PROJECT HYSECURE

PHASE 1 SUMMARY SEPT 2019

INOVYN Enterprises Limited

Holford Brinefield Offices

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Northwich

Cheshire

CW9 7TD

REFERENCE : STU-HYC-ES-00-0003

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1. EXECUTIVE SUMMARY

The HySecure project will demonstrate the deployment of grid-scale storage of hydrogen in a salt cavern. Hydrogen will be an essential component of the UK's transition to a zero-carbon emission economy as required by UK law. The Climate Change Act seeks to reduce greenhouse gas emissions by 100% by 2050.

With the HySecure project, INOVYN and Storengy are aiming to use their combined extensive experience to prove the storage of hydrogen in underground salt caverns, in quantities and at a cost which conventional above-ground storage solutions cannot provide.

Large-scale hydrogen deployment in the gas grid for industrial and domestic consumers will require unprecedented volumes of hydrogen storage capacity. Some natural gas storage capability already exists in the gas grid, but natural gas security of supply also relies on a diversity of sources (European interconnectors, North Sea supply, LNG import and gas grid storage capability). The hydrogen network of the future will not benefit from this diversity of supplies (particularly at the start) and the low volumetric energy density of hydrogen means that the gas grid cannot provide the same amount of "line-pack" storage for hydrogen as it can for natural gas.

This means that proving large-scale, low-cost hydrogen storage is an essential step to demonstrating the viability of a hydrogen energy system in the UK. Proving this part of the hydrogen supply chain will de-risk future, much larger investments by demonstrating that the UK has the capacity to store hydrogen in the volumes needed to maintain security of supply.

INOVYN and Storengy have shown in Phase 1 that it is feasible to create and operate a salt cavern for hydrogen storage of more than 300,000m^3, holding a working gas volume of at least 1100 tonnes of hydrogen. The cost of creating this storage facility would be an order of magnitude lower than the equivalent size storage utilising above ground storage tanks or other large-scale energy storage systems.

2. PHASE 1 SCOPE

Project HySecure is a government funded project to assess the feasibility of bulk storage of hydrogen using salt caverns. The project's overarching objectives include:

- Define the overall detail project scope, programme and costs for the development of the hydrogen salt cavern storage
- Investigate the regulator requirements
- Complete a series of technical / engineering studies
- Assess the hydrogen options to fill the cavern
- Assess the export options and capability of the cavern
- Carry out business planning and economic modelling

A collaboration agreement has been signed between INOVYN as lead partner, Storengy and Element Energy to carry out the Feasibility Study.

The Feasibility Study has been split into three areas:

- Commercial and Business Case
- Phase 2 – Scope of Work
  (funding to be sought via Second Round of BEIS Hydrogen Supply Competition)
- Phase 3 – Scope of Work

(funding to be sought via future BEIS funding opportunities or other funding opportunities.)

This document outlines the work completed in Phase 1 to allow the project to move forward; to inform the application for Phase 2 and develop the understanding of requirements for Hydrogen Storage in salt caverns. The work is broken down into the following areas:

- Project Management
- Cost estimates and Programme
- Permissions
- Engineering
- Hydrogen options; and
- Business planning

3. THE PROJECT

The HySecure project responds to Lot 4 of the BEIS Hydrogen Supply Competition and will demonstrate an innovative, low carbon and cost-effective storage solution for bulk hydrogen.

The HySecure project will demonstrate the deployment of grid-scale storage of hydrogen in a salt cavern in the North West of England. Hydrogen will be an essential component of the UK's transition to a zero-emission economy as required by UK law. The government have set ambitious targets to achieve both clean air and environmental goals. The Climate Change Act (2008, as amended 2019) seeks to reduce greenhouse gas emissions by 100% by 2050 relative to 1990 levels. Hydrogen storage will be an essential component part to this reduction in carbon emissions.
INOVYN and Storengy possess extensive experience of salt cavern storage and the safe manufacture, handling and distribution of hazardous chemicals and gases. With the HySecure project, INOVYN, Storengy and Element Energy are aiming to use their combined experience to prove the storage of hydrogen in underground caverns, in quantities and at a cost which conventional above-ground storage solutions cannot provide.

Large-scale hydrogen deployment in the gas grid for industrial and domestic consumers will require unprecedented volumes of hydrogen storage capacity. Some natural gas storage capability already exists in the gas grid, but natural gas security of supply also relies on a diversity of sources (European interconnectors, North Sea supply, LNG import and gas grid storage capability). The hydrogen network of the future will not benefit from this diversity of supplies (particularly at the start of the roll-out) and the low volumetric energy density of hydrogen means that the gas grid cannot provide the same amount of "line-pack" storage for hydrogen as it can for natural gas.

This means that proving large-scale, low-cost hydrogen storage is an essential step to demonstrating the viability of a hydrogen energy system in the UK. Proving this part of the hydrogen supply chain will de-risk future, much larger investments by demonstrating that the UK has the capacity to store hydrogen in the volumes needed to maintain security of supply. This demonstration project has the potential to constitute an essential component of the phased transition towards a low-carbon economy, necessary to meet the UK's emission targets.

The facility will be able to store over 1000 tonnes of hydrogen and can offer a tremendous cost reduction relative to above-ground equipment, with storage costs falling well below £10 per kg of stored hydrogen (excluding above ground compression/treatment). With an appropriate interface with the gas grid, HySecure will culminate in a critical piece of national energy infrastructure, storing energy in the form of hydrogen for a wide range of potential end users and demonstrating a path to low cost storage for a national hydrogen system.

A previous deployment proved the concept of using underground salt caverns for hydrogen at the Teesside chemicals works, where hydrogen was stored for industrial uses. The Teesside project was, however, much smaller scale and used a less flexible technology which significantly impeded flow rates, as it used a variable volume approach in which salt brine filled a portion of the cavern and would displace hydrogen as needed, thereby ensuring a constant gas pressure within the cavern. Whilst the technology deployed in Teesside was appropriate at the time (1970s), the subsurface hydrogen gas completion and wellhead technology used are not appropriate for the more advanced safety systems deployed in modern gas storage installations.

The HySecure project proposes a variable-pressure approach, rather than a variable-volume approach. It will be approximately 10 times larger in volume and will be built to the latest modern safety standards. This requires extensive design work and engineering assessment to ensure the integrity of the cavern and gas completion, and to develop the associated balance of plant. The potential for rapid cycling of the pressure of the cavern will require computer modelling of the salt strata to confirm its stability. Although comparable approaches have been taken to the storage of other gases, the particular challenges posed by molecular hydrogen requires extensive re-assessments of the involved components and materials. This applies to both the subsurface equipment, which ensures the delivery of hydrogen gas into the cavern and prevents leakages, and the complex above-surface equipment such as the wellhead, which regulates the flow of gas to and from the cavern.

4. ASSESSMENT OVERVIEW

The Phase 1 feasibility study concludes that a cavern could be created at the proposed location with a minimum volume of 300,000m^3. With a range between 300,000m^3 to 350,000m^3. This minimum volume would correspond to a total storage capability for hydrogen of approximately 1850 tonnes; with correspondingly more hydrogen for a cavern at the upper end of the range. The storage cavern would be normally operated by cycling the pressure between a minimum pressure and a maximum pressure. The maximum pressure is determined by the geology and depth of cavern to ensure the pressure containment is not compromised. The minimum pressure is likewise determined to ensure the integrity of the cavern is not stressed. The working gas volume is the quantity of hydrogen that can be injected and withdrawn from the cavern between the minimum and maximum pressures. This value will be set accurately at the end of solution mining when the exact free volume of the cavern is determined by survey. The initial estimate for working gas volume between the minimum pressure of 30bar and the maximum pressure of 80bar is approximately 1,100 tonnes of hydrogen.

As well as maximum and minimum pressures for salt caverns there are also restrictions placed on the maximum injection and withdrawal rates and the temperature of the hydrogen. The Phase 1 feasibility study has shown as part of a thermo-mechanical design study for the cavern, a range of scenarios can be accommodated within the operating window for the project, including injection and withdrawal at 40 tonnes/day.

The nature of the solution mining process and size of cavern required means that it can take over two years to create the optimum sized cavern. Further, this leaching process can only start after the construction of the solution mining infrastructure and drilling of the borehole.

Thus, it will not be possible to fully develop the complete demonstration project hydrogen storage cavern within the time window and cost budget allowed by the Phase 2 Hydrogen Supply Competition. This challenge was set out in the original application for Phase 1. The Phase 1 feasibility study has further confirmed this programme and process required to deliver the entire project. As set out in the Phase 1 application, it will be necessary to continue the project into a “Phase 3”, where funding is secured from another process or source to complete the project and deliver all the benefits. However, development within Phase 2, if granted, still allows substantial progress to be made towards delivering a Hydrogen Supply Solution

As part of Phase 1 feasibility study the benefits and advantages of the Stublach site for the first hydrogen storage cavern with the required capabilities for a growing hydrogen economy were considered.

These benefits can be summarised as follows:

- The site has good existing access and connections to the road network;
- The site has proven geology for the safe creation of salt caverns for the storage of high-pressure gas;
- The project partners have considerable experience of that geology and the solution mining process to create salt caverns;
- The site already benefits from considerable solution mining infrastructure, which allows the abstraction of river water for solution mining and the offtake and beneficial use of brine. A new greenfield site would require a substantial amount of solution mining infrastructure to be created at considerable cost and the brine would probably end up being wasted to the sea.
- The project partners have considerable experience in the development of solution mining programmes, operating the required infrastructure and delivering storage caverns;
- The proposed location for the hydrogen store already has a site road and wellhead compound created, leading to considerable savings in infrastructure costs;
- The proposed location is close to existing brine and water infrastructure. Although not directly connected at present the amount of new solution mining infrastructure is minimized by the close proximity of existing developments;
- The site has previously been consented for solution mining activities and natural gas storage activities. The adjacent site benefits from hazardous substances consent and top tier COMAH consent. Thus, although there has not yet been time to secure the necessary consents for the hydrogen storage project, with regard to land use planning and the control of hazards it should be a reasonable proposition to develop this project in this location; and
- The project partners have considerable experience in the development, operation, maintenance and use of gas storage; chemical processes; hydrogen production and use; and other salt cavern and hydrogen related projects.

5. WORK PACKAGES

5.1. WP1 - Management

Project Management and overall cost control

INOVYN was granted up to £240,962.72 for the Phase 1 feasibility study.

The provisional allocation was split between the project partners and some third-party contracts.

The project partners signed a Collaboration Development Agreement prior to the award of Phase 1 and have been successfully working under its terms since that time. There have been no disputes or disagreements between the project partners. The project partners have been successfully working together on other projects for a number of years.

Communications

Throughout Phase 1 most of the communication between the partners has been by email. In addition to this, there have been a number of telcon discussions with all partners and a greater number between INOVYN and Storengy.

There has been regular face to face meetings between INOVYN and Storengy to discuss all aspects of the project. Including individual discussions with the specialist engineers.

Technical reports in support of each of the work packages have been circulated between the partners and peer reviewed.

The Phase 1 project was delivered within the allotted timescale and below the budgeted amount by approximately £30,000.

5.2. WP2 – Execution Plan / Cost Estimate

**<u>Description = Detailed execution plan and strategy document;
Cost estimates for each package and stage of development; and
Detailed programme for each stage and phase.</u>**

Storengy have considered the scope of work requirements for the ongoing project management; future work packages to continue the project development; procurement strategy; and cavern testing requirements. Together they outline what areas of the project are covered in Phase 2 and what sections will have to be deferred to a future funding / later phase (Phase 3).

The proposed location of the hydrogen storage cavern is known as H325 on the Stublach Site of the Holford Brinefield. The site is owned by INOVYN. A site compound and site access road already exist. The proposed organisation for project execution will include a project manager from INOVYN and a project manager from Storengy. Due to the size of the works all project team roles are assumed to be part-time. Phase 2 is assumed to run from November 2019 to end March 2021.

During Phase 2, hazard studies will be performed during the detailed design to ensure best practice is adopted throughout. Design reviews will ensure the equipment is fit for purpose. Constructability reviews will ensure equipment can be constructed safely and efficiently.

The existing compound at the proposed location is too small for the equipment required and will need to be enlarged a little. The civil design will include the required changes and specifications. A detailed design package will be required for the brine and water infrastructure. It will then be necessary to procure the equipment and suitably qualified contractors to install the equipment.

The scope of work analysis was supported by a project risk analysis, which sets out key areas of the project; potential risks; mitigation measures; and risk factors. The risk analysis will be updated throughout Phase 2 and used to ensure the consequences of challenges or problems are minimised throughout. The top 10 risks are summarised in a table attached at Annex 1.

One of the most significant challenges will be the control of costs. The Phase 1 feasibility study did not include sufficient time and resources to tender any of the work packages or complete a full sanction grade estimate. Instead, all costs are based on 'order of cost' estimates founded on the experience of the project partners. Typically, this form of estimating is +/-30%. To allow the project and HySecure Phase 2 to be delivered within the BEIS Phase 2 budget it is necessary to include some contingency budget, whilst keeping below the total allowance. Should reduced costs be achieved for some or all of the work packages then this may allow some work packages from Phase 3 to be brought forward, with the agreement of BEIS, thus assisting the overall programme and reducing costs in Phase 3 or a saving to government in Phase 2.

Storengy have produced a detailed cost estimate and payment schedule/spend profile for Phase 2 and to a less detailed extent, Phase 3.
Phase 2 is estimated to cost £6,247,201.36 (ex VAT) (£6.25M) – Annex 2
Phase 3 is estimated to cost approximately £12M

Storengy have produced a detailed project programme which covers Phase 1, Phase 2 and Phase 3 activities. A level 1 summary programme for Phase 2 is annexed (Annex 3) to this document. The full programme gives estimated start dates and durations for each of the activities required to deliver the project. From this it is clear why there will need to be a Phase 3 as the solution mining itself cannot be completed within the finance window allowed for Phase 2. Further to this, there are a number of activities that must follow on after the completion of solution mining.

5.3. WP3 – Regulatory requirements

Preparation of planning application and environmental impact assessments;
Preparation of hazard substances consent application;
Preparation of hazard identification study and consideration of COMAH requirements;
Consider all other legal requirements

INOVYN have considered the necessary initial Process Design, Permitting and 'Safety, Health and Environment' Review procedure needed for the project. This process sets out the required stages for project development to ensure all necessary company procedures and legal requirements are met.
These stages can be summarised as follows:

- Scope development – what and why; (feasibility study)
- Front end design – developing the project definition and refining the preliminary cost estimate;
- Detailed design – firm up engineering requirements, programme and cost estimate, complete hazop[1] study process and pre-construction COMAH[2] report, obtain planning consent and other necessary consents;
- Construction – managed in accordance with CDM[3], complete pre-operation COMAH report;
- Commissioning – prior to start of solution mining and then prior to introduction of hydrogen it is essential to verify that the plant has been constructed correctly and is fit for operation in line with all safety reviews;
- Operation – requirements for ongoing monitoring.

INOVYN have considered the Process Specification which defines the high-level process requirements for the project:

- Process description
- Process design basis
- Raw material and utility supply
- Product handling
- SHE Management
- Control and operating philosophy
- Maintenance and decontamination philosophy
- Materials of construction
- Instrument and analytical requirements
- Technical risk

All of these areas will have to be further developed in the next stage of project development in Phase 2.

INOVYN have considered the regulatory requirements for the project.

INOVYN have started the engagement process with the local planning authority, Cheshire West and Chester Council but has been unable to progress matters in the time available.

[1] Hazop = Hazard and Operability Study

[2] COMAH = Control of Major Accident Hazard Regulations 2015

[3] CDM = Construction (Design and Management) Regulations 2015

This will need to be a high priority at the start of Phase 2. INOVYN have started to draft the planning application but this document is still in an early draft form.

It was too early in the project development process in Phase1 to engage in public consultation, however, INOVYN did hold a consultation event with tenant farmers of the land surrounding the proposed location. Given INOVYN's general good relationship with its tenants and the fact that the impact of the proposed project has a minor temporary effect on farming (brine and water pipeline construction) and very little permanent effects (the road and compound already exist), the consultation did not produce any adverse reaction. In fact, there was some positive interest in the project.

INOVYN commissioned an environmental assessment study in support of the planning application process to identify protected species or possible environmental impacts. The Holford Brinefield already has general planning consent for solution mining and the Stublach site has consent for natural gas storage, however, it is still necessary to assess the impacts of each project on its merits. The road and compound already exist but will require some changes. The area already benefits from considerable solution mining infrastructure but not right up to the compound. Therefore, it will be necessary to construct some new sections of buried pipeline. While the effects of this construction on farming activities should only be temporary it may well be necessary to install some great crested newt mitigation measures or other environmental measures to protect species and the environment. The environmental study outlines these requirements and will be used to inform the planning application process and the detailed design of the infrastructure. None of the finding are problematic or unusual for the area thus the study gives confidence for ongoing development.

INOVYN have considered the Hazardous Substances Consent process which will require a submission to the Hazardous Substances Authority (also) Cheshire West and Chester Council. INOVYN have attempted to engage with the Health and Safety Executive on this matter but have been unable to gain interest from them at this time (without a formal application in place). Again, this will need to be given a high priority in Phase 2.

INOVYN have considered the operating and maintenance philosophy for the project. It is expected that INOVYN would be responsible for the solution mining of the cavern and operation of Phase 3 hydrogen storage. The longer-term hydrogen storage facilities could be operated by either INOVYN or Storengy, subject to agreement.

5.4. WP4 - Engineering

Definition of operating limits, equipment sizes and materials of construction;

Thermodynamic and geo-mechanical study of cavern over proposed operating cycle;

Leaching plan and solution mining infrastructure specification, including adaptation of existing infrastructure and systems; and

Wellhead, casings, subsurface equipment and drilling specification.

Storengy have considered a number of detailed engineering areas during Phase 1 in support of the project. These cover cavern design, solution mining specification, drilling specification, materials of construction and various studies to inform the next stage of the project and allow the creation of a project programme and cost estimate.

The geology of the Stublach Site is known to be suitable for the creation of salt caverns for natural gas storage based on previous history. This knowledge has been used to show that a hydrogen storage cavern is possible and what the likely size and capacity of that cavern would be. Using water supply information from INOVYN, Storengy were able to calculate the most appropriate solution mining programme to create the optimal cavern and determine the total duration required.

The first step was to define the drilling programme and the required well acceptance scheme to ensure the eventual borehole and cavern will meet all the required safety standards. This is followed by a solution mining study to determine the optimum shape and size of cavern in parallel with a thermo mechanical study to ensure the operation of the cavern does not lead to unacceptable stresses in the cavern walls.

Throughout this process the materials of construction for the downhole tubulars (casings), wellhead and subsurface safety valve are assessed for their suitability with hydrogen. Hydrogen has different properties to natural gas and not all materials that are traditionally used in salt cavern gas storage are suitable.

Following the creation of the salt cavern by solution mining it will then be necessary to fill with hydrogen and expel the brine. Again, this step is similar to natural gas storage but includes a number of distinct differences both in materials of construction and installation methodology.

Using the above drilling programme information and following a number of technical discussions with the Storengy drilling expert, INOVYN held a number of discussions with a potential drilling contractor. These were used to explore the likely drilling requirements, produce an indicative programme and prepare cost estimates. INOVYN have used this information to start the prepared an indicative Drilling Contract that can be used in the next stage of negotiations with drilling contractors.

All of this work by Storengy and INOVYN have formed the basis for confirmation that the project is feasible. It has been shown that the creation and operation of a hydrogen storage cavern is both technically possible and safe to operate within the defined parameters. The information has informed the preparation of the techno-economic analysis and business case assessment, as well as the planning and hazardous substances assessment. They have provided information to prepare the overall project programme and cost estimate, as well as support the application for funding in Phase 2. Considerable engineering progress towards the development of the project has been made in Phase 1, which will form the basis for further development and confirmation in Phase 2.

5.5. WP5 – Hydrogen Supply Export Options

Consider options for on-site and off-site hydrogen supply / generation;
Produce initial cost estimate and make recommendation for next stage; and
Consider options and opportunities for hydrogen export and supply off-site.

INOVYN have considered the possible options for hydrogen supply and export to and from the site.

The Phase 1 Feasibility Study included a solution mining study and leaching plan by Storengy. Using the known geology for the site and the considerable experience of Storengy it is possible to determine the optimum (maximum) size of cavern that can be created within the salt strata of the Holford Brinefield.

The majority of work performed in the Feasibility Study assumes a full-size cavern will be created at the HySecure site. However, an option for a smaller cavern could be considered if the duration of solution mining (and funding) is considered to be unacceptable for delivery of this demonstration project. The decision for the target size would need to be taken early on in Phase 2 of the project.

The target volume for the full-sized cavern would be a minimum of 300,000m^3. With a range between 300,000m^3 to 350,000m^3. This volume would correspond to a total storage capability for hydrogen of approximately 1850 tonnes.

Modern gas (and hydrogen) storage salt caverns are normally operated by cycling the pressure between a minimum pressure and a maximum pressure. The maximum pressure is determined by the geology and depth of cavern to ensure the pressure containment is not compromised. The minimum pressure is likewise determined to ensure the integrity of the cavern is not stressed. The working gas volume is the quantity of hydrogen that can be injected and withdrawn from the cavern between the minimum and maximum pressures. This value will be set accurately at the end of solution mining when the exact free volume of the cavern is determined by survey. The initial estimate for working gas volume between the minimum pressure of 30bar and the maximum pressure of 80bar is approximately 1,100 tonnes of hydrogen. A larger cavern volume will allow a greater working gas volume of hydrogen.

The amount of hydrogen held in the cavern following the end of debrining to maintain the minimum gas pressure is known as ‘Cushion Gas’, effectively from zero to the minimum pressure of 30bar. For a cavern of this size the cushion gas will be approximately 750 tonnes of hydrogen. The cushion gas cannot be ‘used’ or recovered until the cavern is decommissioned by refilling with brine. However, at that point it can be recovered and utilised so is not lost.

As well as maximum and minimum pressures for salt caverns there are also restrictions placed on the maximum injection and withdrawal rates and temperature of the hydrogen. These are studied as part of the thermo-mechanical design study of the cavern, for which the preliminary assessment has been completed in the Phase 1 feasibility study. A range of scenarios were considered and shown to be acceptable, including injection and withdrawal at 40 tonnes/day.

It should be noted that the pressure of hydrogen required to displace the brine from solution mining and first fill the cavern is close to the maximum pressure and therefore the cavern must be completely filled before hydrogen is then withdrawn. It is not possible to expel all of the brine with only the minimum pressure. However, an option that can be considered if hydrogen availability is limited in the early stages, is to inject hydrogen at higher pressures but a limited volume to only displace a proportion of the brine. The cavern can then be used as a smaller hydrogen store, with less cushion gas tied up, whilst maintaining the option for a later volume increase.

The full-size cavern, regardless of the volume initially used, will require a solution mining duration in excess of 800 days. This will extend beyond the expected funding time window for Phase 2 of the BEIS Hydrogen Supply Programme hence the suggestion of a Phase 3 package. An alternative option would be to create a hydrogen gas storage cavern of approximately 100,000m^3 which would be capable of storing approximately 300 tonnes of hydrogen. This would require a solution mining programme of approximately 400 days taking the development to the end of 2021. The conversion to hydrogen storage, testing, snubbing and installation of hydrogen import/export infrastructure would then naturally follow on in advance of the first hydrogen fill.

A full-size hydrogen storage cavern will be capable of storing a working gas volume of in excess of 1100 tonnes of hydrogen. This will require either significant on-site generation of hydrogen (50 – 100MW electrical generation equivalent, 20 – 40 tonnes/day generation) to be meaningful or a new hydrogen supply pipeline to a site such as INOVYN's Runcorn Site where this quantity of hydrogen can be made available.

In the early stages of the development of the hydrogen economy, the HySecure project can be used to provide backup services to nascent hydrogen transport projects such as hydrogen fuel cell buses within Liverpool City Region. This will require the storage of lower quantities of hydrogen (200 – 300 tonnes) which can be delivered to the storage site and collected from the site when required by tube trailer. Thus, the initial use proposed in Phase 3 is to include a tube trailer import / export option at the HySecure site (wellhead).

Hydrogen supply options considered:

- Tube trailer delivery
- Pipeline from Runcorn
- Pipeline network
- Local generation at Stublach
- Local generation at Lostock

Hydrogen export options considered:

- Tube trailer refilling
- Pipeline to Runcorn / network
- Pipeline to Warburton / LDZ (*local distribution zone for natural gas network*)
- Export to NTS (*national transmission system for natural gas*)
- Local consumption / use

Tube Trailer/Tanker delivery

The simplest means of supply of hydrogen to HySecure considered in the Phase 1 Feasibility Study and proposed as the first step in the deployment of the project is to utilise tube trailers or tankers to deliver hydrogen by road. This is not considered to be the best long-term solution as the quantity that can be carried by a single vehicle is low (by mass) and the transport cost for that vehicle is high compared to pipelines. But as a first step in the initial development of the facility this would represent the lowest cost and quickest route to market.

Typically tube trailers carry approximately 0.5 tonnes of hydrogen in a single load although there are a number of companies that offer 1 tonne trailer options or are looking to expand the quantity per vehicle. In mass terms this is low compared to say approximately 25 - 30 tonnes of liquid fuel carried by a fuel tanker. However, in terms of energy density hydrogen is much greater per weight than diesel or petrol, thus each vehicle delivery does represent a significant amount of energy / value transported.

As a backup store to the North West hydrogen fuel cell bus and vehicle projects, it is proposed to bring in 200 – 300 tonnes of hydrogen over a few months period, which could then be held until needed in the event of a supply interruption at the source plants. Tube trailers would then be filled at the HySecure site and driven direct to the vehicle stations where hydrogen fuel cell buses or other vehicles are deployed.

The infrastructure required to allow the import and export of hydrogen by tube trailer is summarised as:

- Extension to the existing wellhead compound;
- Minor modifications to the existing site road to allow safe tanker turning and a holding area for offloading;
- Tanker loading / off-loading point
- Compressor
- Drying / purification unit
- Metering, control and safety features.

The cavern will initially be filled with hydrogen from the tube trailer (350bar) at approximately up to 80 bar. Thus, the tube trailer could initially be coupled to the cavern with very little infrastructure. Only the safety equipment and pressure letdown would be required. There is no requirement for drying or purification when feeding into the cavern. However, for maximum efficiency of transport a compressor could be used to fully empty the tube trailer below the cavern fill pressure of approximately 80 bar to avoid excessive hydrogen remaining on the vehicle. The same compressor is used for both loading and unloading.

Stored hydrogen within the cavern will initially pick up small amounts of nitrogen from the solution mining process and water vapour from the brine. This must be removed before export / use in fuel cell applications. Water can be removed by a number of different drying options, such as desiccant dryers, but nitrogen is harder to removed. Further design work would be required to fully explore all the alternative methods and the most appropriate technology. Based on previous experience with hydrogen projects the two main options considered that can achieve fuel cell quality hydrogen are Palladium Diffusion and Pressure Swing Absorption. Palladium Diffusion can achieve qualities in excess of that required for this project, but the process suffers from a number of operating challenges. Very high temperatures are required for normal operation and a fall in temperature due to, say a loss of power, can result in expensive irreversible damage to the palladium silver alloy diffuser. The high temperatures required lead to a high carbon footprint for the process or loss of useful hydrogen. Pressure Swing Absorption is commonly used for the clean-up of industrial gases. Standalone units can be switched on and off easily on demand, typically operate in the pressure range for this project and will successfully remove nitrogen, water vapour and oxygen as required to achieve fuel cell quality hydrogen. For this application, a pressure swing absorption process has been selected that can remove both water vapour and nitrogen. For the tanker export option, a relatively small unit is required.

Following the initial set up and commissioning, the units would be fully automated, capable of start-up and normal operation by the tube trailer delivery driver. Security, monitoring and oversight would be by INOVYN personnel based at Lostock, although at any time operators from INOVYN can visit the site. The delivery driver would enter through controlled secure gate access having made contact with INOVYN. The offloading or loading would then be started by the driver locally. The performance, flow and operation of all equipment would be monitored by INOVYN staff in the control room. Remote shutdown can be deployed as required whenever needed. Security cameras and intercom will be in use continuously. This type of driver self loading / offloading is common in the chemical industry.

The initial cost estimate for the compressor / treatment / loading off-loading infrastructure is of the order of £3.5M (+/- 30%). The figures will be further refined in Phase 2.

The tube trailers could be filled at INOVYN's Runcorn Site or BOC's St Helens site, or further afield at other hydrogen manufacturing sites in the UK, such as Teesside.

It is expected that the tube trailers would typically be dispatched to customers in the North West region, although deployment to London is an option for backup storage to TFL's hydrogen transport plans.

Pipeline from Runcorn

INOVYN's Runcorn Site has been producing hydrogen for the last ~100 years. The site typically produces approximately 10,000 tonnes/year for both internal and external customers use. Runcorn Site produces and has available sufficient hydrogen to fill the HySecure cavern over a reasonable time period, however, there is currently no available suitable pipeline between the two sites.

Project Centurion is a separate feasibility study, part funded by INNOVATE UK (UKRI), investigating options for a new (100MW) water electrolysis cellroom at Runcorn Site and options for cavern storage. One package of work under investigation is pipeline options between Runcorn Site and the Holford Brinefield. This package is not yet complete but has considered two main options.

The lowest cost option would be to repurpose an existing 8 inch ethylene gas pipeline that connects Runcorn with the Holford Brinefield. The pipeline is currently not in service, but the integrity is being maintained. The pipeline is owned by Sabic UK Petrochemicals. There has not yet been any engineering or legal work done to establish whether the pipeline is suitable and can be repurposed for hydrogen duty, however, it has been shown that it would have the capacity to carry more than 40 tonnes/day of hydrogen in either direction. The pipeline would need to be extended at both ends to the appropriate connection point for supply and storage. This option would require: a legal agreement with the pipeline owner; legal agreements with the land/easement owners; change of use consent; planning consent for the new sections; and pipeline regulations approval.

A new pipeline could be constructed between Runcorn Site and the HySecure site. The direct line distance between the two sites is approximately 24km, however, the pipeline route is likely to be in excess of 30km. The construction cost of such a pipeline would be approximately £50 – 60M. A new pipeline could be installed with potentially greater capacity than the existing ethylene pipeline. This option would require: planning consent; legal agreements with all the land owners; and pipeline regulations approval.

Local Generation

It would be feasible to construct a water electrolysis hydrogen generating cellroom somewhere on the Stublach site or elsewhere on the Holford Brinefield or at Lostock Works (approximately 5-6km from the HySecure Site). The cellroom could then be connected by local pipeline to the cavern. The cellroom would require separate planning consent (not covered by Phase 1 Feasibility Study). The cellroom may require additional electrical import supplies that would need to be made available. There is a ScottishPower Energy Networks 132kV electrical system in the vicinity. The amount of hydrogen generated would depend on the cellroom size and power availability. Each 10MW of power would equate to approximately 4 tonnes/day of hydrogen generation. The capital cost of electrolysers for hydrogen generation are in the range £750 -1000 / kW. At large scale deployment this figure should be reduced to £500/kW.

Export Options

If tube trailer import or pipeline options are constructed to bring hydrogen to the site then these can also be used to export hydrogen. Alternatively, hydrogen can be export from the site directly into the natural gas grid. The National Transmission System (NTS) is the trunk main system of high-pressure natural gas that runs up and down the UK, connecting the incoming gas supplies with the local distribution zones. The Stublach Gas Storage site already has a large-scale gas connection to the NTS pipeline which runs through the site. In the future it would be possible for hydrogen to be injected into the NTS at Stublach for both trials and future beneficial lower carbon operation.

Also, on the Holford Brinefield is a dedicated pipeline from another natural gas storage cavern to the local distribution zone (LDZ) at Warburton. This could also be considered as a route out for hydrogen.

If a significant volume of hydrogen was required for testing hydrogen consuming equipment, such as burners, fuel cells and engines then this could be made available at the Stublach site (subject to planning), allowing the construction of a testing facility.

If electricity generation from hydrogen (combustion or fuel cell) became more economic or desirable, then this could also be achieved at the Stublach site.

Utilities, such as electricity, water, nitrogen, natural gas, telecommunications and road infrastructure are all present on site.

5.6. WP6 – Business Planning

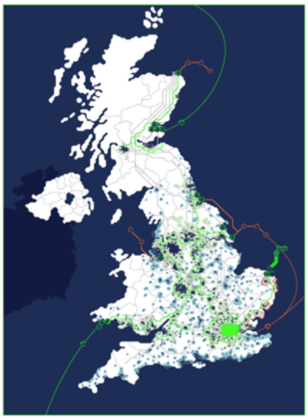
<u>Develop a business plan for the storage technologies to include potential market size and steps to commercialisation;</u>
<u>Compare with alternative storage options;</u>
<u>Prepare a business plan for the specific deployment planned in Cheshire to include the options for hydrogen supply and hydrogen end uses for the cavern, and consider the capex, and opex needed; and</u>
<u>Funding plan for further development and deployment in Phase 2 and beyond Phase 2.</u>

Element Energy have considered a detailed Techno Economic Analysis of hydrogen in support of the business case for the project.

The analysis can be summarised as follows:

There is growing interest in hydrogen as a low carbon fuel that could be used in place of incumbent fossil fuels in a wide range of sectors and applications, both in the UK and in other countries across Europe and beyond. The Committee on Climate Change's Hydrogen in a Low Carbon Economy report (published in November 2018) identified hydrogen as a "*credible option to help decarbonise the UK energy system*" and called on the Government to develop a low-carbon heat strategy (including clear signals on the future use of the gas grid) within the next three years.[4] Several high profile, industry-led initiatives setting out visions for repurposing the UK's gas grid to deliver low carbon hydrogen produced at scale (with carbon capture and storage) have also been developed in recent years, including:

- **H21 North of England** – building on the H21 Leeds City Gate study (2016), this project describes an ambition to convert the gas network to hydrogen across the country, starting in the North of England from 2028.
- **HyNet North West** – this Cadent-led project seeks to develop a low-carbon industrial cluster in the Liverpool-Manchester region, with dedicated hydrogen pipelines supplying industrial consumers and ultimately domestics customers and transport applications. The delivery phase is scheduled to begin from 2023.



H21 envisages six phases of conversion of the gas network to hydrogen:
- Phase 1 (2028–34): North of England
- Phase 2 (2033–38): South Yorkshire and East / West Midlands
- Phase 3 (2030–32): Scotland
- Phase 4 (2036–37): South Wales and South West England
- Phase 5 (2040–45): East Anglia and Home Counties
- Phase 6 (2045–50): London

H21 vision for conversion of gas distribution networks to hydrogen by 2050
Source: H21 North of England, Figure ES.12, p.22

- **ACT Acorn** – this project aims to "*deliver a low-cost carbon capture and storage (CCS) system in north east Scotland by 2023*". The Acorn project is supported by funding from the European Union, and the UK and Scottish Governments.[5]

Large-scale hydrogen storage will be a critical element in any energy system involving bulk production, distribution, and use of hydrogen. While various options for storing hydrogen exist, previous studies in this area indicate that salt cavern-based storage is the optimal solution. North West England benefits from geology that is conducive to creating stable salt caverns that can be used

[4] www.theccc.org.uk/publication/hydrogen-in-a-low-carbon-economy/.

[5] https://actacorn.eu/.

for long-term storage of gases under pressure. The HySecure project seeks to create a dedicated hydrogen storage facility in this region that will demonstrate the technical and economic viability of salt cavern-based bulk hydrogen storage. A phased approach is envisaged to match the expected growth in demands for storage:

- **Phase 1: feasibility study (2019)** – this report is one of the main deliverables from the BEIS-funded initial phase of the study.
- **Phase 2: cavern infrastructure construction (2020–21)** – provided funding can be secured, the next phase involves deploying the infrastructure required to allow the cavern to be created via solution mining in the next phase.
- **Phase 3: solution mining and surface facilities for transport applications (2021-2023)** – the salt cavern will be solution mined and required facilities constructed. A portion of the total cavern capacity will be used initially, which along with compression and purification equipment, will allow the facility to offer storage services to customers supplying hydrogen for transport applications.
- **Phase 4: upgrade to full capacity, heat applications (mid-2020s)** – investments in additional surface equipment and commissioning of the entire storage capacity is envisaged in the mid-2020s, in line with delivery of the HyNET project or similar grid scale hydrogen projects.

This report summarises the results of an analysis of the techno-economic performance of the proposed HySecure facility and sets out the business case for progressing to the construction and operation phases, including consideration of the case for further public funding. The key conclusions are:

- The HySecure facility offers a very cost-effective solution in terms of capital investment per unit storage capacity (kilograms of hydrogen or kilowatt hours of energy). The estimated investment needed for the complete Phase 4 cavern is c.£41/kgH_2 (£1.2/kWh). This is an order of magnitude lower than the cost of above-ground pressure vessels (>£400/kg) and compare favourably with literature value costs in the range of c. €8–90/kWh for other large-scale energy storage solutions such as pumped hydro and compressed air energy storage (and > €100/kWh for large-scale batteries).
- The total investment required to deliver a working hydrogen storage facility exceeds the grant funding that BEIS has indicated is available in Phase 2 of the Hydrogen Supply Programme. While some small cost savings could be achieved (e.g. by reducing the size of the cavern that is created), most of the initial costs are fixed (i.e. independent of the size of the cavern) and there is a strong rationale for maximising the capacity.
- Total costs of hydrogen storage when expressed per unit of gas output from the facility are sensitive to the throughput, with a decline in per-kilogram costs with increased utilisation of the facility. In the short to medium term, these costs (which include capital, fixed operating, and variable operating costs) are dominated by the capital cost element. Grant funding to cover some or all of this investment would therefore greatly reduce the level of income that the facility operator would need to secure to ensure sustainable on-going operation.
- Based on the budgetary figures for Phase 4, the total cost of storage per kilogram of hydrogen output range from around £0.4/kg to several £/kg, depending on throughput. With an estimate of the total variation in inter-seasonal heating demand that could be met (with the storage offered by HySecure), the cost of storage is around £0.12 per kilogram of hydrogen delivered to end users. This is believed to be within an acceptable range for the value of having resilience in the system and the security of supply that large-scale storage offers.
- The business case for the HySecure facility needs to be considered in two phases. For Phase 4 (full deployment), the cavern will be connected to sources of hydrogen supply and demand via pipelines, and the operator will be able to run the facility much like natural gas storage assets are operated today (with revenues available from price arbitrage, “warehousing” services, etc.). As with similar gas storage facilities, the investment case is based on securing multiple sets of revenues to cover the investments

and on-going operational costs. The economic analysis undertaken here shows that the Hysecure facility can offer cost-effective hydrogen storage at scale.

- Bulk storage is a pre-requisite for large-scale hydrogen use in heat / industry and can take years to build, so there is a strong case for progressing with the construction phase for HySecure as soon as possible. This will ensure that this strategic infrastructure is available to support implementation of the various hydrogen projects now being planned in the transport, heat, and industrial sectors. Progressing the construction phase now will also allow learnings from the creation and operation of the HySecure cavern to occur before significant investment is required in further salt caverns that would be required to support the large-scale use of hydrogen for heat, thereby informing the decisions on these projects and de-risking the hundreds of million pound investments that may be required for salt cavern storage for these projects. While there are risks associated with the future development of the hydrogen market in the UK, these are manageable and should not prevent work starting on HySecure.
- While there is a clear case for developing bulk hydrogen storage solutions when considered from a national (strategic) perspective, the investment case for private sector organisations in the near term is more challenging. The HySecure facility will require many millions of pounds of investment and a multi-year construction programme before commissioning, i.e. before any potential for revenue generation. Furthermore, while a range of potential customers for the facility have been identified, the market is not guaranteed and the ability / willingness of these organisations to pay for storage is subject to a high degree of uncertainty. The size of the at-risk investment needed, the time needed before any revenues are possible, and uncertainties surrounding the size, nature, and value of the market for hydrogen storage suggest a strong case for public sector intervention in the form of capital grant support. Without such support it is highly unlikely that the HySecure or any other similar facilities will be delivered.
- In the near term, before large-scale hydrogen for heating and industry projects are implemented, a smaller scale facility planned in Phase 3 could provide back-up supplies to hydrogen projects across the UK in case of failure or planned downtime. This will allow hydrogen suppliers to reduce the up-front costs and space and maintenance requirements of redundant equipment in case of failure, or remove the availability risk and high fees associated with seeking hydrogen from the market in case of failure.
- Assessment of the potential revenues available by considering the costs of alternative back-up solutions suggests that customers in Phase 3 (i.e. organisations with contracts to supply hydrogen to vehicle fleets) may be able to pay low tens of thousands to low hundreds of thousands of pounds per annum to use the HySecure facility (for suppliers supplying 20 to 100 fuel cell buses, with roughly one week downtime every three years). Given that the fixed costs are around £1.7m per year (total), or £140k per year (fixed opex only), there is a need to write off some or all the up-front investment in order to develop a sustainable case.
- If demand for hydrogen storage exceeds the capacity of the HySecure facility (measured in absolute capacity (tonnes of storage available) or withdrawal rate (tonnes per day)), there may be an opportunity to "over-sell" the capacity to customers requiring back-up supplies. This is possible due to the relatively low probability of unplanned outages happening at the same time given a sufficiently diverse pool of customers. Such a strategy would improve the business case by allowing greater overall revenues and could provide wider benefits to the market by reducing the costs of storage to all end users.

6. ANNEXES

Annex 1 – Risk assessment summary, top 10 risks

Annex 2 – Phase 2 Cost summary

Annex 3 - Level 1 Summary programme for Phase 2

6.1. Annex 1

Top 10 Risks from the risk register

Risk Type (i.e. is it in nature: technical, legislative/regulatory, environmental, policy, economic, commercial, financial or project management)	**Risk Description** (Describe the risk)	**Cause of Risk** (Describe the conditions under which the risk arises)	**Risk Owner** (who has the power to manage the risk and therefore takes responsibility for it)	**Probability (1-5)**	**Impact (1-5)**	**Overall risk rating: (Probability**	**Mitigation Action** (Describe what can be done to reduce the probability or severity of the risk)	**Revised Probability (1-5)**	**Revised Impact (1-5)**	**Revised Overall risk rating**
Safety	Serious Construction Injury	Poor management of site safety, inadequate controls	Storengy – Project Manager	1	4	4	Safety Management System fully implemented on project with contractors employed with strong safety culture	1	2	2
Regulatory	Planning Approval, Hazardous Substances Consent (HSC) delayed	Local authority slow to respond or do not grant planning approval / HSC	INOVYN / R Stevenson	3	3	9	Early dialogue with Local Authority to discuss plans. Adjust development plans where necessary to meet regulators requirements	2	3	6
Financial	Cost escalation on drilling contract	Unforeseen sub-surface issues results in programme delays	Storengy – G Blettner	2	4	8	Ensure learning from INOYN and Storengy drilling campaigns included in contract specification	1	3	3
Financial	Cost escalation on infrastructure contract	Poor performance of Work Contractor	Storengy – Project Manager	2	3	6	Detail scope of work and fixed price contract	1	2	2
Financial	Delays in obtaining approval for equipment to be used on hydrogen installation	Equipment tests do not meet industry standards	Storengy – Project Manager	2	4	8	Work with equipment suppliers to understand requirements to obtain approval	1	4	4
Economic	Costs higher than anticipated due to market conditions drive construction costs higher	Market conditions make finding construction contractors more difficult increasing costs	Storengy – Project Manager	2	3	6	Early tendering process to allow time for negotiation / change of contracting strategy	1	2	2
Environmental	Drilling operation results in environmental incident	Geological issue results in loss of containment at surface	Storengy – G Blettner	1	4	4	Implementation of diverter / blowout prevention equipment	1	2	2
Project Management	Inadequate resourcing of project, loss of key personnel	INOVYN / Storengy Project Teams overloaded with work	Storengy – Project Manager	2	4	8	Monitoring of resource work load, use of retention bonus	1	3	3
Commercial	Commercial	INOVYN and	INOVYN / R	3	4	12	Continue to	2	3	6

	need for bulk hydrogen storage does not develop	other projects for conversion to hydrogen buses do not materialise. Large infrastructure projects do not get government funding	Stevenson				lobby government. Provide support to local infrastructure project			
Project Management	Dispute between partners	Cost escalation, programme dealys	INOVYN / R Stevenson	2	4	8	Oversight by INOVYN and clear reporting of cost and programme from Storengy	1	3	3

6.2. Annex 2

Summary costs for Phase 2.
A breakdown of these costs is given in the finance form attached to Phase 2 application.

Total Labour Costs	**£1,146,980.00**	18%
Total Overhead Costs	**£306,380.20**	5%
Total Material Costs	**£1,048,288.16**	17%
Total Capital Equipment Costs	**£0.00**	0%
Total Sub Contract Costs	**£3,433,182.00**	55%
Total Travel & Subsistence Costs	**£0.00**	0%
Total Other Costs	**£312,371.00**	5%
Total Eligible Project Costs	**£6,247,201.36**	

Example sheet of the breakdown of costs

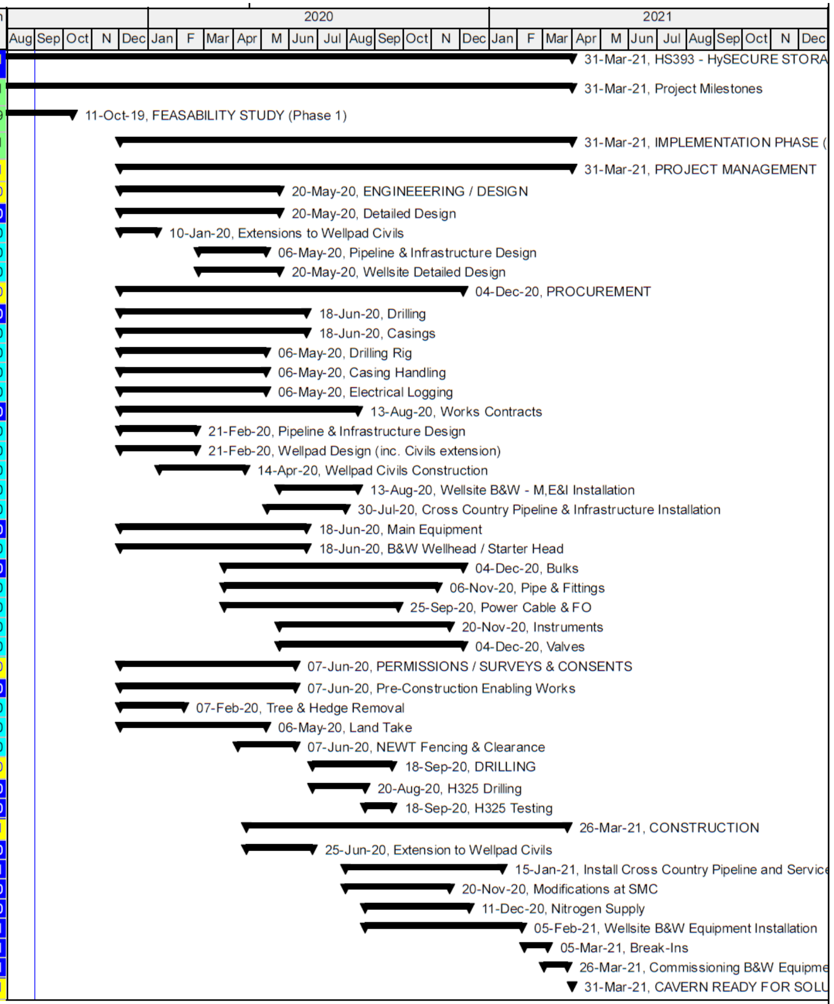
Hydrogen Supply Competition Phase 2 - Material Costs

Please provide a breakdown of the materials you expect to consume during the project

Item	Quantity	Cost per unit	Total
B&W Wellsite & Cross Country Bulks			**£0.00**
Pipe & Fittings - Cross Country	1	£208,761.04	**£208,761.04**
Pipe & Fittings - B&W	1	£101,834.65	**£101,834.65**
Power Cable - Cross Country	1	£45,825.59	**£45,825.59**
Power Cable - B&W	1	£10,183.47	**£10,183.47**
Fibre Optic -Cross Country	1	£6,205.00	**£6,205.00**
Instruments	1	£64,155.83	**£64,155.83**
Valves	1	£50,917.33	**£50,917.33**
2 x LER (refurbished)	1	£61,100.79	**£61,100.79**
			£0.00
Drilling Materials			**£0.00**
Drilling Equipment	1	£83,706.05	**£83,706.05**
Casings	1	£415,598.42	**£415,598.42**
			£0.00
			£0.00
			£0.00
			£0.00
			£0.00
			£0.00
			£0.00
		Total Material Costs	**£1,048,288.16**

6.3. Annex 3

Activity ID	Activity Name	Start	Original Duration	Finish
	HS393 - HySECURE STORAGE PROJECT (Rev T1)	01-Mar-19 A	529.0	31-Mar-21
	Project Milestones	01-Mar-19 A	529.0	31-Mar-21
	FEASABILITY STUDY (Phase 1)	04-Mar-19 A	160.0	11-Oct-19
	IMPLEMENTATION PHASE (Phase 2)	02-Dec-19	333.0	31-Mar-21
	PROJECT MANAGEMENT	02-Dec-19	333.0	31-Mar-21
	ENGINEEERING / DESIGN	02-Dec-19	110.0	20-May-20
	Detailed Design	02-Dec-19	110.0	20-May-20
	Extensions to Wellpad Civils	02-Dec-19	20.0	10-Jan-20
	Pipeline & Infrastructure Design	24-Feb-20	50.0	06-May-20
	Wellsite Detailed Design	24-Feb-20	60.0	20-May-20
	PROCUREMENT	02-Dec-19	250.0	04-Dec-20
	Drilling	02-Dec-19	130.0	18-Jun-20
	Casings	02-Dec-19	130.0	18-Jun-20
	Drilling Rig	02-Dec-19	100.0	06-May-20
	Casing Handling	02-Dec-19	100.0	06-May-20
	Electrical Logging	02-Dec-19	100.0	06-May-20
	Works Contracts	02-Dec-19	170.0	13-Aug-20
	Pipeline & Infrastructure Design	02-Dec-19	50.0	21-Feb-20
	Wellpad Design (inc. Civils extension)	02-Dec-19	50.0	21-Feb-20
	Wellpad Civils Construction	13-Jan-20	65.0	14-Apr-20
	Wellsite B&W - M,E&I Installation	21-May-20	60.0	13-Aug-20
	Cross Country Pipeline & Infrastructure Installation	07-May-20	60.0	30-Jul-20
	Main Equipment	02-Dec-19	130.0	18-Jun-20
	B&W Wellhead / Starter Head	02-Dec-19	130.0	18-Jun-20
	Bulks	23-Mar-20	180.0	04-Dec-20
	Pipe & Fittings	23-Mar-20	160.0	06-Nov-20
	Power Cable & FO	23-Mar-20	130.0	25-Sep-20
	Instruments	21-May-20	130.0	20-Nov-20
	Valves	21-May-20	140.0	04-Dec-20
	PERMISSIONS / SURVEYS & CONSENTS	02-Dec-19	121.0	07-Jun-20
	Pre-Construction Enabling Works	02-Dec-19	121.0	07-Jun-20
	Tree & Hedge Removal	02-Dec-19	40.0	07-Feb-20
	Land Take	02-Dec-19	100.0	06-May-20
	NEWT Fencing & Clearance	06-Apr-20	41.0	07-Jun-20
	DRILLING	26-Jun-20	60.0	18-Sep-20
	H325 Drilling	26-Jun-20	40.0	20-Aug-20
	H325 Testing	21-Aug-20	20.0	18-Sep-20
	CONSTRUCTION	15-Apr-20	245.0	26-Mar-21
	Extension to Wellpad Civils	15-Apr-20	50.0	25-Jun-20
	Install Cross Country Pipeline and Services (from H320 to H325)	31-Jul-20	120.0	15-Jan-21
	Modifications at SMC	31-Jul-20	80.0	20-Nov-20
	Nitrogen Supply	21-Aug-20	80.0	11-Dec-20
	Wellsite B&W Equipment Installation	21-Aug-20	120.0	05-Feb-21
	Break-Ins	08-Feb-21	20.0	05-Mar-21
	Commissioning B&W Equipment	01-Mar-21	20.0	26-Mar-21
	CAVERN READY FOR SOLUTION MINING	31-Mar-21	0.0	31-Mar-21



Remaining Level of Effort | Actual Work | ◆ Milestone
Actual Level of Effort | Remaining Work | summary

Programme Data Date: 31-Aug-19
Page 1 of 1

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