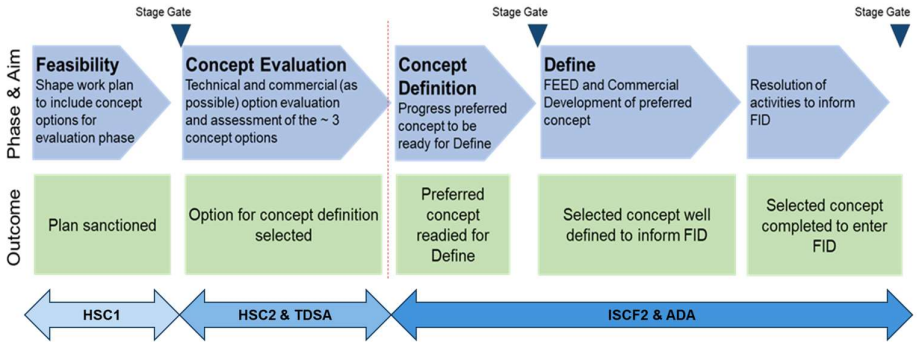


Figure 3-1: Project development stages

Acorn Hydrogen is now just concluding the HSC-2 (£2.7m) and Acorn Technical Development Study Agreement (TDSA) (£2.85m) funded Concept Evaluation stage of project development. A TDSA funded Alternative Reformer Technology (ART) Study has been completed in parallel. The output of both these studies has defined the input for a Call for Tender to select the reformer technology solution to progress into Front End Engineering Design. In parallel, Non-Technical aspects of project development, i.e., permits and consents, route to market, business model, financing, stakeholder engagement etc., complete the Define stage of project development. Together the Technical and Non-Technical work scopes provide the evidence upon which a Final Investment Decision (FID) can be made which, once approved, then enables the project to proceed into Execute (final design, installation and commissioning) ahead of Operation.

Funding to complete Concept Definition and Define is in place from the Industrial Strategy Challenge Fund Phase 2 (ISCF2) and the Acorn Development Agreement partners, (Harbour, Shell and Storegga).

Concept Definition has commenced in parallel with the wrap up of HSC-2. The Call for Tender process is underway with a Call for Consultation just concluded with the shortlisted reformer vendors. FEED is projected to commence on or before the 3rd December 2021 on the finalised Concept. The current target date for FID, subject to numerous aspects, is early 2024.

3.2 Delivery of the HSC-2 Acorn Hydrogen Project

The HSC-2 funded project started on the 12th of December 2019 with a Kick-Off Meeting held on the 19th and 20th of February 2020. The latter and subsequent Framing workshops completed in March provided the foundations upon which 93 Outputs and 16 Deliverables have been delivered on time, in full and within approved budget of £5.55m. The original schedule was 15 months with a project completion date of 31st of March 2021. Whilst this could have been achieved, to provide some relief for the project team arising from the incremental impacts of homeworking due to COVID-19, the project applied for and secured a 2 month extension through a COVID-19 Extension application process offered by BEIS to all their Innovation Programme projects. Submission of this report to BEIS on the 31st of May 2021 concludes the HSC-2 funded stage of the project, for which

more than 80% has been delivered from homes and thus outside of a traditional workplace, which is testament to the delivery team and wider stakeholders.

Deliverable	Deliverable Report Title
D01	Kick Off Meeting Minutes
D02	Project Schedule for Phase 2 (HSC-2)
D03	Risk Register for Phase 2 (HSC-2)
D04	Stakeholder Engagement and Communication Plan
D05	HSE Permits and Consents Register
D06	The Role of Acorn Hydrogen in Enabling UK Net Zero
D07	Basis of Design
D08	Alternative Technology Options Report
D09	Site Selection Report
D10	Public Engagement Report
D11	Concept Select Report
D12	Route to Market Report
D13	Statement of Requirements for Define
D14	Design Specification for the JM LCH Plant
D15	Project Lessons Learned
D16	Project Summary

Figure 3-2: Final report titles of the HSC-2 Deliverable Reports

Figure 3-2 summarises the final titles of the sixteen Deliverable Reports produced under the HSC-2 project:

- Deliverables D01, D02, D15 and D16, shaded blue, are project management related output;
- Deliverables D03, D04 and D05, shaded yellow, are ongoing project delivery outputs, evolved from HSC-1 material with all three since updated in preparation for further review early within Define;
- Deliverables D07, D08, D09, D11, D13 and D14, shaded red, are the six Technical Deliverables; and finally,
- D06, D10 and D12, shaded green, are the three Non-Technical Deliverables.

The original project schedule consisted of eight Milestones two months apart with two Deliverables to be delivered to BEIS at each Milestone. A Detailed Static Budget was produced and uploaded into the Microsoft Project Schedule to produce a Dynamic Budget for the project. As the Project Management Office (PMO) was established for Acorn CCS, Acorn Hydrogen also aligned on certain aspects, specifically the move from Microsoft Project to Primavera (P6) for the ongoing management of the Schedule and a more robust Cost Report.

4.0 Deliverable Summaries

4.1 D01 Kick off Meeting Minutes

To mark the start of the HSC-2 Acorn Hydrogen project a Kick-Off Meeting was held on the 19th and 20th of February 2020 in multiple locations in Aberdeenshire. The meeting was very well attended with relevant personnel in attendance from BEIS, the TDSA parties (Pale Blue Dot Energy, Chrysaor, Shell and Total) and the project delivery team, Pale Blue Dot Energy, Total Exploration and Production UK (TEPUK) and ERM.

The Deliverable 01 Kick Off Meeting Report provided a compilation of the presentation materials, photographs taken and key Notes and Actions from the meeting. The Kick-Off Meeting objectives were achieved with consensus from participants of a successful workshop that provided further foundation for delivery of the project. All Work Packages and key Outputs were discussed and any ambiguity about scope interdependencies or timing discussed and either resolved or actioned for follow up. Relationships were further established between the participants throughout the two days and the intervening team dinner. In short, the event confirmed the project to be fully mobilised with team members clear about responsibilities and work scope.

4.2 D02 Project Schedule for HSC-2

Informed by the Kick-Off Meeting the HSC-2 Bid Project Schedule and the Milestone Payment Schedule were updated and provided to BEIS within D02. Given the nature of a Concept Study both Schedules remained living documents throughout the project. The Project Schedule has tracked the delivery of 93 Project Outputs that were originally mapped against the ten work packages. These Outputs effectively formed the inputs for the sixteen Deliverables as confirmed during a mapping exercise completed in preparation for the Kick-Off Meeting. The sixteen Deliverables remained unchanged and have been delivered in full. As detailed in Section 3.2, the eight Milestone dates became nine with due dates adjusted to accommodate the COVID-19 two-month extension that saw the project completion date moved from the 31st of March to the 31st of May 2021.

In preparation for the Kick-Off Meeting, Pale Blue Dot worked with ERM and TEPUK to review project activity, i.e., confirmation of scope, by who and by when. Workshops were then completed during the Kick-Off Meeting aimed to ensure agreement and alignment on the Project Structure (Deliverables and Outputs and their respective due dates). TEPUK were confirmed as now being responsible for delivery of the six Technical Deliverables.

The Proposal Milestone Payment Schedule spread the cost of the project across the work packages with actual work completed between Milestones then evidenced and invoiced at each Milestone. TEPUK confirmed that their Deliverable costs would be fixed and would not be invoiced for until the completion of and submission of each of the six Technical Deliverables. This resulted in a significant rephasing of the Technical budget across Milestones MS04, MS05, MS06 and MS07. This rephasing was initially on the original £5.4m budget which was extended to £5.55m when a further £150k of budget cover from the TDSA was agreed in June 2020. The Milestone Payment Forecast spread the cost of the project across the Deliverables with actual work that was completed between Milestones then being evidenced and invoiced at each Milestone.

4.3 D03 Risk Register for HSC-2

This Deliverable report summarised the HSC-2 Acorn Hydrogen Project Risk Management Plan and Health, Safety and Environment (HSE) Plan alongside updated Risk and Opportunities, and Commercial Agreements Registers. These documents came together to detail how the Project was to identify and manage risks and opportunities across different sectors during the Concept Evaluation phase.

The Risk Management and HSE Plans described the processes and responsibilities for risk identification and management. The Registers detailed the risks and opportunities identified to date, alongside mitigation measures and actions required to minimise risks. The Risk and Opportunities, and Commercial Agreements Registers remained living documents throughout HSC-2 with regular updates made to both. They will remain living documents given that effective risk and opportunity management is central to the successful delivery of Acorn Hydrogen and its subsequent project stages. Early identification of potential risks and mitigation measures within a project, allows well-informed, well-judged and high value decisions to be made, which manifest themselves as the value delivered during Execute and Operation.

This Deliverable Report outlined the framework and processes that have been put in place by the Acorn Hydrogen Project Team to identify, address and manage risks and opportunities during both the current stage (Concept Evaluation) of the HSC-2 Project, through subsequent engineering stages, and then through to Execute and Operation.

The Risk Management Plan provides the structure for the Risk Management System alongside individual roles and responsibilities. It details the process followed to generate the Risk and Opportunities Register. Whilst the Risk and Opportunities Register is currently focused on risks within the pre-Final Investment Decision (FID) stages of the project, it also captures post FID Risks and Opportunities and remains a living document, subject to regular review and update as the Project progresses.

The HSE Plan details how Health, Safety and Environmental factors are to be embedded within and throughout each of the phase's decision-making process in order that HSE risk is reduced to as low as reasonably practicable. As the HSE Plan will evolve with the project stages, for HSC-2 it detailed the studies and activities to be undertaken during Concept Evaluation to be used as input for project decisions, alongside HSE responsibilities and objectives.

The Commercial Agreements Register provided details of contract, scope and status in order that commercial contracting risks were tracked.

Together these documents form both the framework for risk management within the Project, and evidence of how the Project will continue to identify and manage commercial and technical risks and opportunities.

4.4 D04 Stakeholder Engagement and Communication Plan

Hydrogen is gaining significant momentum for its role in the energy transition, which is increasing the profile of hydrogen projects in the UK, including Acorn Hydrogen. Acorn unlocks the carbon capture and storage and hydrogen infrastructure essential for meeting the Scottish and UK Government Net Zero targets. The Acorn Hydrogen project benefits from an elevated profile because of the preceding Acorn Carbon Capture and Storage (CCS).

Pale Blue Dot continue to build on existing stakeholder engagement activities across a broad range of areas, including with industry and regulatory stakeholders, government and the public sector, commercial stakeholders, environmental NGO's, academics and the workforce and communities impacted by the project. The Acorn Hydrogen and Acorn CCS projects benefit from a coordinated Stakeholder Engagement Strategy which provides the opportunity to capitalise upon engagement activities with shared stakeholders for the benefit of both projects.

During Concept Evaluation, the Acorn Hydrogen project took the opportunity to build on the recommendations and early stakeholder engagement and communication work undertaken during HSC-1. Materials were refreshed to take account of changes to stakeholders and adapted to cater for the impact of the COVID-19 pandemic.

This Deliverable report set out a cohesive stakeholder engagement and communication plan to shape all future stakeholder engagement and knowledge dissemination work for the HSC-2 project. This plan is designed as a living document, subject to frequent review and adjustment throughout the course of the project to remain flexible on engagement approaches.

4.5 D05 HSE Permits and Consents Register

This Deliverable report detailed the Health, Safety and Environmental (HSE) Permits and Consents Register anticipated for the design, construction and operation of the Acorn Hydrogen project.

At the time of writing at a preliminary stage of Concept Evaluation, the aim of the Register was to provide guidance to ongoing work which was subsequently summarised in the Deliverable 11 Concept Select Report, Deliverable 13 Statement of Requirements for Define and Deliverable 14 Design Specification for the JM (LCH™) Plant. The Register will remain a live document until the Acorn Hydrogen Plant is operational.

The Acorn Hydrogen Permits and Consents Register details the permits and consents required throughout the design, construction and operation of the Acorn Hydrogen facility. The Register covers the hydrogen reformer and associated plant. Currently, the Register does not explicitly include permits and consents relating to any of the route to market options for the supply of hydrogen, although it includes a non-exhaustive list of regulations and potential consent requirements relevant to the conveyance of hydrogen around the UK. In addition, the Register does not include the export and storage of CO_2 produced by the facility, which has been included in the Acorn CCS Permits and Consents Register. The initial Permits and Consents Register identified the following number of permits, consents and regulations that are relevant to Acorn Hydrogen:

- 16 onshore permits and consents
- 7 offshore permits and consents
- 19 health and safety regulations
- 16 environmental regulations
- 4 other relevant regulations

Two onshore permit and consents were relevant to the Concept Evaluation stage of the project. All other permit and consents are applicable to future stages of the project. The Health, Safety and Environmental regulations identified will apply throughout the duration of the project stages and as such have no timescales attached. The Register remains a living document, which will be updated as the project progresses.

4.6 D06 The Role of Acorn Hydrogen in Enabling UK Net Zero

Building on the foundations established by Acorn Hydrogen, Scottish hydrogen production could reach between 19 to 121 TWh/yr by 2050. In addition, hydrogen can become a key export commodity for Scotland with the potential to export 48 TWh/yr to European markets by 2050. As such, Acorn Hydrogen could provide a GVA to the UK economy of £130 million/yr and offer up to 1,600 jobs by 2030.

Acorn Hydrogen has a key role to play in the transition to Net Zero, it offers the potential to enable major steps towards decarbonisation of heat, industry, power generation and transport. The first deployment of Acorn Hydrogen, operational from the start of 2027, can pave the way towards decarbonisation of heat through blending with natural gas demonstrating the technology at a significant scale and placing the UK amongst the forerunners of “blue hydrogen” technology. Later build outs of Acorn Hydrogen will be crucial to have the scale of impact on emission reductions that will be required to meet Scottish and UK Net Zero targets.

Early and ambitious progress towards realising a hydrogen economy can be realised through utilising the Acorn Hydrogen project as a foundation and catalyst to enable further hydrogen production in Scotland to reach 19 to 121 TWh/yr by 2050, with an approximate 50:50 split between green and blue hydrogen production routes in this timeframe.

This major roll out of hydrogen could provide a cumulative GVA addition to the UK economy of £8.6 to £22.5 billion. Peak job creation of 13,000 to 28,900 jobs available is circa 2040, both direct and indirect through the investment required to enable major decarbonisation through hydrogen. These jobs provide key opportunities for the local region leveraging the oil and gas industrial expertise and heritage that are well established in the North East of Scotland. In the longer-term, establishment of hydrogen infrastructure across Scotland would yield 2,500 to 7,700 long-term jobs in 2050.

The proposed scenarios would require a capital expenditure of £6.0 to £19.1 billion between 2020 and 2050 to realise the required infrastructure to enable such a major transition to a hydrogen economy. Much of this capital would be invested between 2035 and 2040 and would lead to significant jobs both in the Aberdeenshire region around St Fergus but also across Scotland with significant direct and indirect jobs being generated in the industries involved and in the associated supply chains.

Acorn Hydrogen is key to enabling a Net Zero transition for Scotland and the UK, the exact role it will play will be dependent upon the level of ambition, the investments made, policies implemented and the resources available. Current developments in Scotland point towards a future in which CCS and hydrogen will play a significant role and both Acorn CCS and Acorn Hydrogen can together enable early swift progress in this transition.

The extent of the role of Acorn Hydrogen and the resultant economic, social and environmental benefits will depend on the level of regional and national ambition. To provide an evidence-based approach to the consideration of these impacts, for D06, Element Energy have completed their Hydrogen in Scotland report in which they developed three scenarios to reflect the potential role of Acorn Hydrogen in realising a Net Zero transition at differing levels of regional and national ambition. Element Energy then completed a techno-economic

assessment to provide a view on the economic, social and environmental benefits associated with each scenario.

The three scenarios developed by Element Energy consider hydrogen use across Heat, Industry, Power, Transport and Export, with the timeline of each sector considered in all scenarios. The scale of hydrogen demand in each scenario varies from 19 TWh/yr to 121 TWh/yr in 2050 with the supply of this split evenly between green and blue hydrogen sources. The scenarios are titled as below and consider progressively larger regions corresponding to possible levels of ambition.

- Regional Growth
- Scottish Hydrogen Economy
- European Outreach

The European Outreach scenario considers the case in which Scotland is a major global leader in the hydrogen market and can export significant quantities of hydrogen to meet international demand from Europe and other areas of the UK. In this scenario the export market met by Scotland stands at 48 TWh/yr by 2050 and is a major export commodity for the country.

These scenarios highlight the range of potential growth-rates of the hydrogen market over the coming decades, reflective of the potential levels of ambition to realise a Net Zero economy. In addition to the environmental benefits that could be realised in each scenario, there are also significant potential economic benefits associated with each. As summarised above, Element Energy completed a techno-economic assessment of the proposed scenarios taking into consideration the capital expenditure and operational costs and realised jobs associated with each scenario.

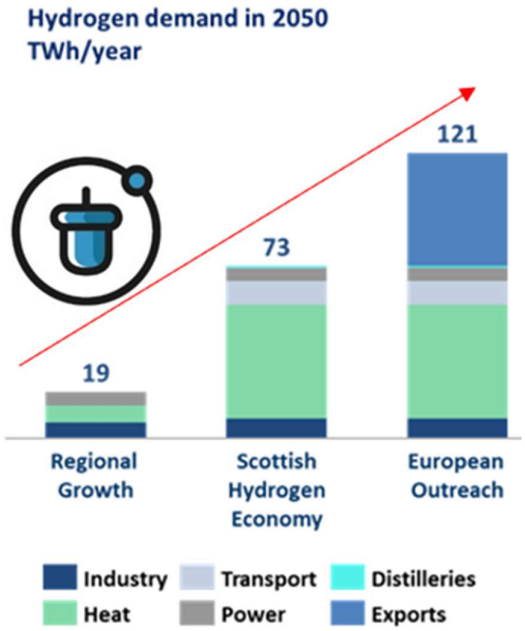


Figure 4-1: Hydrogen in Scotland Scenarios

4.7 D07 Basis of Design

This Deliverable Report documents the Basis of Design for work performed under HSC-2. The focus was defining the basis for the concept design options and the basis for the Johnson Matthey (JM) Reforming Island Basic Engineering Package (BEP), Deliverable D14.

The conclusions from the Acorn Hydrogen screening work, D08, informed the options studied in more detail and summarised within the D11 Concept Select Report and informed the basis for the JM BEP on the reformer island.

This Basis of Design includes the key decisions required to be studied to select the optimum concept involving the JM Low Carbon Hydrogen (LCH™) advanced reforming technology and defines the Base Case concept to enable the JM BEP to be progressed.

Key parameters for the Concept Select Phase and the JM BEP for the reforming island included:

- A 200MW plant capacity and identify further routes to market in addition to the initial 2% hydrogen blend by volume into the NTS.
- A base case concept involving cryogenic Air Separation Unit (ASU) oxygen supply, amine CO_2 capture and Pressure Swing Absorption (PSA) hydrogen purification using imported grid electricity. This also formed the basis for the JM BEP on the reforming island.
- Evaluation, versus the above base case, a scheme with reduced oxygen purity and increased operating pressure with the aim to evaluate the potential for reduced carbon intensity and operating expenditure.
- Further assessment of the suitability of the Miller and Feeder 10 pipelines for seasonal hydrogen storage and smaller capacity options for intra-day storage.
- Aspects to be included in the assessment of site locations which considered synergies between Acorn Hydrogen and Acorn CCS projects.

Whilst the concept is based around Johnson Matthey's LCH™ reforming technology the majority of Deliverable D07 was also used to form the basis of design for the ART Study.

4.8 D08 Alternative Technology Options Report

D08 summarised the Concept Study Screening Phase work completed which focused on 'Greenfield' design aspects and evaluation of alternative technology options for the reformer balance of plant. A framing process identified key decisions to address and mapped out technical options to screen. The subsequent work included reforming studies by Johnson Matthey and CO_2 capture / hydrogen purification studies with various licensors and overall balance of plant studies.

Key recommendations for work to be completed within the D11 Concept Select Report are summarised by the five bullet points in the previous Section, 4.7.

Under HSC-2 a development concept based around Johnson Matthey's Low Carbon Hydrogen (LCH™) reforming technology was matured. D08 concluded and presented the summary of HSC-2 study framing and Screening work.

A reforming study by Johnson Matthey evaluated operating condition sensitivities and how the LCH™ reforming equipment could integrate with non-reforming technology options. Studies were performed involving licensors of oxygen supply, CO_2 capture and hydrogen purification technologies. To make an overall holistic assessment of the technology options, a balance of plant study evaluated parameters including overall energy balance, CO_2 capture efficiency and technical cost for the various options. Work also included a review of plant size and turndown / hydrogen storage requirements.

Study framing identified key technical decisions to be taken during the HSC-2 Concept Study and mapped out a range of options to be considered. Screening studies documented under Deliverable D08 addressed technical decisions relating to plant size, turndown, hydrogen storage, CO_2 capture technology,

hydrogen purification technology, oxygen supply technology, reformer operating pressure and related compression requirements, power supply and key utilities. The main recommendations developed by the Screening Study are below.

4.8.1 Plant sizing, storage, and turndown

The main recommendations relating to plant sizing, storage and turndown screening studies were:

1) **Plant size:** Based on current forecasts of natural gas supply to St Fergus a 200MW plant is larger than required by the route to market of blending an initial 2% hydrogen by volume into National Grid's National Transmission System at St Fergus, unless hydrogen demand for the Aberdeen Vision project was included. However, it was agreed that Acorn Hydrogen would continue with a 200MW plant size for the Concept Select study whilst continuing to evolve additional routes to market for hydrogen. A smaller plant would degrade value and there is a growing body of evidence of future material growth in demand for hydrogen from the North-East of Scotland and beyond.
2) **Seasonal hydrogen storage:** Retain the Miller and Feeder 10 pipelines as options for further evaluation within the Concept Select study including desktop studies to evaluate material and integrity suitability. Note that the subsequent study confirmed that neither option was suitable for hydrogen storage.
3) **Intra-day hydrogen storage:** Retain the Atlantic & Cromarty pipeline, Aberdeen Vision pipeline, Miller pipeline and Feeder 10 pipeline as options for further Concept Select study. Note that the subsequent study confirmed that the linepack option for both the Aberdeen Vision Pipeline and NTS Feeders are to be considered for further post HSC-2 study.
4) **Turndown:** Perform a preliminary availability study in the Concept Select study to better assess the overall impact and capability of plant turndown. Establish if turndown could replace seasonal storage.

4.8.2 Process building block options

The main recommendations for the Concept Select study, relating to the process building block options studied, were:

5) **CO_2 capture technology:** Only retain the base case Amine option.
6) **Hydrogen purification technology:** Only retain the base case PSA option. Direct export of hydrogen to a fuel cell market remains a limited volume option and thus the hydrogen export specification remained guided by the NTS assumed requirements, mainly carbon monoxide content of <20ppmv.
7) **Oxygen supply:** Retain the cryogenic ASU technology. Evaluate both Johnson Matthey's current base case oxygen purity assumption and a lesser purity to assess if material Capex and Opex savings may be realised.
8) **Reformer operating pressure and compression:**
    - Evaluate both Johnson Matthey's current base case operating pressure and a higher operating pressure case to assess if net savings can be realised by reducing compression requirements.

- Assume natural gas is supplied from a source above these battery limit pressures, and compression is at hydrogen export to meet market pressure requirements.
- Perform a commercial evaluation of the potential cost benefit of sourcing gas upstream of National Grid entry charges. Evaluate if potential savings are more or less than additional costs involved with the Acorn Hydrogen project needing to compress natural gas from NSMP to reach required inlet battery limit pressure for reforming.

9) **Power supply:**
   - Retain only the electrical import options rather than any self-generation option.
   - Continue to investigate ethical arrangements to commercially source green power (Guarantees of Origin).
   - Monitor Acorn CCS Project's power import decisions. These could impact how electrical import infrastructure to St Fergus is developed.

4.8.3 Screening Phase Results Review Status

The results and recommendations of the Screening study were reviewed and endorsed by a TOTAL E&P Quality Review (QR Screening) held on the 23rd of July 2020. This was subject to validation by the Acorn Hydrogen Project Partnership through a Decision Note process.

4.9 D09 Site Selection Report

Deliverable D09 reports on the selected site location for the Acorn Hydrogen Facilities at St. Fergus. Six site locations were identified, and via a structured methodology and evaluation, a clear recommendation was made to site the Acorn Hydrogen Facilities at Blackhill (Plot 1), an area of available industrial land north of the National Grid Terminal.

As part of the brownfield integration study that provided input into the site selection decision the priority interfaces were matured:

- Natural Gas import and hydrogen export will tie-in to the NTS at the National Grid Terminal;
- CO_2 export will tie-in to the Goldeneye Facilities on the SEGAL Terminal; and
- Electricity will be Grid import from SSE or SHET, and water will be supplied from the Scottish Water Network.

Integration with Acorn CCS was also assessed to provide input into the site selection decision. A maximum integration scenario was presented in D09 to inform on the opportunities that could be available to allow consideration of a more integrated approach, highlighting potential synergy benefits of up to £60m of capital expenditure (Capex) and £2.5m per year of operational expenditure (Opex).

On the 26th of March 2021, National Grid confirmed that Blackhill (Plot 1) will need to be retained by them for 18-24 months to enable parallel FEEDs on either a) a full refurbishment and upgrade of their existing terminal; or b) proceeding with a new terminal on Plot 1. This led to the completion of Heads of Terms for Acorn Hydrogen to secure a Land Option for National Grid's Plot 2 (immediately

north of Plot 1) and Plot 3 (immediately east of Plot 2) with easement for a pipeline corridor through Plot 1. Plots 2 and 3 are also greenfield and designated for industrial use.

There is minimal impact on the completed Concept Select work. Plot 2 is 2.5 times larger than Plot 1 and thus better suited to the revised Acorn Hydrogen Phase 1 approach of three staged units. Whilst some pipeline runs will see an increased length, i.e., natural gas and hydrogen, others such as water and dense phase CO_2 become simpler. The planned FEED level work being completed on the interfaces during the Define stage will be adjusted accordingly.

4.10 D10 Public Engagement Report

Throughout the Acorn Hydrogen Concept Select study, there has been a comprehensive suite of communications and stakeholder engagement activity. It has built on stakeholder identification exercises and communications activity completed during HSC-1 as well as benefitted from an integrated approach with the Acorn CCS project, which during the Acorn Hydrogen Concept Select study has been conducting a public consultation programme.

All the public communications and stakeholder engagement activity completed during this phase of the Acorn Hydrogen project have been completed during the Covid-19 pandemic, and because of this, have taken place digitally. The primary outcome is that there is a suite of digital resources that communicate the project which have been designed to be accessible and serve several purposes. These materials have been positively received by the public.

D10 summarised the public engagement completed throughout the Concept Select period, up to the time of writing the report, and set out the approach for communications and stakeholder engagement through the remainder of the Concept Select and subsequent Concept Definition and Define stages. From a communications perspective, activity had focused on laying strong foundations and introducing the Acorn Hydrogen Project to key stakeholder groups.

Going forward, this activity will continue, as the team regularly meet with key stakeholders, deliver presentations for technical and non-technical audiences, participate in educational outreach activity and design high-quality graphics for project dissemination. As an example, since submitting D10, the stakeholder engagement and communications activity has continued in a similar nature including ongoing engagement with key political and industry stakeholders, participation in technical and non-technical events, and engagement with pupils at schools local to St Fergus, as well as the publication of a newsletter and updates on the @TheAcornProjectUK Twitter account.

The subsequent Define stage will need a higher volume of more specific engagement activities, particularly delivering a formal consultation programme as part of the permitting and consenting regime required for the project to make a positive Final Investment Decision.

4.11 D11 Concept Select Report

D11 summarises 12 months of technical study work including an optimum design concept for the Define stage, with an understanding of the cost, schedule, risks, opportunities, and build-out constraints of the project.

The Concept Select study considers all unit operations within the plant and the integration aspects with utility providers and sites. This is based on the Johnson Matthey Low Carbon Hydrogen (LCH™) Technology.

In the first part of the HSC-2 study, several concepts were investigated and screened, allowing many decisions to be made, principally on the unit operation

technologies. As a result, two concepts were selected, a Base Case and a Sensitivity Case, as reported in deliverable D08. These two cases have been developed further in the concept select phase to enable a concept selection.

Deliverable D11 selects an optimum design concept for the define phase, with an understanding of the cost, schedule, risks, opportunities, and build-out constraints of the project.

The concept selected, when considering the agreed project value drivers and performance metrics is the Base Case concept.

The Base Case Capex is estimated at £426m, including Company Costs. The Opex is estimated at £1.6bn over the 25-year operating life. The Capex estimate represents an 18% cost increase on the previous phase estimate, mainly due to transportation constraints limiting larger module deliveries thus requiring a "stick build" approach to construction. A stick build approach also increases project execution duration. The overall schedule now estimates first Hydrogen by Q1 2027. Early in Define, a Transportation Study is to be completed to challenge the transportation constraints and to determine the module dimensions and road preparation works required for a more modularised solution. Such an approach would likely reduce the overall site man-hours, thus reducing safety risks and potentially bringing the schedule back in line with an earlier start-up target.

The D11 report and its Annexes extend to circa 1000 pages summarising the considerable work completed by TEPUK, their Engineering Contractor, Genesis, and the various technology vendors engaged, principally Johnson Matthey. The D11 Cover Report provides a short overview of the extensive engineering analysis completed. This includes condenses summaries of the following:

- Concept Technical Decisions
- Technical Assurance including the Assurance Review, Quality Reviews and Decision Notes
- Technology Readiness Level (TRL)
- Output OP1110 Conceptual Cost Estimate
- Output OP1111 Tie In Conceptual Design for Natural Gas Supply
- Output OP1112 Tie In Conceptual Design for Hydrogen Product Export
- Output OP1113 Process Safety Reports – Hazard Identification (HAZID)
- Output OP1114 Coarse Quantified Risk Assessment
- Output OP1116 Outline Agreement for Export of CO_2 To Acorn CCS
- Output OP1117 Economic Analysis of Options
- Output OP1118 Lay Out Drawings and Equipment
- Output OP1119 Coarse Operating Philosophy
- Output OP1120 Design Basis
- Output OP1121 Heat and Material Balances
- Output OP1122 Process/Utility Flow Diagrams (PFDs/UFDs)
- Output OP1123 Utilities and Power Schedule
- Output OP1124 Main Equipment List
- Output OP1125 Site Location Report
- Output OP1126 Preliminary Safety Concept (Including HAZID)
- Output OP1127 Capex Class 4 and Opex
- Output OP1128 Uncertainties, Risks and Opportunities Analysis
- Output OP1129 Project Schedule
- Output OP1130 Concept Study Report (CSR)
- Output OP1131 Specification for all Interfaces
- Output OP1132 Request for Services Datasheets

- Output OP1133 Engineering Outputs Similar to Conceptual Level and "Pre-Project" Level for High Risk Integration Aspects Identified
- Output OP1134 Identification and Evaluation of Potential Synergies with Acorn CCS
- Output OP1135 Quantify Hydrogen Plant Scaling and Learning Cost Benefits
- Output OP1136 Outline the role of Hydrogen Storage in Connection with Growth Scenarios
- Output OP1137 Outline Development Plan for Further Growth and Build Out, Including Schedule, Cost and Potential Hydrogen Volumes
- Output OP1138 Commercial Screening on Short List Technologies Identified in Screening

The detailed work for the above list was included within Annexes supplied alongside the D11 Cover Report:

- Annex 1: Genesis Concept Select Report Volume 1
- Annex 2: Genesis Concept Select Report Volume 2
- Annex 3: Genesis Concept Select Report Volume 3
- Annex 4: Johnson Matthey LCH™ Concept Select Report
- Annex 5: Project Assurance Review (PR0) Findings Table with Responses
- Annex 6: Acronyms and Abbreviations

4.12 D12 Route to Market Report

D12 report was accompanied by the following separately supplied studies:

- A localised hydrogen purification study completed by Costain.
- A study also completed by Costain to evaluate the options to road haul hydrogen direct to end users.
- A hydrogen storage assessment completed by Atkins Global.
- A Frontier Economics evaluation of Acorn Hydrogen's interaction with the emerging hydrogen market that sought to summarise how hydrogen could be marketed and traded at scale.
- An Oil & Gas Technical Centre led study completed by ERM on the marine export of hydrogen.
- A high level feasibility study completed by Siemens on the opportunities to introduce a hydrogen blend into the two Siemens power generation turbines at SSE's Peterhead Power Station.

In addition to the Executive Summary below, the Conclusions captured sixteen pages of key Route to Market points, both those already established and those recommended for further study.

D12 summarised that Acorn Hydrogen is a key enabler for the UK transition towards Net Zero, with a major role to play in meeting UK and Scottish Hydrogen production and utilisation targets. Acorn Hydrogen is targeting hydrogen production at scale in the mid 2020's and can be a key part of achieving the UK's ambition for 1GW of production capacity in this timeframe.

A 2% volume blend into the NTS is the primary Route to Market for Phase 1 of Acorn Hydrogen, capturing ~400,000 tCO_2 annually. Acorn Hydrogen could supply 20% hydrogen to Aberdeen City by the end of 2026 with Aberdeen being well placed to be the UK's first 100% Hydrogen City by 2030. Hydrogen development across the UK could add up to £18 bn/y to the UK economy with total employment of 221,000 by 2050.

There is growing global interest in the role of hydrogen in achieving Net Zero with over 14 countries having now announced national hydrogen strategies and many more under development. In the UK both the Scottish and UK Governments have committed to publishing their respective National Hydrogen Strategies in early 2021. Ahead of this, both Governments have announced some of their key hydrogen development targets:

- To complete testing by 2023 to enable 20% blending of hydrogen into the gas distribution grid (UK)
- A Hydrogen Neighbourhood by 2023, a Hydrogen Village by 2025 and a Hydrogen Town by 2030 (UK)
- 1GW hydrogen production capacity by 2025 (UK)
- 5GW hydrogen production capacity by 2030 (UK)
- 5GW hydrogen production by 2030 (Scottish)
- 25GW hydrogen production by 2045 (Scottish)

Acorn Hydrogen is well placed to be a key project in enabling both UK and Scottish targets to be met, being one of few projects targeting mid-2020's operation as per the 2025 1GW UK target, with the planned 200MW Unit 1 plant equivalent to 20% of the UK ambition, and with significant opportunities for build-out by 2030 and 2045.

Identified build-out options for hydrogen in Scotland total 121TWh in annual hydrogen demand by the year 2050, while maximum blue hydrogen generation based on the forecasted 2050 gas flows into St Fergus is circa 60TWh. By 2050 therefore, it is anticipated green hydrogen will have a major role to play producing around 50% of the hydrogen demand. St Fergus could be a major import location for hydrogen produced via offshore wind and the infrastructure development started through Acorn Hydrogen will be key to transporting this hydrogen to point of use.

The UK Prime Minister Boris Johnson's recent '10 Point Plan' provided details for developing hydrogen regions including a "Hydrogen Town" by 2030. Work started by the Aberdeen Vision project places Aberdeen as a potentially leading location for this and regional engagement around the development of hydrogen could place the region as a leading "Hydrogen Valley".

Testing is underway across a range of projects, to develop the evidence required to enable hydrogen utilisation in the existing gas grid and at points of end use. Key projects developing the safety case evidence are H21 NIC, HyNTS Future Grid, HyStreet, Hy4Heat and HyDeploy. Except for HyNTS FutureGrid these projects target completion dates before the end of 2021, HyNTS Future Grid targets completion of Phase 1 in April 2023 with Phases 2 and 3 being scheduled to continue beyond 2023.

There are a range of potential hydrogen demands under development which could be met through Acorn Hydrogen. Blending into the NTS at an initial 2% by volume continues to be the basis of demand for Phase 1 of Acorn Hydrogen. Engagement with SGN indicates the Aberdeen Vision Pipeline could be completed before the end of 2025 and thus has an aligned timeline to enable the 20% blend to Aberdeen City to form part of the demand in Phase 1.

To enable blending of hydrogen produced by Acorn Hydrogen into the National Grid and SGN systems several changes to both technical and commercial aspects of the UK Gas market and Network management need to occur. Firstly, revision of the Gas Safety (Management) Regulations to allow blending above the current standard is necessary and work is under way by BEIS and IGEM to do this. This work needs to be concluded quickly to meet Government targets

for hydrogen use and carbon reduction targets. The second aspect of blending is the commercial arrangements for placing hydrogen into the UK gas system. Changes are needed in that the energy market itself to ensure effective pricing across the balancing, trading, capacity and commodity markets. This can be achieved in several ways, but urgent work will be required to determine the optimum commercial structure.

Also, under development is supply of hydrogen to SSE's Peterhead Power Station (PPS), road haul of hydrogen to large energy users and export of hydrogen to European markets. Acorn Hydrogen is well located to transport hydrogen via road haul, with 94 malt distilleries within 200 miles with a total demand of circa 4.7GWh/d, equivalent to 109% of the output of a 200MW reformer.

Most sources of hydrogen demand are likely to exhibit significant intraday and inter-seasonal demand variations. A key technology to enable efficient operation of hydrogen production assets may be to incorporate hydrogen storage as part of an integrated hydrogen transportation system. Required volumes of storage capacity vary depending on acceptable hydrogen production turndown rates and the balance of hydrogen demands. Acorn Hydrogen analysis suggests that within Scotland a hydrogen storage capacity of up to 5,600GWh may be required by 2050 to meet inter-seasonal hydrogen demand variations assuming hydrogen production turndown is not economically viable, this figure will decrease if green hydrogen production plays a significant role.

Development of hydrogen is a major economic opportunity across the UK. Phase 1 of Acorn Hydrogen is likely to be one of the first low carbon hydrogen production facilities operating at a significant scale, as such it is a key part of the path towards enabling hydrogen to realise its full economic and decarbonisation potential. Based at St Fergus it is a key part of transitioning the northeast of Scotland to being a low carbon energy capital. Within Scotland the development of hydrogen has the potential to have major economic benefits with the potential to add up to £22.5 bn in cumulative GVA by 2050 and up to 7,700 long term jobs to the Scottish economy. Across the UK, this impact is even more pronounced with the potential to add up to £18bn/y to the UK economy with total additional employment of 221,000 by 2050.

BEIS are currently in the process of developing low carbon hydrogen production Business Models to support the development of low carbon hydrogen in the UK. This support from Government will be key to enabling low carbon hydrogen production projects to develop in the coming decade. The BEIS timeline for the development of these business models is aiming for completion in 2022, some significant time after the completion of the HSC-2 stage of Acorn Hydrogen.

Based on the preliminary business models currently under scrutiny by BEIS, Acorn Hydrogen has developed six economic screening models, to evaluate the impact of operating under the shortlisted business models. Internal analysis and discussions with BEIS are ongoing to understand and identify the most appropriate and preferred business model for the Acorn Hydrogen stakeholders.

Following the completion of the Concept Evaluation project development stage in May 2021, the Acorn Hydrogen Levelised Cost of Hydrogen (LCOH) will be in the range of 5.4 to 8.4 p/kWh based on a Class 4 level of cost estimation. A finance discount / WACC rate of 10% has been used within the economic calculation. This is for hydrogen injected into the gas network at St Fergus and includes the carbon capture and sequestration fee. It excludes any gas distribution network use of system charges or Gas Shipper charges/margin.

No Government revenue support mechanism for hydrogen is included which could enable the price per unit of energy payable for hydrogen to remain comparable with an energy equivalent volume of natural gas. BEIS have stated the hydrogen business model / revenue support mechanism will be confirmed by the end of 2022.

Acorn Hydrogen will complete a Call for Tender in 2021 to finalise the reformer technology selection upon which the project will commence Front End Engineering Design (FEED) in Q4'21. The next sensible re-evaluation of Acorn Hydrogen's LOCH will be upon the completion of FEED in 2023 when a revised figure can be confirmed that considers the revenue support mechanism.

As part of the Concept Evaluation study, Acorn Hydrogen commissioned Costain to complete a road haul feasibility study comparing compressed gaseous hydrogen (CGH_2), liquid hydrogen, ammonia and liquid organic hydrogen carriers (LOHC). It concluded that CGH_2 at 520barg was the most cost-effective means to transport hydrogen for all mainland UK distances <450 miles. Incremental unit costs to the above LCOH, for a full chain solution, were confirmed as 2.6 and 4.2 p/kWh at 50 and 200 miles respectively. Thus, circa 8.8 to 11.8 p/kWh delivered cost to within 100 miles from Aberdeenshire, prior to any support mechanism.

These costs are provided purely as a mid-2021 snap shot indication, are non-binding and do not represent commencement of any commercial discussion.

Acorn Hydrogen is a key step in the UK transition towards Net Zero, with a major role to play in meeting UK and Scottish Hydrogen production and utilisation targets. Early development of Acorn Hydrogen in the mid 2020's will be a key hydrogen production project to achieve the UK target of 1GW of low carbon hydrogen production capacity by the mid 2020's. With the major build-out opportunities and scaling capability of the project holding the potential to supply a large portion of the hydrogen to meet the subsequent 2030 and 2045 UK and Scottish targets.

To maximise this opportunity and plant the Acorn for a hydrogen economy in Scotland a cross supply chain and key stakeholder coalition of the willing is needed to expedite a focused plan.

4.13 D13 Statement of Requirements for Define

With the Acorn Hydrogen Project close to completion of the HSC-2 Concept Evaluation Study, the collective parties across the Acorn Hydrogen Project Team produced this summary report of outline the requirements to take the project through to a Final Investment Decision (FID).

The project development stages were summarised providing a high-level walkthrough through to FID and then to First Hydrogen. The Journey to FID was then detailed by outlining the main areas of work scope prior to summarising the aspirational 20-month development plan and its associated £23m budget. This is supplement with Annexes that provide the detail of:

- The technical requirements for Front End Engineering Design (FEED);
- The Basis of Design for FEED;
- The Contracting Strategy for all the Technical and Non-Technical main workscopes;
- The Project Execution Plan (PEP); and
- The Level 1, 2 and 3 Project Schedules through to FID

Several key project outputs on environmental activity were integrated into the D13 report including a headline Green House Gas assessment and the plan for the Environmental Impact Assessment to be completed within FEED.

Finally, a short overview was provided on the Journey to First Hydrogen outlining the development plan and budget for Execute including a Level 1 Project Schedule. The project is well placed to proceed through the remaining project development stages required for a Final Investment Decision (FID).

The Journey to an aspirational FID target date and the requirements to achieve this landmark result have been outlined. The Project Budget for the Concept Definition and Define project development stages through to FID has been calculated at £23m. How this has evolved from the ISCF-2 Bid submitted on the 7th of October 2020 has been detailed.

A swift mobilisation of resource to deliver early activity at a high quality is key to ensuring a successful FID at the aspirational date. Specifically, this involves the:

- Consultation with the shortlisted reformer vendors ahead of the writing and issue of the Call for Tender. The subsequent evaluation of returns and selection of one or more vendors depending on whether a Single or Dual FEED is pursued.
- The framing sessions to reassess Acorn Hydrogen's Value Divers, Givens and Performance Criteria and the subsequent setting of the required Technical and Non-Technical Decision ahead of FID.
- A refocused approach with both National Grid Gas and SGN to further mature the Route to Market requirements to underpin an FID and accelerated Build Out.
- The creation and implementation of a plan to complete the hydrogen supply chain through the engagement of off takers / shippers and end users.

A positive Final Investment Decision could then see "First Hydrogen" production at St Fergus by the start of 2027 through two newly created and matured routes to market. Acorn Hydrogen remains well placed to be a major contributor to the common aim of both the Scottish and UK Governments to deploy 5GW of hydrogen production by the end of 2030.

4.14 D14 Design Specification for the Johnson Matthey Low Carbon Hydrogen Plant

D14 presents the Johnson Matthey Low Carbon Hydrogen (LCH™) FEED study of their reforming island. The FEED study assumes the use of JM's LCH™ plant with a production capacity of 67 kNm³/hr. The LCH™ plant can attain an overall carbon capture rate of 97%.

D14 also presents the preliminary safety concept, performance metrics for the JM LCH™ technology, operability and reliability study results, the preliminary plan for site abandonment, and dispersion analysis assessment results.

A preliminary Statement of Requirements (SOR) has been prepared to list the points considered as structuring for the Acorn Hydrogen Project development. If changed or challenged, they would significantly modify the Project's technical definition. When fully matured in the next development stage, the SOR can be used as a practical tool for monitoring basic engineering.

The Preliminary Safety Concept defines the engineering basis for the development of equipment and systems to be included within the design.

Performance metrics defined in the D07 Basis of Design were calculated for the JM LCH™ reforming technology. Based on the results of the Reliability Availability and Maintainability (RAM) analysis performed, a production availability of 94.1% is achieved when no market constraints are considered that impact the hydrogen plant's ability to produce. Market constraints, i.e., intraday and inter seasonal impact of hydrogen demand reduce the availability by 2.8% to 91.3%.

The site abandonment costs are estimated at £64m, calculated conservatively as 15% of the Capex costs presented in the D11 Concept Select Report.

The preliminary version of the SOR lists the points considered as structuring for the Project. It is recommended to mature the SOR to an initial Rev0 version during Concept Definition or part way through the Define stage, when the reference base reflects design intentions, frames design bases, and can be used to check Project compliance. The SOR can then be used as a practical tool for monitoring basic engineering.

The Deliverable D14 scope includes the following main Outputs:

- Output OP1403 Safety Concept
- Output OP1404 Performance Indicators
- Output OP1405 Preliminary Piping & Instrument Designs (P&ID's)
- Output OP1406 Preliminary Material Take Off (MTO)
- Output OP1407 Operability and reliability Assessment (OR&A)
- Output OP1413 Plant Shutdown (ESD) Cause & Effect Matrix
- Output OP1408 Hazard and operability study (HAZOP)
- Output OP1409 Preliminary Plan for Site Abandonment
- Output OP1411 Statement of Requirements for next phase
- Output OP1412 Dispersion Analysis Report

The main part of the D14 deliverable, the Johnson Matthey limited perimeter FEED study or Basic Engineering Package Report (March 2021) is supplied as Annex 2 of the D14 Report.

Further detailed work was included within other Annexes supplied alongside the D14 Report:

- Annex 1: Preliminary Safety Concept
- Annex 3: Preliminary Material Take Off
- Annex 4: Reliability Availability Maintainability (RAM) Technical Note
- Annex 5: Preliminary Plan for Site Abandonment
- Annex 6: Statement of Requirements
- Annex 7: Dispersion Analysis Report

4.15 D15 Project Lessons Learned

The Hydrogen Supply Competition Phase 2 (HSC-2) funded Concept Evaluation Study for Acorn Hydrogen has, over 17 months, delivered 93 Outputs and 16 Deliverables on time in full within the approved budget.

Whilst the project has been successfully delivered it was recognised, through the upfront inclusion of scope to produce a summary of project delivery lessons learned, that not everything may go to plan. Thus, feedback was actively sought throughout the project with multiple lessons learned workshops run during the final project milestone to establish key lessons learned that would benefit future projects, either the subsequent development stages of Acorn Hydrogen or future BEIS Innovation Programmes.

A series of conclusions were presented of both:

1. Key learnings for Acorn Hydrogen progression; and

2. Further key learnings for Future BEIS Programmes.

The main findings were summarised as:

- A flexible approach to a well prepared and facilitated Kick-Off and Framing process that enables the associated “forming, storming and norming” likely at the start of a project will derive value. Providing this is a) recognised and b) constructively managed by all parties, it can then deliver the foundations for subsequent successful project delivery.
- Efficient kick off meetings and framing workshops are key to establish common focus at the start of the project, aligning scopes and priorities which are then maintained through establishing a meeting cadence to ensure a regular rhythm of review. Clear and transparent communication is well received and aligns all involved on the project.
- The rigour of planning and subsequent schedule driven activity can ensure a regular release of material that provides sufficient review time through forewarning and thus securing dedicated assessor resource for the Review and Verify of output.
- Appropriate and timely intervention by and support from the BEIS Innovation Team has been greatly valued and has enabled the project team to improve and mature an early-stage project and successfully navigate it to the next stage of project development.
- Align flexibly funded programmes that facilitate progression between project development stages which require each project stage to produce a clear “Statement of Requirement” for the next stage of project development with minimum requirements specified. This enables a comprehensive and efficient mobilisation of each follow-on project stage.
- Future projects will need to adapt to an increase in home working whilst balancing the importance of group based activity and social interaction. Resilience can be strengthened through embedding the effective use of digital tools including the wider capability of Mural, SharePoint, Teams, etc., supplemented with an up-to-date knowledge dissemination library of easy to access and self-digestible material.

4.16 D16 Project Summary

This document. BEIS were separately supplied with a shorter eight page brochure style executive summary document. This digital document is available as a download from the Acorn Project website, https://theacornproject.uk/.

5.0 Project Assurance Review

The Acorn Hydrogen Project is currently proceeding through the Concept Select stage, which entails Concept Evaluation and Concept Definition as outlined in Figure 3-1. HSC-2 covers the Concept Evaluation stage of the project, for which this section summarises the assurance process completed.

Separate peer reviews were carried out for each scope, including HSC-2 technical and commercial scopes as well as the independent Alternative Reformer Technology (ART) study completed in parallel. Once the peer reviews were complete, the project team carried out an Overall HSC-2 Project Assurance Review (PAR) prior to the project moving into the Concept Definition. The assurance process is outlined in Figure 6-2 below:

Figure 5-1: Acorn Hydrogen Concept Evaluation Assurance Process

The Commercial or Non-Technical Assurance peer review, encompassing project economics and commercial framework was carried out during the week of 22nd March 2021. The peer review consisted of expert representatives, independent of the Acorn Hydrogen Project, from all project partners assessing the approach and results of the completed commercial work.

The key focus of the commercial review included:

- Route to market
- Business model and funding
- Economics
- Regulatory
- Risks and mitigations

There were 17 recommendations from the Non-Technical review team with only one recommendation being ranked as high importance and high urgency, and therefore, required to be closed out before the end of HSC-2. This was for the Project Team to work with the Business Development Team to incorporate further competitor analysis into the Route to Market which has since been completed.

The HSC-2 Technical Deliverables were completed by TEPUK and therefore the Total Group assurance process was followed. This process consists of:

- Screening Development Quality Review (QRDEV Screening)
- Project Review (PR0)
- Relevant Discipline Quality Reviews (QR)
- A Development Quality Review (QRDEV)

The Overall Project Assurance Review (PAR) was carried out across the 4th to the 7th of May 2021. The review objectives were to confirm that the project had completed the HSC-2 scope of work and therefore the Concept Evaluation project phase and to:

- Confirm that the key decisions and assumptions that underpin the evaluated concept is sound and coherent.
- Assess the robustness and competitiveness of the evaluated concept.

- Assure that technical risks are identified, and appropriate mitigation plans are in place.
- Identify where technical and non-technical decisions require further input, clarification, study or further review.
- Ensure that the evaluated concept is credible and is adequate to establish the Basis of Design for the Concept Definition Phase.
- Review of the status / close out of previous assurance actions (e.g., commercial review and PR0)

The review team consisting of project partners independent assurance reviewers confirmed the project readiness to move to the next project stage, Concept Definition. The review team had 18 recommendations with two of those being considered of high importance and high urgency. The review team concluded that all recommendations are required to be closed out before the end of Concept Definition which is currently envisaged as at or before the 31st of October 2021.

The assurance process for the next project stage is currently being prepared and it will include as a minimum:

- Review of the status / close out of previous assurance actions (e.g., commercial review, PR0 and PAR)
- Gate Readiness Review at the end of Concept Definition
- Commercial and technical peer reviews prior to FID
- Gate Readiness Review prior to FID

6.0 The Way Forward

As stated in Section 3.0, and outlined in Figure 3-1, the Acorn Hydrogen Project has an established pathway through to Final Investment Decision, (FID). Funding to complete Concept Definition and Define is in place and mobilisation of and initial work for Concept Definition is well progressed. Define, specifically FEED work on the reforming plant and its interfaces, is projected to commence on or before the 3rd of December 2021 on the finalised Concept. Further to the aspirational target summarised in D13, the current target date for FID, subject to numerous aspects, is early 2024.

In the latter stages of the HSC-2 project the approach to Acorn Hydrogen Phase 1 was revised to reflect the accelerated deployment both required and achievable to meet the stated Scottish and UK Government statements for hydrogen deployment of 5GW by 2030. For St Fergus, Build Out to 10GW of hydrogen capacity is required in a relatively short timeframe to meet legislated Net Zero targets of 2045 (Scotland) and 2050 (UK).

The existing natural gas profile for St Fergus Gas Terminal throughput and its 10 Year Gas Statement future forecast were converted to potential hydrogen demand as summarised within D12. The plan initially drafted into D12 for Acorn Hydrogen Phase 1 was the deployment of a single 200MW Unit with a series of subsequent Build Out Phases comprising of 1000-1300MW for each Phase. A total of 10GW of hydrogen capacity would be required to fully mitigate the natural gas volumes still forecasted to flow through the St Fergus Gas Terminal in 2045. Within D12, a St Fergus Vision, buildout around Acorn CCS and Acorn Hydrogen was articulated to address BEIS's aspiration within the 10 Point Plan for UK industrial "SuperPlaces". This highlighted the 20Mt/yr of CO_2 removal and sequestration associated with the deployment of the 10GW of blue hydrogen capacity.

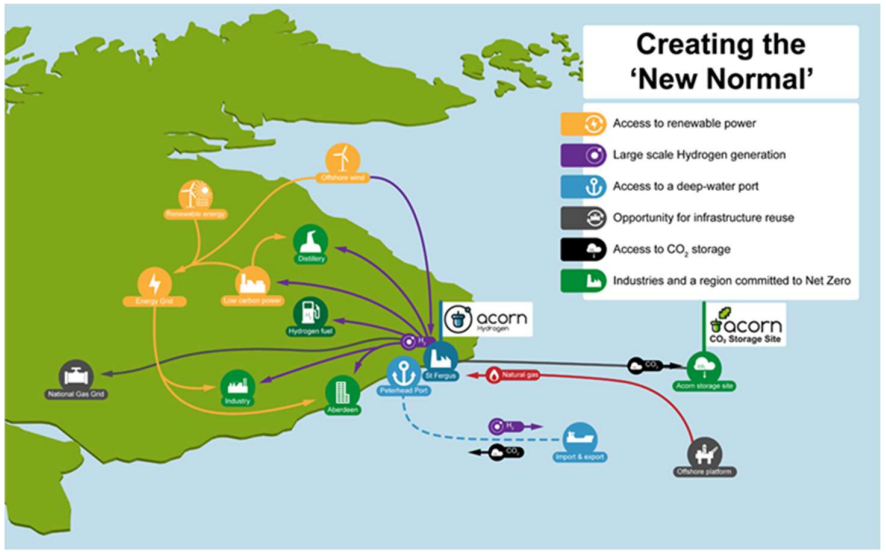


Figure 6-1: St Fergus as a UK "SuperPlace"

Ongoing work with the Hydrogen Business Model highlighted the material impact of the Levelised Cost of Carbon (LCOC) associated with Acorn CCS Transport and Storage. The Phase 1 of Acorn CCS enables at least 5Mt/yr of offshore transport infrastructure for CO_2 sequestration through the repurpose of the Goldeneye Pipeline. The 400kt/yr of CO_2 associated with the Acorn Hydrogen Phase 1 200MW Unit utilises only 8% of Goldeneye's capacity. Thus, in preparation for the Scottish Cluster Plan, to further optimise the Levelised

Cost of Hydrogen (LCOH) for Acorn Hydrogen Phase 1, the approach to deploying the initial reformer capacity has been revised.

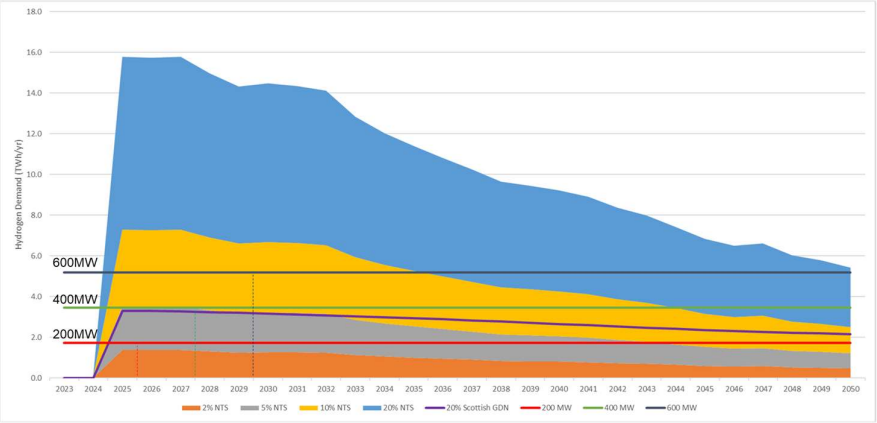


Figure 6-2: The deployment of 200MW Units to meet 2%, 5% and 10% NTS blends

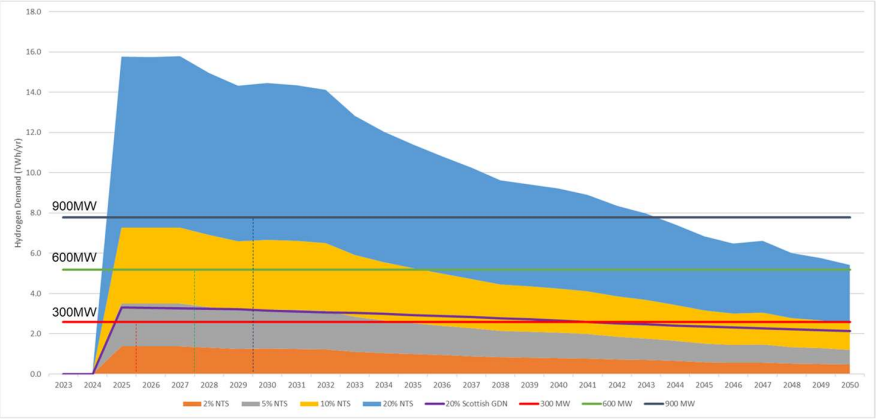


Figure 6-3: The deployment of 300MW Units to meet 2%, 5% and 10% NTS blends

Figure 6-2 and Figure 6-3 summarise modelling of multiples of 200MW and 300MW units respectively which have led to the revised approach for Acorn Hydrogen Phase 1 which will now comprise of three staged Units, a Unit 1 of 200MW with a 300MW Unit 2 and 300MW Unit 3, each staged to be 18-24 months later. Exact details will be finalised within Define ahead of FID. This will include the review of pre-investment for Units 2 and 3 alongside Unit 1. Hydrogen blending into the NTS will need to increase to 5% to support full operation of Unit 2 without turndown and 10% to support Unit 3 at full output. Ongoing conversations with National Grid have confirmed that they are directionally aligned to these % steps and their respective timelines, i.e., approval of at least a 10% hydrogen blend into the NTS at St Fergus Gas Terminal by 2030. The associated CO_2 for Phase 1 now increases from 400kt/yr from the start of 2027 to the latter now being 1.6Mt/yr by early 2030.

The above is subject to review during Define prior to or at FID, particularly with respect to the conditions required for and timing of deployment for Units 2 and 3 but also the subsequent development plan that gets Acorn Hydrogen to 3.5-4Mt/yr with the initial Phase of Build Out (Phase 2) and then subsequent Acorn Hydrogen Phases of 1GW+ Build Outs until all carbon emissions associated with the natural gas flow through St Fergus are fully mitigated at St Fergus or beyond.

In the BEIS Launch of the Cluster Sequencing Phase 1 on the 8th of May 2021, the Gas Safety (Management) Regulations (GSMR) and the requirement of a HSE exemption for a higher hydrogen blend into an existing natural gas network beyond the current 0.1% by volume was raised. It was stated that the:

"HSE is currently considering how a review of GSMR can be taken forward which would allow the existing hydrogen limit to be amended to allow for, say 20% hydrogen blend. Any such change would, of course, must be safe, with the

safety evidence being presented to HSE for assessment before any change could be made to the regulations (earliest 2023) and be accompanied by a completed BEIS value for money case, followed by necessary legal and regulatory change. Hydrogen producers planning to blend hydrogen into the existing gas network are still able to apply for support through this Phase-2 process. However, any financial support allocated through this process would be subject to the necessary policy decisions and regulatory changes required for the proposed hydrogen and natural gas blend into the existing gas network. An expected decision on whether to blend into the existing gas network or not is expected to take place earliest by Q4 2023. However, this decision may extend beyond this date."

Thus, for Acorn Hydrogen Phase 1, the BEIS Q4'23 direction on blending, infers that the Project will be unable to take FID until Q1'24 (Plan A). This is 9 months later than Acorn Hydrogen's aspirational target. Plan B would be to retain the current position of FID in Q2'23 by pursuing options with BEIS and /or National Grid Gas for the exemption etc. to bring blending forward, and thus bring FID forward. For both Plan A and Plan B, Unit 1 is 200MW and Units 2 and 3 are 300MW. The difference is on the delivery schedule. Both Plan A and Plan B are subject to sufficient Off-Taker evidence. Figure 6-4 provides a simplified outline of Plan A and B created to summarise the Acorn Hydrogen position for the Cluster Sequencing plan.

If the relevant parties, i.e., BEIS, IGEM, HSE, National Grid etc. can work with Acorn Hydrogen to further expedite the approval of the Safety Case and Hydrogen Standard for the initial 2% hydrogen blend by volume but more so 5%, 10% and ideally 20% blending within the NTS to match that planned by several of the low pressure Gas Distribution Network operators, then Acorn Hydrogen can be deployed faster with larger reformer capacities. This is also contingent on addressing investment needs of retrofit requirements for the gas network asset base and/or customer protection, i.e., deblending for existing natural gas users whose operation is sensitive to hydrogen. The 200MW capacity for Acorn Hydrogen Unit 1 is considered small in the context of the average reformer size being deployed globally for industrial applications which are more in the region of 300-700MW per reformer train. The replicability of modular reformer trains closer to the current global experience will lead to a major reduction in LCOH and a cyclical effect of increased CO_2 volumes leading to a reduced LCOC that further improves LCOH leading to further investment in the next Build Out Phase, etc. Ultimately the aim must be to optimise value for money for UK Taxpayers with the view, backed by investor support, that "if we build it, they will come". The demand is already there in the form of natural gas off-takers from the NTS. To achieve Net Zero, the carbon emissions associated with this demand needs to be mitigated through energy efficiency, electrification, hydrogen or most likely a combination of all pathways. Blue hydrogen will play a prominent role and where better to deliver this at scale than at St Fergus where a third of the UK's natural gas is currently landed and where three existing, but unused gas pipelines have the capacity to convey 20Mt/yr of CO_2 to well appraised world class offshore CO_2 storage capacity within short reach of those pipelines.

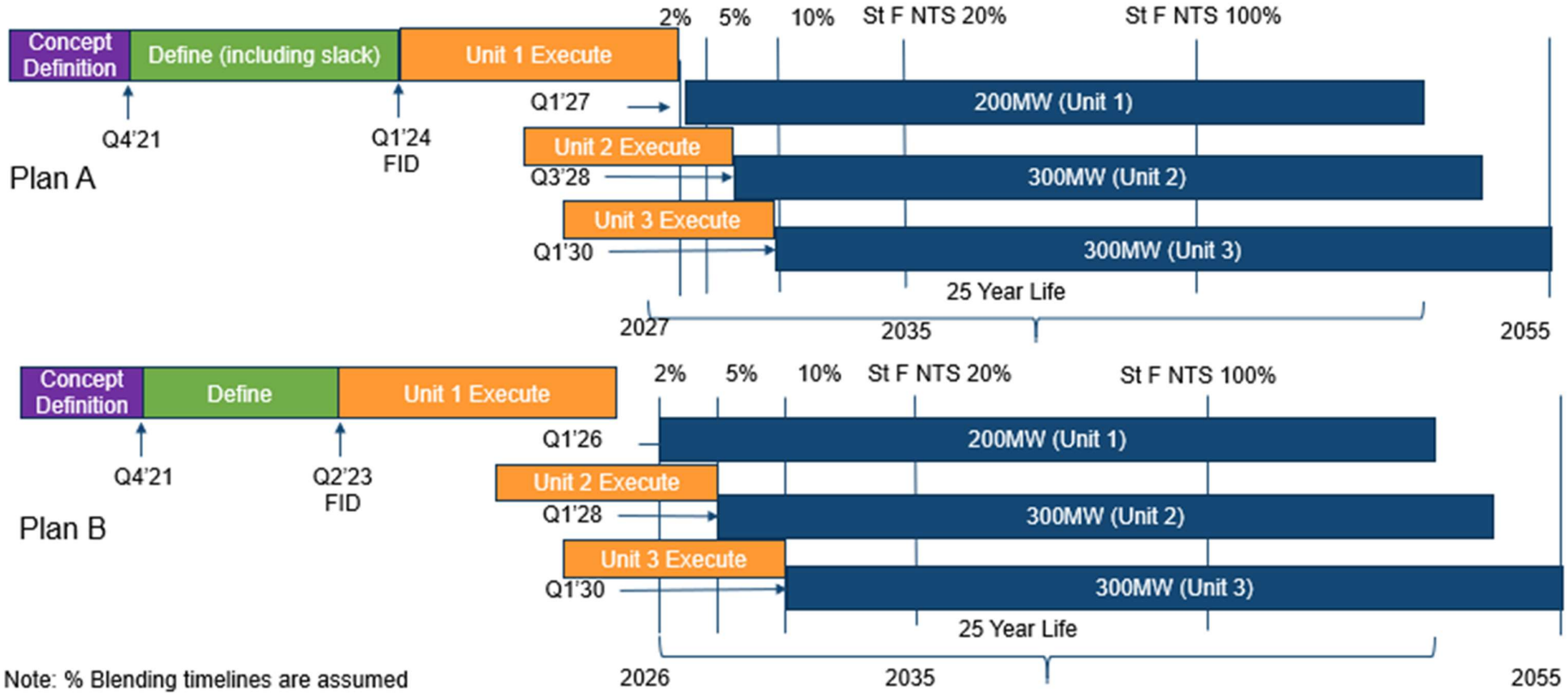


Figure 6-4: Plan A and Plan B for Acorn Hydrogen Phase 1 as determined by GSMR timing