The Ince BECCS Project

Phase 1 Report – Final (Public Version)

December 2021

Greenhouse Gas Removal (GGR) Programme: Phase 1 - TRN 4696/11/2020

Prepared by WSP, Bioenergy Infrastructure Group, Peel NRE and C-Capture,

Department for Business, Energy & Industrial Strategy

PROJECT DEFINITION

Funding Programme	Greenhouse Gas Removal (GGR) Programme: Phase 1 - TRN 4696/11/2020
Project Eligibility Criteria	Lot 2: Mid-stage (minimum capacity of 1000 tCO_2e per annum)
Project Monitoring Officer	Mott Macdonald - Sandy Nimmo
Project Name	Ince BECCS Project (InBECCS Project)
Project Site Location	Ince Bio Power Facility, Protos, Chester, CH2 4RX
Project Site Owners	Ince Bio Power Limited (IBPL) (Part of the BIG)
Project Lead Stakeholders	Peel NRE Ltd. - Jane Gaston, Development Lead, Protos Site Bioenergy Infrastructure Group (BIG) - Alex Young, Development Lead
Technology Supplier	C-Capture - Phil Southerden, Chief Technology Commercialisation Officer - Duncan Holdsworth, Head of Engineering - George Wright, Process Lead
Project Management / Engineering	WSP - Prashant Thapar, Project Director - Rob Makin, Project Engineering Management

QUALITY CONTROL

Issue / Revision	First Issue	Revision 1	Revision 2
Remarks	First Issue – Public Version)		
Date	17th December 2021		
Authors	Core Project Team (WSP, C-Capture, BIG and Peel)		
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Contents

1 INTRODUCTION

Peel NRE Developments Limited (Peel) and Bioenergy Infrastructure Group have received funding from BEIS under the Greenhouse Gas Removal (GGR) Programme (the "Programme") to develop a CO_2 capture pilot plant (the "Pilot Plant") to be integrated within their existing waste wood gasification plant, the Ince Bio Power Plant (the "Existing Facility").

The primary objective of the Programme is to identify approaches to remove CO_2 or other greenhouse gases from the atmosphere and drive innovation in these through the development of pilot / demonstration scale plants. This project is classified as a bioenergy with CCS (BECCS) solution and based on the proposed scale and TRL of the technology, is eligible for funding under Lot 2 'Mid-stage'[1] projects. Although this Programme covers the design (Phase 1) and implementation (Phase 2) of a pilot scale plant, it is acknowledged and understood that the ultimate objective of the Programme is to use the learnings from the Pilot Plant to further develop the technology at $MtCO_2$ removal scale and at a competitive price.

This report forms the deliverables required under the Phase 1 Programme. The process modelling and proprietary design for the Pilot Plant has been produced by C-Capture. WSP have further developed the proprietary design into a pre-front end engineering design (pre-FEED), undertaking work for interfacing with the Existing Facility, the supply and return of utilities (process, electrical and control) to the Pilot Plant and the necessary civil works and structural infrastructure.

The pre-FEED technical deliverables produced have been used to formulate a Phase 2 Project Implementation Plan for the proposed Pilot Plant, which includes a Construction and Operations Programme and an AACE Class 3 Capital and Operating Cost Estimate for delivery of the project. (Refer to Section 7).

When formulating the technical deliverables, a 20 tonnes/day CO_2 capture Pilot Plant has been used as the basis of design. This was originally estimated to be within range of the £5m SBRI grant funding, a compelling scale-up from the previous 1 tonne/day prototype plants already demonstrated by C-Capture and meets the land and process constraints set by the Existing Facility.

Development of the draft cost estimate for the Project Implementation Plan for Phase 2 indicated a cost range significantly greater than the project team preliminarily estimated for a 20 tonnes/day Pilot Plant at project inception and consequently more than the available SBRI grant funding for a Lot 2 Project. The fundamental reasons for the underestimate at the Phase 1 application stage was due to not anticipating the increase in material / supply chain costs seen in 2021, combined with not fully appreciating the extent of supporting plant (OSBL) required to ensure Pilot Plant success with minimal disruption to the Existing Facility. To ensure alignment with the SBRI grant funding threshold, the project team have developed an alternate scaled down Pilot Plant option, sized to capture 10 tonnes/day of CO_2. This capacity has been selected to enable key performance criteria of the C-Capture design to be demonstrated and support risk mitigation of the C-Capture design at higher capacities. Although the basis of this report is centred around the 20 tonnes/day Pilot Plant, Section 6 discusses how the scaled down 10 tonnes/day Pilot Plant can be deployed at the Existing Facility and demonstrates how at this scale, a productive testing regime of the C-Capture technology can be undertaken. Section 7 presents the Project Implementation Plan for the Phase 2 part of the Programme for both the 20 tonnes/day and 10 tonnes/day CO_2 capture plant solutions.

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[1] Approaches eligible for Lot 2 will need to demonstrate that they have already reached TRL 6 and the proposed application will need to demonstrate a plan to deliver innovation to take the approach to TRL 7 or higher by the end of Phase 2. Projects in Lot 2 must have a minimum capacity of 1000 tCO2e per annum.

2 PROJECT GUIDING PRINCIPLES

At project inception, the project team agreed a set of guiding principles which was followed throughout the Phase 1 part of the Programme. When formulating these guiding principles, the importance of scalability and future development of the technology was recognised and so this was a consideration alongside ensuring successful implementation of the Pilot Plant during Phase 2:

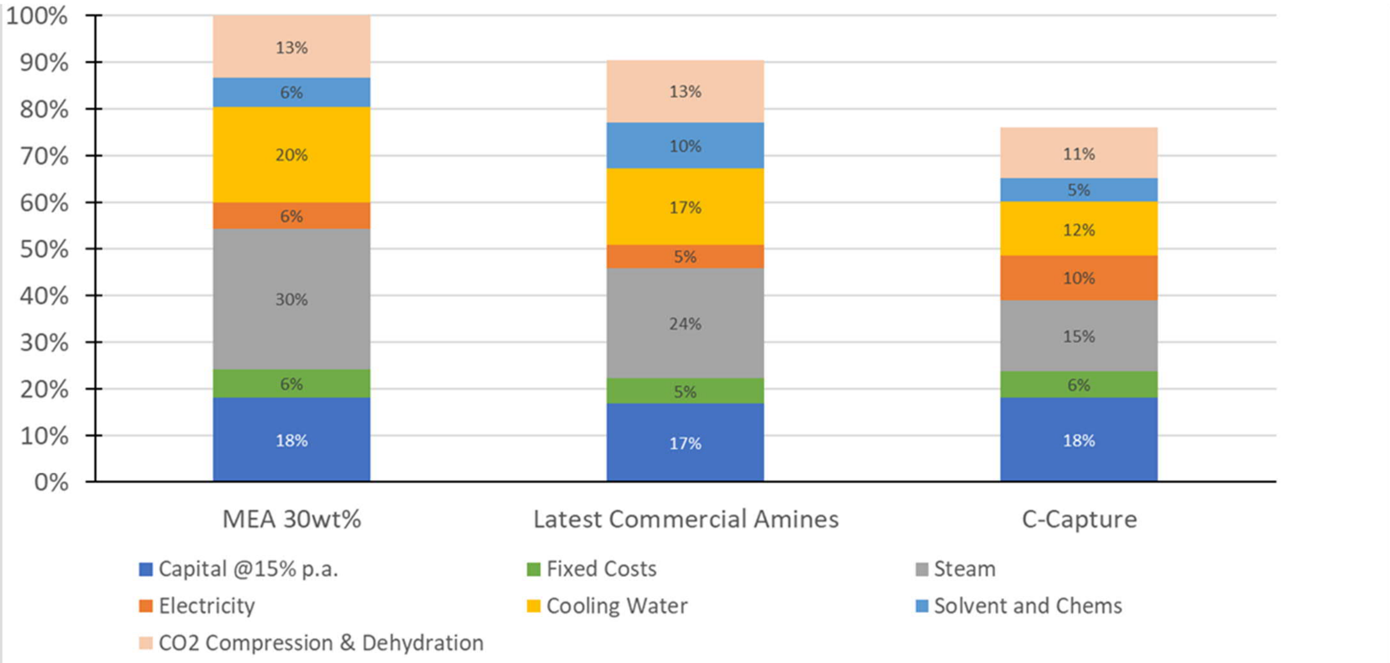
1. Where technically and economically practical, the C-Capture Pilot Plant shall be standalone i.e., during construction and operation of the C-Capture Pilot Plant. Interruption to operation of the Existing Facility shall be minimised.
2. Where technically and economically practical, the plant equipment shall be modular and for non-innovative aspects of the process, off-the-shelf equipment shall be used. This is to simplify construction / installation and provide the opportunity to relocate the C-Capture Pilot Plant to alternate sites.
3. Consideration for future scaling of the technology when developing the process design and determining testing regime for the Pilot Plant. Be able to demonstrate scalability as part of the "Programme and Business Plan for Commercial Scale Plant" deliverable.
4. Minimise plant footprint whilst still maintaining good constructability and operability.
5. Consideration of the testing requirements for the C-Capture Pilot Plant I.e. What are the objectives that C-Capture, BIG and Peel would like to achieve from the testing phase and how these de-risk future scale-up of the technology.

3 THE C-CAPTURE PROCESS AND TECHNICAL UPDATE

3.1 Technology Summary

C-Capture has patented a unique, solvent-based technology which offers a safe, low-cost way to remove carbon dioxide from atmospheric emissions using a post-combustion capture approach and has been specifically developed as an alternative to amine-based systems, which are the main commercial offerings at present. C-Capture's solvent is amine and nitrogen free, leading to distinct commercial and environmental benefits when compared with existing technologies and particularly well-suited to low-cost carbon capture in power generation and hard-to-abate industries. C-Capture technology is sufficiently differentiated that it will provide customers with multiple benefits, including reduced CAPEX and OPEX, due to the fundamentally different nature of the technology. When combined, these represent a significant reduction in cost per tonne of CO_2 abated when compared with alternative commercially available solvents. Figure 3-1 represents C-Capture's inhouse evaluation of these benefits and refers to the core ISBL technology only (i.e. additional potential OSBL benefits are not included in this comparison).

Figure 3-1 – Cost of CO_2 Capture – Normalised to MEA 30wt% Technology



Reference : Internal study from public domain data for commercial scale plant

C-Capture's technology represents an attractive option due to lower energy requirements, reduced solvent degradation without potential nitrosamine formation or emissions and reduced materials of construction costs due to very low solvent corrosivity. The solvent components are not classed as hazardous and are based on inexpensive commodity chemicals which are biodegradable and potentially also available from sustainable resources.

The fundamentally different chemical processes operating in the C-Capture process means it represents a true step change in performance, requiring an energy requirement between 1.5 - 2 GJ/tonne CO_2 captured, compared to >2.5 GJ/tonne CO_2 for the best of the amine-based systems. (This range is general to C-Capture technology and is non-project specific).

3.2 Process Overview

The C-Capture technology is a post-combustion carbon capture process tailored for use with a novel, amine and nitrogen free solvent with inherently lower energy requirements than other commercially available solvents.

Flue gas from the Existing Facility is cooled prior to entering an absorber column and then passes counter-currently with the unique solvent, where the CO_2 is removed from the flue gas.

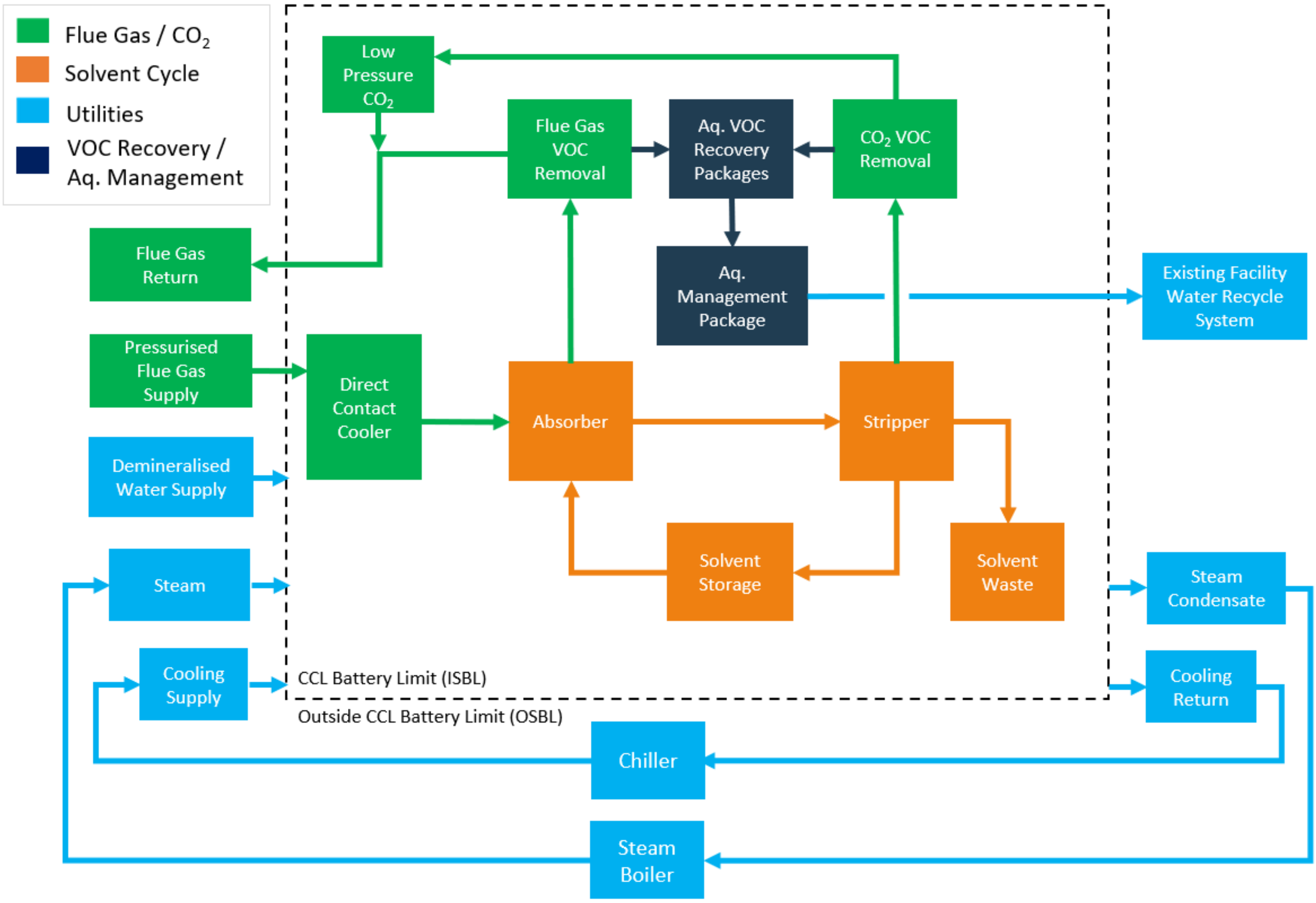
The treated flue gas exits the absorber column and enters the absorber wash column where wash water is recirculated to reduce the VOC content within the stream. The treated flue gas exits the absorber wash column and then passes through a gas-gas heat exchanger where it is heated against the incoming cooler flue gas before returning to the Existing Facility. The accumulated water/VOC from the bottom section is sent to the absorber VOC recovery package for recovery of organic compounds. The concentrated waste stream is directed to the aqueous management package where it is treated to recover a VOC rich stream which is recycled back to the solvent storage system. The effluent from the Aqueous Management Package will be sent to the Existing Facility's water recycle system. Fresh solvent is added to the system to maintain the overall balance.

The loaded 'rich' solvent exits at the bottom of the absorber column and is pumped through the lean/rich heat exchanger where it's heated against the returning unloaded 'lean' solvent. The rich solvent is further heated through the stripper steam boiler to create a multi-phase flow before entering the stripper column where CO_2 readily releases from the solvent following a marginal decrease in pressure within the stripper column. The lean solvent is collected at the bottom ready for recirculation through the lean/rich heat exchanger.

The resulting CO_2 stream enters the stripper wash column where the circulating wash water condenses the water vapour and recovers the VOCs from the CO_2 stream. The accumulated water/VOC from the bottom section of the stripper wash column is sent to the Stripper VOC Recovery Package, which performs a similar process to the Absorber VOC Recovery Package. The resulting CO_2 stream exits the top of the stripper wash column where the purification and composition are measured and then for the purpose of the Pilot Plant, is reduced in pressure and remixed with the returning treated flue gas. Alternatively, for commercial design plants, this concentrated CO_2 stream could then be compressed and dehydrated ready for distribution into a pipeline system or fed directly to a utilisation process if required.

The above description makes up the C-Capture process which for the purpose of this project, is grouped as ISBL. The supporting utilities to include supply of flue gas and return of flue gas / CO_2 and supply of utilities (steam, cooling water, demineralised water, electricity) has been grouped as OSBL. Further discussion on the OSBL services has been included in Section 4. A block flow diagram of the C-Capture Process (ISBL) and supporting services (OSBL) specific to the Pilot Plant is presented in Figure 3-2.

Figure 3-2 – Block Flow Diagram - C-Capture Process (ISBL) and Supporting Systems (OSBL)



3.3 Technology Update and Knowledge Gained During Phase 1

At the start of the Phase 1 Programme, C-Capture developed their proprietary design for a 20 tonnes/day carbon Pilot Plant based on their novel post-combustion carbon capture process. The proprietary design deliverables included a Process Description, Process Flow Diagram and Heat and Mass and Sized Equipment List.

Since issue of the proprietary design deliverables, minor updates have been undertaken for the 20 tonnes/day plant based on specific site requirements, but no changes have been made to the fundamental C-Capture process design itself.

Phase 1 of the project has developed significant learnings in exploring the options for constructability of the plant where the temporary nature of the Pilot Plant has supported the innovative development of semi-modular approaches to construction strategy. This has resulted in a proposed methodology for the 20 tonnes/day design, which will support further explorations towards a fully containerised / modular approach for future plant designs.

As part of the Phase 1 Programme, work was also undertaken to develop a scale down Pilot Plant, sized at 10 tonnes/day CO_2 capture, to meet the SBRI grant funding requirements for capital, whilst maintaining a meaningful scale up of the technology. The scaled down Pilot Plant uses the same fundamental C-Capture process with the only changes being to equipment sizes. Acknowledging the reduced equipment sizes, a methodology adopting a modular layout / construction was deemed the most suitable approach for a 10 tonnes/day CO_2 capture Pilot Plant. Further details on the 10 tonnes/day CO_2 capture Pilot Plant, including definition and implementation of the proposed solution within the SBRI grant funding requirements, is provided in Section 6 and Section 7.

Further learnings have also occurred during engagement with equipment vendors which enabled the project team to gain further insights into the suitability of equipment supply at a 20 tonnes/day scale. This has created a broader relationship with external equipment suppliers and potential learnings which could be incorporated within future designs. It also enabled the project team to gain clearer visibility of what a 10 tonnes/day CO_2 capture plant design would look like in terms of size and number of equipment items.

The cost build-up activity has given C-Capture a better definition of the overall plant cost (ISBL and OSBL) and identified areas where efforts can be focussed to achieve significant future cost reduction. The detailed CAPEX and OPEX estimation can be used to support future decisions on process optimisation opportunities particularly when linked with varying OSBL requirements at their deployment sites.

Participation in the project HAZID (Refer to Section 4.4) deepened the understanding of the requirements for an operating site of this type and enhanced areas of the process safety particularly with regard to safety zone ratings and impact on equipment design and costs.

In parallel to the Ince BECCS Project, C-Capture have been undertaking a number of independent development activities at their own facilities, which focused on further supporting the project.

- C-Capture has undertaken significant independent testing and trials and have confirmed that the absorber design, as proposed within the original design data, has met expectations of performance. As such, the initial expectation to incorporate details for an updated absorber design as part of the project delivery is no longer a requirement for the project. These tests included a number of inhouse operating trials on our proposed absorber internals, supplied by our preferred supplier, which demonstrated and met our required operational performance targets.
- C-Capture is also currently working with the University of Leeds to carry out life cycle analysis studies, to understand the impact and quantify the total greenhouse gas emissions associated with different solvents used within a carbon capture plant. The solvents under study range from benchmark solvents, such as 30%wt. MEA and PZ, and novel C-Capture solvents. This work is still in progress but will be available to further support the low carbon credentials of C-Capture's technology before the end of this academic year.
- With regards to monitoring, reporting and verification, the overall capture efficiency of the plant will be continuously determined via FTIR measurements on the absorber output, flue gas mass balance calculations, and flow rate of CO_2 from the stripper. C-Capture are also in discussions with a number of industry recognised benchmarking/validation companies. These are well known in the industry to provide independent technology evaluations for amine-based solvents. We are exploring ways in which they can support us through application of their expertise to our unique solvent process and provide similar external validation to the Pilot Plant when operational.
- C-Capture are also working with National Physics Laboratory to provide effective monitoring and evaluation for any effluent emissions from the process. Work has been ongoing for the past 2 years and it involves National Physics Laboratory evaluating C-Capture's process by performing emissions measurements post-absorber, post-VOC wash and post-stripper. This partnership will continue and include an exhaustive study on the Pilot Plant when operational.

4 DEVELOPMENT OF THE PRE-FEED

4.1 Basis of Design

Following completion of the propriety process design from C-Capture, WSP worked with all project stakeholders to further develop the design to a pre-FEED level and have carried out the work for interfacing with the Existing Facility including the supply and return of OSBL utilities (process, electrical and control) to the Pilot Plant and the civil works and supporting infrastructure.

With consideration of the testing approach and the required tests and trials needed from the perspective of both the development of C-Capture technology and demonstration of integration with the Existing Facility, a base case Pilot Plant operation (‘Option 1’) has been assumed. Option 1 is based on continuous operation (24 hours a day, 7 days/week, assuming 90% availability from the Existing Facility) for a 6-month duration. A second operational case has been looked at (‘Option 2’), which is based on operating 8 hours a day, Monday to Friday for 6 months. Option 2 is considered an alternative approach in which the required testing data can be obtained and has been modelled at this stage for OPEX comparative purposes only. The OPEX costs for both Options have been presented in Section 7.3.

A site visit was undertaken early in the programme to understand the limitations and opportunities of the Existing Facility and formed the basis for development of the Site Visit and Basis of Design Report.

At project commencement, an Assumptions Log was created which captured the key assumptions to be used throughout the project. Following agreement of the Site Visit and Basis of Design Report, all decisions made as part of this report were added to the Assumptions Log and the log was reviewed on a monthly basis with any new assumptions added. Some key assumptions which were agreed at the start of the project, which underpinned the C-Capture process modelling have been outlined below:

- Flue gas composition to be used for modelling purposes should be based on lowest CO_2 concentration, resulting in the most conservative absorber sizing to enable 90% CO_2 capture under normal operation.
- The Pilot Plant will only operate when the Existing Facility is operating between 70% - 110% load. At this load range, the CO_2 concentration within the flue gas will remain at or above the level indicated in the agreed nominal flue gas composition.
- Pressure of flue gas at tie-in point is -10 mbar(g). Flue gas blower to be incorporated upstream and be designed to overcome the required pressure difference through the C-Capture process.
- Following analytical measurements, the CO_2 will be let down in pressure and remixed with the flue gas prior to passing through the gas-gas heat exchanger. This is to ensure sufficient buoyancy for effective dispersion.

4.2 Site and Plant Overview

The IBP waste wood gasification plant, located within the Protos Energy Park, near Ellesmere Port has been chosen as the location for the Pilot Plant. The location provides an opportunity to demonstrate the C-Capture technology at scale in a market which would enable carbon negative emissions. The site is also well placed within the HyNet industrial cluster[2] to allow any such future commercial scale plant to deliver carbon dioxide into the HyNet pipeline network.

The Pilot Plant will be located to the south east within the Existing Facility boundary due to its available space, proximity to Existing Facility tie-ins and its benefits around constructability.

[2] *Selected as Track 1 cluster project under Cluster Sequencing process with BEIS*

The Pilot Plant will have process tie-ins with the Existing Facility for supply and return of flue gas and supply of demineralised water. Treated process waste-water will be sent to the Existing Facility's recycle system, where it will be reused and any effluents collected for off-site disposal under the Existing Facility's normal operating procedure. A tie-in is required to the Existing Facility's 11kV switchboard for provision of an electrical cable supply to the Pilot Plant and tie-in to the Existing Facility's control system via a fibre optic cable communication link. To align with the project's guiding principles, the 20 tonnes/day Pilot Plant will obtain process steam supply from a standalone steam generating boiler (Note: 10 tonnes/day Pilot Plant solution will receive steam directly from the Existing Facility. Refer to Section 6 for further details) and cooling from standalone chillers to minimise interruption from the Existing Facility. A parasitic load required to operate the ISBL and OSBL equipment has been calculated to be 665 kW.

4.3 Pre-FEED Technical Delivery

Following agreement of the Basis of Design, technical deliverables were developed to help inform the Phase 2 Project Implementation Plan. A key activity for this was to engage with vendors to obtain non-contractual quotes for all ISBL and OSBL equipment items required for the plant. To support this, WSP developed an Interface Block Flow Diagram and Interface (Tie-In) Schedule to help understand how the additional supporting equipment interfaces with the C-Capture plant. From this, a detailed and complete Equipment List was produced. This enabled equipment datasheets to be developed for all items, which were sent out to an agreed list of equipment vendors to allow them to provide the non-contractual quotes. Upon receiving the multiple quotes from the equipment vendors, a technoeconomic assessment was carried out to determine the most appropriate quote to use in the CAPEX build-up.

To formulate an accurate cost for the civil and structural works and plant installation, a detailed Scope of Services document was prepared and issued to a selected number of construction contractors. Table 4-1 summarises the engagement with the construction contractors. Input from Chilworth and Ledwood has been used to inform the construction and installation costs in the CAPEX build-up.

Due to exclusion of a control system PLC from construction contractors, WSP have engaged with the supply chain to obtain an independent quote for this item.

Table 4-1 – Construction Contractor Engagement - Summary

Construction Contractor	Comment
Chilworth	Contractor to supply civil and structural scope only Scope Excludes - Process equipment installation - Piping and cabling procurement and installation (In process of being discussed) - Control System PLC
Ledwood	Contractor to supply civil and structural scope and installation scope. Scope Excludes - Control System PLC
TGE Gas	Contractor could not provide a quote due to lack of resources.
Westbury	Contractor could not provide a quote due to lack of resources.
Murphy	Quote received at latter part of Programme and so not considered as part of Phase 1. Quote and engagement with contractor to be revisited during Phase 2.

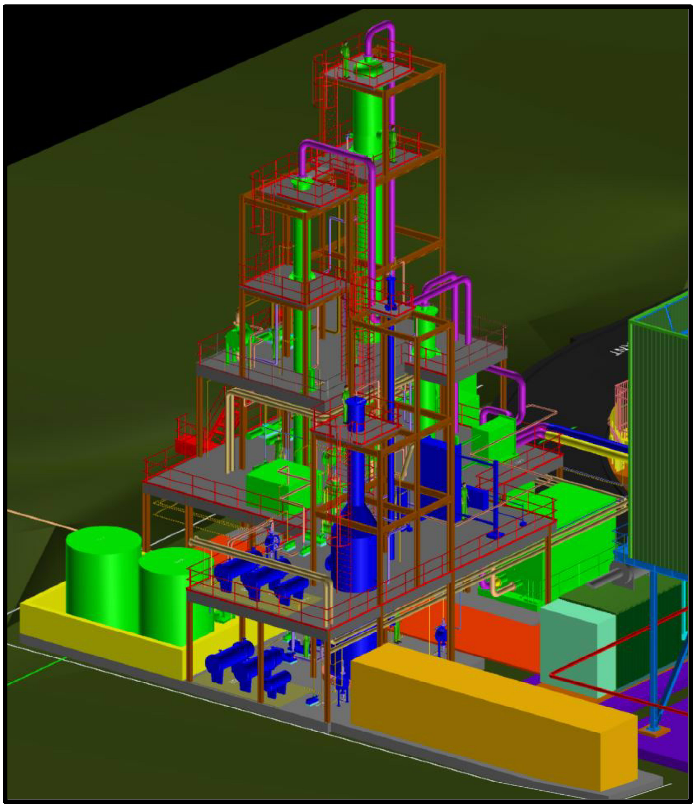
The technical information received from equipment vendors (parasitic load, weight, interface points) was used to develop specific discipline deliverables to include the P&IDs (new and mark-ups), the Control System Design Criteria, the Electrical Supply Criteria and Integration Philosophy and development of the 3D model which then enabled production of the Project Interface and Site Layout Drawings.

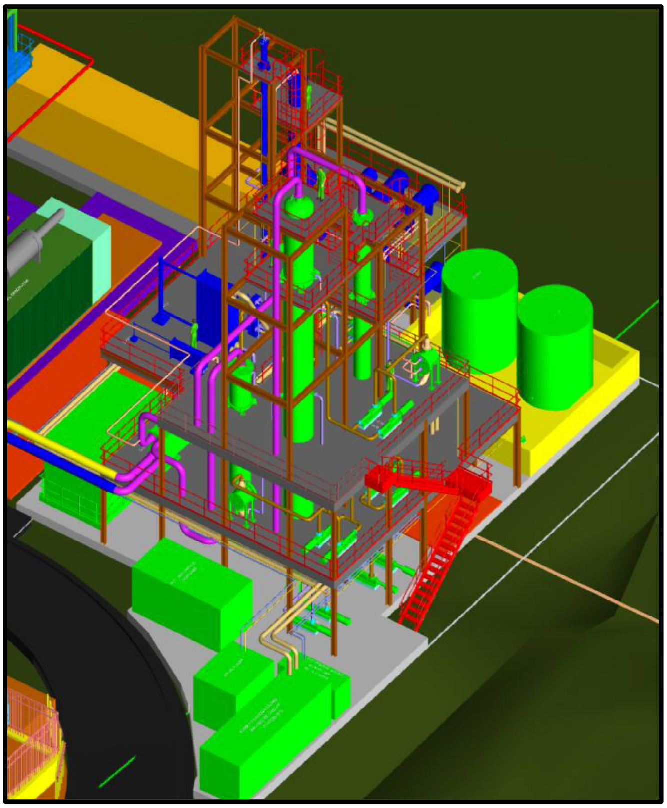
These deliverables were fundamental in developing the CAPEX build-up (Refer to Section 7.3) and to support the construction contractors in developing their procurement, fabrication and installation quotes. In particular, the 3D model and the associated drawings enabled costs to be developed for ground preparation (piling and foundation), the structural steel frame, the piping / cable and other bulk items and equipment installation.

With respect to the development of the layout and construction approach for the Pilot Plant, workshops were held with attendance from the different project stakeholders, and it was deemed a 'semi-modularised' layout and construction would be the best approach for a 20 tonnes/day Pilot Plant. A semi-modularised approach consists of multiple equipment items on pre-assembled skid mounted units and specific equipment packages in containerised form to simplify transport to site, simplify installation and reduce on site testing (installation of multiple components with piping, fittings and instruments allows a more cohesive factory acceptance testing regime. Full system acceptance and functional testing would still be required on site). This approach also enables the equipment to be easily transported in the scenario where the Pilot Plant is relocated to another site. A fully modularised / containerised equipment approach was looked at, but it was concluded not to be the preferred option at 20 tonnes/day scale (The added risk and complications associated with vessels needing to be AILs and restrictions in terms of layout meant at this scale, we were unable to optimise equipment configuration to maximise process efficiency. A more modularised / containerised approach has been adopted for the 10 tonnes/day solution. Refer to Section 6 for further details).

A multi-platform steel structural frame has been specified to provide structural support for the tall column vessels, whilst housing the pre-assembled skid mounted units in strategically located positions to maximise process efficiency. The footprint required to accommodate the 20 tonnes/day Pilot Plant and associated supporting packages has been determined to be 680 m^2. Figure 4-1 provides snapshots of the 3D model (Left Image: Looking at the Pilot Plant from north east. Right Image: Looking at the Pilot Plant from south west).

Figure 4-1 – Pilot Plant 3d Model Snapshots. Left: Looking at the Pilot Plant from north east. Right: Looking at the Pilot Plant from south west.





Using the concepts agreed for the semi-modularised layout and construction approach, a Civil and Structural Works – Preliminary Design was developed. The report outlined the preliminary design and associated drawings for the substructure works (site preparation, piling and foundations), the superstructure works (main process structure and pipe bridge) and required drainage and site finishing. The report's associated calculations and drawings were shared with the construction contractors and enabled them to produce an accurate cost and programme to cover the civil and structural works.

4.4 Project HAZID

A HAZID Study, chaired by WSP and attended by representatives from WSP, C-Capture, BIG and IBPL was completed on the 29th September 2021. The HAZID Study comprised a pre-agreed set of guidewords and concentrated around a single node which included all equipment of the Pilot Plant, the Existing Facility, tie-in points and connecting pipework. Hazards, risks and mitigation measures were identified for the design, construction, commissioning, operation and decommissioning of the Pilot Plant.

During the HAZID Study, 11 actions were identified and recorded and following the workshop, a draft HAZID Summary Report was distributed to all team members along with the actions log. Following completion of the actions, a final version of the HAZID Summary Report, to include completed and signed HAZID Action Sheets was generated.

It was acknowledged by the project team that some areas of the design were not developed enough to include a specific action to be completed at this stage and as such, these were highlighted to be carried out during Phase 2. Completion of these activities has been considered when developing the Phase 2 Implementation Plan:

- Fire Risk Assessment
- DSEAR Risk Assessment

- Process vent assessment and associated dispersion modelling
- Plant Start-up and Shutdown Philosophy (For control hierarchy)
- COSHH Assessment
- Electromagnetic Field Assessment on existing 33kV Line
- Earthing Study
- Pilot Plant Commissioning Plan
- Temporary works design documentation.

4.5 Risk Workshop and Development of the Risk Register

A Project Risk Register has been developed and continuously updated throughout the Programme by the project team. In developing the register, risks associated with the ISBL and OSBL equipment, as well as any risks related to the Existing Facility, were taken into consideration.

The risk register was initially populated with risks identified by Peel/BIG during the proposal stage, with WSP adding risks based on development of the project. A risk workshop was undertaken midway through the Programme to refine the Project Risk Register so it could be used as a tool to help inform the contingency estimate for the CAPEX build-up for the project. Representatives from WSP, C-Capture, BIG and Peel attended the risk workshop.

The Project Risk Register was issued as final on the 19th November. Some of the risks identified require actions to be addressed during Phase 2 and as such, it is important the Project Risk Register continues to be reviewed and updated as the project develops.

5 CONSENTS AND LICENSING

5.1 Planning

The Existing Facility obtained planning permission from Cheshire West and Chester Council, the local planning authority under the Town and Country Planning Act. (Latest consent is covered under ref 14/05050/NMA). The available planning options for incorporating the Pilot Plant within the Existing Facility is set out in Table 5-1.

Table 5-1 – Pilot Plant Planning Options

Planning Process	Notes
Approval of Section 96A [1] application for a non-material amendment	There is a precedent for this based on previous non-material amendment, however the scale of the amendment may be a consideration
Approval of Section 73 application for amending the conditions including a minor material amendment. [2]	This approach would focus on a change to Condition 1 (Approved Plans) including the Pilot Plant on the amended plans.
Approval of a Section 70 application – a new application	This should be considered the fallback position.

[1] Of the Town and Country Planning Act 1990

[2] Government guidance on 'Minor Material Amendments' does not define what changes may be treated as 'minor material amendments' although the government has confirmed that they "agree" with the definition proposed by WYG (White Young Green Planning and Design): "A minor material amendment is one whose scale and nature results in a development which is not substantially different from the one which has been approved". This is not however a statutory definition.

A judgement on "materiality" in any particular case is one of fact and degree, along with taking into account the likely impact of the amendment on the local environment. Materiality is considered against the development as a whole, not just part of it. The basis for forming a judgement on materiality is always against the original planning permission. The cumulative effects of any previous amendments need also to be assessed against any original permission.

The Project Team has made initial contact with the local planning authority (LPA) informally to explore available options for how to approach the amendments to the existing consent. The LPA indicated their preliminary position to be a full application and as such, the Phase 2 Programme and Costing Plan has been developed based on this route. The LPA were however receptive to receive an evidence base for an alternative pathway which will be discussed at a formal pre-application meeting. The project team believe that there is an alternative pathway to a full application, considering the scale of the Pilot Plant and the temporary nature of it.

5.2 Permitting

A Consenting Strategy has been developed by WSP for securing the required environmental permit variation to the Existing Facility permit for the addition of the Pilot Plant. The consenting strategy also considers future planning for the installation of a commercial plant.

The Consenting Strategy identifies the first step in the process is to engage with the Regulator to organise a pre-application meeting and obtain further clarification on the variation approach and the prescribed activities. (A pre-application meeting is in the process of being organised).

An indicative timeline for the variation application has been presented in the Consenting Strategy Report and incorporated into the Phase 2 Programme. The timeline could be anywhere between 9 - 19 months. The key determining step in the permit programme is the processing and determination time from the EA. The EA published timeframes for variations to bespoke Part A (1) installations, such as this, is 3 months. However, experience suggests this could be 12+ months for a decision / permit to operate.

6 ALTERNATE SCALED DOWN PILOT PLANT – 10 TONNES/DAY CO_2 CAPTURE

6.1 Overview

Following development of the initial draft cost estimate for a 20 tonnes/day CO_2 capture solution, it became apparent that the estimate was more than the SBRI grant funding for a Lot 2 Project. To ensure alignment with the GGR Programme, an alternate scaled down Pilot lant option has been developed, sized to capture 10 tonnes/day of CO_2. The objective of this exercise is to bring forward a meaningful capacity for the core technology to support the demonstration of key performance criteria and support risk mitigation of the C-Capture design at higher capacities whilst keeping project costs down.

C-Capture have undertaken further process engineering work to develop a new heat and mass balance and ISBL equipment list for the 10 tonnes/day CO_2 capture solution. This information has been used to redefine the OSBL requirements and enable the team to gain an understanding of what this scaled down solution looks like in terms of size and interaction with the Existing Facility.

6.2 Design and Implementation

The 10 tonnes/day Pilot Plant uses the same fundamental C-Capture process but with reduced equipment sizes. With the exception of steam supply, it was agreed that the utilities (flue gas supply / return, cooling, demineralised water make-up and electricity) and interfaces with would remain unchanged. Due to the lower requirement for steam, a tie-in to the Existing Facility steam cycle was deemed the most suitable option compared with steam supply from a standalone steam generator. This was concluded through a technoeconomic assessment considering the marginal impact to the Existing Facility operation and performance against the CAPEX / OPEX associated with a standalone steam generator.

Whilst a new plant configuration layout has not yet been developed for the 10 tonnes/day solution as part of the Phase 1 work, the reduced equipment size enables a more containerised / modularised layout and construction approach to be adopted, which will be advanced in the Phase 2 programme, if successful. This means a reduced steel structure frame footprint will be required (structure now only needed for support and access for the column vessels), with the majority of equipment being located in pre-assembled containers. This translates to a reduced construction programme, with time savings (and in some cases, cost savings) in the following areas:

- Procurement: Reduced equipment size enable a slightly shorter lead time and delivery from vendor.
- Substructure: Reduced steel structure frame and concentrated area for location of stacked containers means slight reduction in plot footprint and smaller diameter piles.
- Superstructure: Reduced steel structure frame meaning quicker erection time.
- Mechanical Installation: Majority of mechanical equipment pre-installed in containers with just installation of the containers and piping and cable hook-ups. (Note: Time and cost saving at site but still require installation of equipment within containers off site. This has been accounted for in the programme and cost estimate for the 10 tonnes/day solution).

The above rational has been carried through when looking at implementation of a 10 tonnes/day Pilot Plant as part of Phase 2 and is reflected in the cost build-up for this scale. Presentation and commentary for implementation of both the 20 tonnes /day and 10 tonnes/day CO_2 capture plant options has been provided in Section 7.

7 PHASE 2 PROJECT IMPLEMENTATION

7.1 Phase 2 Delivery Strategy

When developing the Phase 2 Programme and CAPEX & OPEX estimates, it is anticipated that the project will be delivered by the Phase 1 core team (WSP, C-Capture, BIG, IBPL and Peel) with supplementary support from construction sub-contractors and equipment vendors. This approach aligns with an EPCm (Engineering, Procurement, and Construction Management) delivery model where a consortium of engineering, procurement and construction management organisations are appointed to manage and control the delivery of the project. This approach has the following advantages:

- Reduces unnecessary risk provisions (cost).
- Reduces the number of personnel needed 'on the ground' to supervise the contractor.
- Allows IBPL a greater degree of access and intervention in the design of the Works and Services.
- Allows flexibility in procurement, where IBPL may wish to procure some equipment items themselves.
- Allows better management of change.
- Reduces important programme time in selecting a 'Main' Contracting Entity.
- Offers IBPL extended arm management as the EPC (M) will report direct to and serve IBPL.
- Allows IBPL to hold and control contingency.

Although the Phase 2 delivery strategy has been based on a 20 tonnes/day capture solution, the same approach will be applied to the 10 tonnes/day capture solution.

At Phase 2 commencement, a FEED will be undertaken to refine the design based on a finalised Pilot Plant scale. It is envisaged that WSP will lead the FEED with C-Capture providing specialist process engineering. Near to the end of the FEED stage, the team will engage with construction contractors in order to sub-contract the construction works. A multi-contractor approach is foreseen based on discussions during Phase 1. It is envisaged that a civil sub-contractor will undertake the substructure works (ground preparation and piling) and other sub-contractor(s) will be appointed to deliver structural, mechanical, electrical, and C&I installation.

Following FEED, a detailed design phase has been programmed, again led by WSP with support from C-Capture and the selected construction contractor(s). As part of the detailed design, tendering and negotiation will be held with the specific equipment suppliers and construction sub-contractors to enable purchase orders and contracts to be issued. The work undertaken as part of the detailed design will formulate the required level of detail for the equipment suppliers and sub-contractors to complete their design, procurement, and fabrication.

Throughout the construction phase, the core project team will remain fully involved to ensure project continuity and to supervise the construction and installation works. The commissioning will be led by the construction / installation team, with specialist support from C-Capture. Following commissioning, the Pilot Plant will be handed over to enable commencement of the testing phase.

7.2 Phase 2 Programme

A Gantt chart has been prepared which shows the programme for implementation of the 20 tonnes/day plant for Phase 2. The programme assumes a Phase 2 start date of April 2022, with some planning and permitting activities being carried out ahead of this date. A 30-month programme is estimated which includes a 6-month testing / operations phase. The programme indicates a project completion date in September 2024. (This is 6 months ahead of the specified date for Phase 2 completion of March 2025). A simplified Gantt chart for the 20 tonnes/day Pilot Plant has been presented in Figure 7-1.

Figure 7-1 – Simplified Gantt Chart showing Key Activities – 20 tonnes/day Plant

20 tonnes/day

Activity Name	Responsible Partner(s)	Duration
Phase 2 Programme	*All*	*35 months*
Pre-Application Planning & Consenting and Permitting	Contractor TBC	5 months
Post-Application Planning & Consenting	Contractor TBC	12 months
Post-Application Permitting	Contractor TBC	14 months
Front-End Engineering Design (FEED)	BIG, C-Capture & WSP	4 months
Detailed Design	BIG, C-Capture & WSP	7 months
Construction Contractor Engagement	BIG & WSP	7 months
Procurement	BIG & WSP	15 months
Construction	Construction Contractor TBC	11 months
Commissioning	Construction Contractor TBC	3 months
Pilot Plant Testing Phase	BIG & C-Capture	6 months
Handover of Phase 2 Project Report	BIG, C-Capture & WSP	1 month

A simplified Gantt chart has been presented for the 10 tonnes/day Pilot Plant in Figure 7-2. Minor time reductions would be expected at the detailed design and procurement phase (not depicted in the simplified Gantt chart as only months are presented). Major reduction is observed at the construction phase due to the reduced footprint, smaller steel frame and more simplified installation of the containerised equipment units. This translates to a project completion date in July 2024, two months ahead of the 20 tonnes/day Pilot Plant.

Figure 7-2 – Simplified Gantt Chart showing Key Activities – 10 tonnes/day Plant

10 tonnes/day

Activity Name	Responsible Partner(s)	Duration
Phase 2 Programme	*All*	*33 months*
Pre-Application Planning & Consenting and Permitting	Contractor TBC	5 months
Post-Application Planning & Consenting	Contractor TBC	12 months
Post-Application Permitting	Contractor TBC	14 months
Front-End Engineering Design (FEED)	BIG, C-Capture & WSP	4 months
Detailed Design	BIG, C-Capture & WSP	7 months
Construction Contractor Engagement	BIG & WSP	7 months
Procurement	BIG & WSP	15 months
Construction	Construction Contractor TBC	9 months
Commissioning	Construction Contractor TBC	3 months
Pilot Plant Testing Phase	BIG & C-Capture	6 months
Handover of Phase 2 Project Report	BIG, C-Capture & WSP	1 month

7.3 Phase 2 Costed Plan

A Phase 2 Implementation Costed Plan has been developed in which the CAPEX, OPEX and subsequently a OPEX levelized cost per equivalent tonne of CO_2 removed has been calculated for the 20 tonnes/day Pilot Plant and the 10 tonnes/day Pilot Plant. The 20 tonnes/day CAPEX build-up is made up of quotes from vendors for equipment items, quotes from construction contractors for construction / installation services and in-house estimates for Engineering and Project Management. The CAPEX build-up for the 10 tonnes/day Pilot Plant has been formulated through scaling of the 20 tonnes/day cost items using data from the 10 tonnes/day plant heat and mass balance developed by C-Capture.

The CAPEX has been split into two separate cost build-ups:

- The ISBL costs includes for the equipment, installation, engineering and construction management for the C-Capture plant equipment scope. This ISBL costs will make-up the eligible cost within the Phase 2 Application.
- The OSBL costs, which include for the equipment and installation associated with interfacing with the Existing Facility and supporting utilities. The costs are associated with ensuring minimal disruption to the operation and performance of the Existing Facility as part of the Pilot Plant installation but are not

considered fundamental within the C-Capture (ISBL) process. As such, these costs are considered ineligible for the SBRI grant funding and will not be included as part of the Phase 2 Application.

The total ISBL CAPEX and OSBL CAPEX (For both the 20 tonnes/day Pilot Plant and 10 tonnes/ day Pilot Plant) has been presented in Table 7-1. The total OPEX costs and OPEX levelised costs (For both Option 1 and Option 2 for the 20 tonnes/day and 10 tonnes/ day plant) has been presented in Table 7-2.

Development of the 20 tonnes/day CAPEX has been a useful reference and has been influential in the decision in taking the 10 tonnes/day scale plant forward into Phase 2. With respect to the 10 tonnes/day solution, the estimated total funding required for Phase 2 can be determined by considering the ISBL CAPEX and the OPEX, assuming Option 1. This equates to an estimate of £4,967,524. Further work will be done to refine the accuracy of this figure as part of the formal Phase 2 application process.

Table 7-1 - Phase 2 CAPEX Estimate

Description	Cost Value (£)	
	20 tonnes/day Plant	10 tonnes/day Plant
Total ISBL CAPEX	£6,487,692	£4,773,589
Total OSBL CAPEX	£6,448,938	£5,164,007

Table 7-2 - Phase 2 OPEX Summary

Description	Cost Value (£)			
	20 tonnes/day Plant		10 tonnes/day Plant	
	Cost (Option 1 [1])	Cost (Option 2 [2])	Cost (Option 1 [1])	Cost (Option 2 [2])
Total OPEX (£)	£193,935	£92,145	£193,935	£92,145
OPEX Levelised Cost (£/tCO_{2eq})	59	106	118	213

[1] Option 1 is base case operational scenario based on operation of 24 hours a day, assuming 90% availability, for 6-month duration.

[2] Option 2 is an alternate operating scenario presented in the OPEX for comparative purposes only. Based on operation (on average) of 8 hours a day, Mon - Fri, assuming 100% availability, for 6-month duration.

7.4 Cost Accuracy

Using WSP's in-house cost confidence matrix, it is possible to estimate an overall level of accuracy for the 20tonnes/day cost estimate. For each major cost line within the estimate, a category is assigned based on the quality (or maturity) of the design and the quality of the cost information obtained, with each category corresponding to an accuracy percentage within the upper limits of an AACE Class 3 estimate. The cost confidence assessment indicates an accuracy of -11.3% to +17% for the overall CAPEX and so well within the AACE Class 3 limits.

The estimate for the 10 tonnes/day plant has been costed using the 20 tonnes/day cost breakdown as the basis and then scaled based on capacities and adjusted using engineering principles. This methodology is therefore consistent with a AACE Class 4 estimate. Further work is being undertaken with equipment vendors and construction contractors to improve the accuracy of the estimate ahead of formal submission to the Phase 2 application process.

7.5 Cost Savings Relative to **Private / Exclusive Funding**

Within the C-Capture process there are a number of proprietary designs which C-Capture are developing with third party suppliers. These include areas such as the absorber internals and aqueous management packages, for which, once demonstrated on C-Capture's own 1 tonnes/day Pilot Plant, will evolve into longer term commercial relationships. Although not included at this time, we believe that significant benefits will be available for future cost reductions of several key equipment items for Phase 2 part of this project. This will include a procurement strategy to deliver improvements and savings linked to supply chains being identified for a commercial scale facility, as particularly described in section 8.4.

7.6 UK Tender Price and Building Cost Indices

The cost for a 20 tonnes/day Pilot Plant is higher than the project team preliminarily estimated at project inception. A key reason for this elevated cost is due to the unprecedented inflated tender price and building cost indices.

As outlined by the Office for National Statistics[3], the cost of construction for new work has increased across all sectors. The annual rate of growth of construction output prices in June 2021 was 3.8%. Construction output prices have been increasing since December 2019 resulting in 19 consecutive months of positive monthly growth. This escalation has been further documented in a market forecast published by AECOM in November 2021[4]. The publication indicates a tender price increase of 5% from Q3 2020 to Q3 2021 and a building cost increase of 11% from Q3 2020 to Q3 2021.

With specific relation to this project, the key materials required for the construction of the Pilot Plant have increased over the past year. The cost of steel has seen a significant increase in price, increasing by almost £500 per tonne since July 2020[5]. The increase in the cost of steel has been due to an increased raw material (iron ore) cost, increased electricity prices, and increased transport costs. Furthermore, the increase in steel price has also been linked to an increase in concrete prices, with major contractors increasing cost for supply of concrete materials by 15% in September 2021[6].

With consideration of the project moving into Phase 2, engagement is scheduled to be held with equipment vendors and construction contractors in Q3 2022. With further reference back to the market forecast published by AECOM, a 2.1% drop is projected from Q4 2021 to Q4 2022 for tender price. As such, a reduction can be anticipated in the equipment and construction quotes to be received (large proportion of the cost build-up) and subsequently a reduction in the overall CAPEX.

[3] https://www.ons.gov.uk/economy/inflationandpriceindices/articles/pricemovementsinconstructionmaterialsandplanthireuk/2019to2021

[4] Market Forecast Q4 2021 (Edited version of the article that first appeared in Building magazine in November 2021, Michael Hubbard, Associate, Cost Management, AECOM.

[5] https://www.building.co.uk/news/british-steel-price-hike-sign-of-the-next-phase-of-cost-inflation-consultant-warns/5113994.article

[6] https://www.constructionenquirer.com/2021/08/27/contractors-rocked-by-15-price-hike-on-concrete-products/

8 SCALING UP OF THE TECHNOLOGY FOLLOWING PILOT PLANT DEMONSTRATION

8.1 Introduction

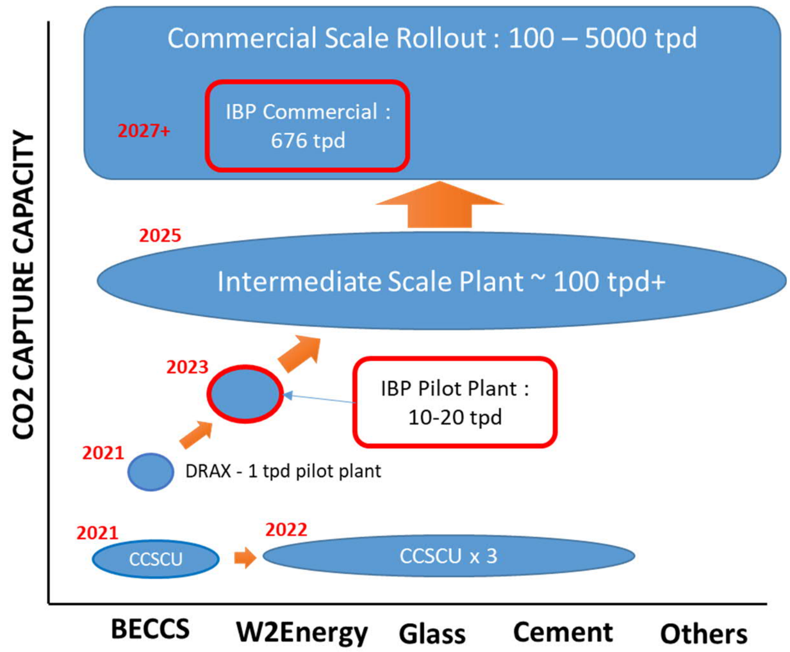
The two overarching drivers for successful demonstration of the Pilot Plant is to further establish and progress the C-Capture technology and to install full scale commercial carbon capture technology at the IBP facility and subsequently at other biomass and waste to energy assets BIG have in their portfolio. These assets serve as the pathfinder opportunities to retrofit carbon capture technology connecting to the transport and storage infrastructure benefiting from government support for an emergent carbon capture, utilisation, and storage industry to achieve net zero. In addition, there is an opportunity to bring forward new BECCS facilities supported by a BECCS contract delivering negative emissions from first commercial operations integrating the capture plant in the planned development.

BIG have selected C-Capture technology due to its unique benefits in using a non-amine based solvent with higher robustness to contaminants and a lower environmental impact with lower parasitic energy loading. It is believed that this can be commercially demonstrated through the planned Pilot Plant trials and related commercial scale up programme.

8.2 C-Capture Technology Commercialisation

C-Capture is committed to supporting BIG to meet their strategic goal through developing their technology at a pace which will support the development of a full-scale commercial scale plant by the end of 2027. This is represented in Figure 8-1 below.

Figure 8-1 – C-Capture Commercialisation Pathway



C-Capture is scheduled to install a new, fully integrated 1 tonne-per-day demo at Drax by Q1 2022 (as funded through BEIS Innovation 1.0 grant fund). This will incorporate the latest absorber design proposed for this Pilot Plant in combination with all other associated unit operations which will be used to de-risk the Pilot Plant project during detailed design and operation.

In particular, key development learnings from this project will further support the understanding of operation in BECCS environments and further develop the C-Capture technology to support and demonstrate both the latest absorber design performance and direct measurement of the lower energy use which is a key differentiator for the technology. Overall, the expectation is that the C-Capture technology will have advanced from TRL 6 to TRL 7/8 once the Pilot Plant has been constructed, commissioned and operated for 6 months. Further discussion on the knowledge hoped to be gained during the Phase 2 part of the Programme has been outlined in section 8.3.

To further support commercialisation, C-Capture is currently identifying potential partners and sites in hard to abate industries such as cement, glass, waste to energy, lime and steel to support the development of the intermediate 100+ tonnes/day plant scale-up. These industries are perfect to exploit the specific benefits of the C-Capture technology and it is planned that an initial solvent compatibility study is deployed across these industries in 2022. A number of these potential sites are currently undertaking a feasibility study for an intermediate scale plant and it is intended that the most appropriate site will be selected and enter into pre-FEED by mid-2022.

8.3 Knowledge and Experience to be Gained During Phase 2

The project team recognise the importance of using the Phase 2 programme (the engineering design, construction and testing phase) to help inform and define the commercialisation path of the C-Capture technology. A summary of some of the main areas which will be explored during Phase 2 to gain this knowledge and experience include:

- Absorber operational experience – Demonstration at higher scale of the novel absorber design across a range of operation regimes and performance modes.
- Relationship and experience built up by key process equipment vendors – As part of Pilot Plant procurement, the project team will work with equipment vendors to ensure they understand the relationship between pilot and commercial scale and let them feed into the testing regime to help scale-up development of their equipment packages.
- Demonstration of lower energy requirement – Ability to demonstrate C-Captures inherently lower energy requirements at a scale where this can be directly measured. (Note: smaller (laboratory) scale testing introduces a higher rate of heat loss which can significantly impact the ability to demonstrate this effectively, whereas this Pilot Plant size is more in line with a commercial scale offering).
- Direct experience of Solvent compatibility on BECCS waste wood gasifier – Develop fundamental data on solvent degradation rates (losses) and pathways.
- Operational control and stability whilst linked to Ince Bio Power operating facilities – Direct operation with the gasification off-gas, demonstrating stable operation through process variability and potential upsets. (Demonstrates effective operational control links with the Existing Facility).
- Ability to perform dynamic response tests – To further understand operational flexibility and optimise process response.
- Demonstration of optimal heat integration and operation relative to the previous smaller scale demonstration plants to enable an understanding on performance for future scale up.
- A cohesive Pilot Plant testing regime with foresight of commercialisation pathway – Consideration will be given to what tests, trials and data will be needed to support, validate and de-risk C-Capture's proprietary process with future scaled up plants.

8.4 Ince Bio Power - Commercial Scale Plant

Design Basis

A commercial scale carbon capture plant at the IBP facility would be sized to capture circa 676 tonnes/day of CO_2 and would compress the CO_2 on site to enable connection into the HyNet industrial cluster. If the IBP facility deploys C-Capture technology, it is estimated that an area of 5,000m^2 (~2,500m^2 for ISBL and ~2,500m^2 for OSBL) could accommodate the C-Capture plant and supporting equipment, with a parcel of land directly to the east of the Existing Facility earmarked.

The commercial scale plant would be fully integrated with the Existing Facility, with supply and return of flue gas and supply of utilities / supporting systems (process steam, process cooling, potable water, fire water, instrument air and electricity). It is thought a new demineralised water plant would be required to meet the process water demand for the C-Capture plant and new cooling system supported by a chiller system to ensure cooling requirements can be met during high ambient temperatures (Note: Pilot Plant design is solely based on chillers to allow performance to be assessed at lower process temperatures as part of the testing regime but the commercial scale plant may operate at higher process temperatures).

Development from Pilot Plant to Commercial Scale Plant

The specific function of the Pilot Plant is to undertake a testing regime of the C-Capture technology to validate and help advance the technology whereas the commercial scale plant will capture, process and compress the CO_2 for interconnection into the HyNet industrial cluster. As such, the design, equipment (size, arrangement, redundancy) and construction approach will differ between the two plants. With respect to the scale up of equipment and redundancy, consideration needs to be given to ensure that a ‘fit for purpose’ commercial plant is designed to ensure an optimum design in both CAPEX and operability. C-Capture anticipates that the future commercial design will incorporate benefits from the following activities:

- Standardisation and Value Engineering – Where possible equipment design and suppliers will be simplified and standardised across all future plants to enable cost reductions through procuring multiple, identical equipment items. A value engineering exercise will also be carried out to identify the optimum level of redundancy whilst maintaining the required plant flexibility and operability.
- Strategic Suppliers – Where identified, C-Capture will develop close relationships with a few, pre-qualified suppliers for key technology items. This ensures that the supply maintains an element of competition but also that the equipment is delivered as required to guarantee operability.
- Economies of Scale – rollout of this technology will drive the technology to deliver higher economies of scale as the cost of equipment versus production rate reduces at higher capacities. C-Capture envisage that ultimately, there will be a balance between the provision of low-cost modular design plants and larger bespoke, higher capacity design plants depending upon its application.
- Instrumentation / Analytical Equipment – at the pilot scale the high cost of instrumentation and analytical needs, in order to operate the plant effectively, is a large part of the overall project costs. C-Capture envisage that this equipment will be independent of the scale of plant and hence will have a much lower cost impact at commercial scale.
- Design and Construction Activities – The amount of design work required at Pilot Plant is in the same order of magnitude as any such commercial scale plant. Any estimate for the design and construction aspects shall be costed using a programme and resource basis, with allowance to account for the novel nature of the technology. This allowance would be reduced as the technology continues to be commercialised and understood and can be further reduced as additional plants are built and the design becomes more standardised.

Interaction with the HyNet Industrial Cluster

The Ince Bio Power (IBP) Plant is a named Negative Emission Plant (NEP) in the HyNet North West industrial cluster that has been selected as a Track-1 Cluster in the BEIS cluster sequencing programme. However, as a GGR facility, the process and timetable for securing a BECCS contract to support retrofitting a commercial scale carbon capture solution connecting to the HyNet infrastructure has not been confirmed by BEIS at the time of issue of this report.

In addition, Mersey Bio Energy (MBE), a waste wood power plant located in Widnes on the other side of the Mersey has the potential to provide further negative emissions if a connection can be made to the HyNet infrastructure. This is currently being treated as an expansion project due to the current extent of the HyNet infrastructure.

Peel NRE has a further 3 occupiers named in the Track-1 cluster located at the Protos development. Peel NRE is currently completing an engineering feasibility study with a view to progressing development and delivery of a local CO_2 transportation network around Protos for occupiers to connect into and provide an easy interface with the HyNet CO_2 pipeline network to accommodate the increasing need for capture and transportation of CO_2 from both existing and future occupiers at the Protos development. It is anticipated that this would be available to align with the operational date for the HyNet infrastructure.

Cost Analysis

To help further understand the commercial aspects of a carbon capture plant at the IBP site, a levelised cost of CO_2 abatement has been calculated to be in the range of £77.57/ tCO_{2eq} - £82.61/tCO_{2eq} (Conservative range of £75/tCO_{2eq} - £85/tCO_{2eq}). The levelised cost is project specific and so includes CAPEX costs associated with land purchasing and insurances and CAPEX and OPEX costs associated with supporting utilities from the Existing Facility (electricity supply and steam supply). The estimate has been developed using scaling and lang factors and is deemed consistent with an AACE Class 5 estimate accuracy. Further work is required to refine the accuracy, but it can be concluded the range is well below the <£200 per tonne CO_2eq target indicated in the Programme guidance.

An energy requirement, specific to a commercial scale carbon capture plant at the Ince Bio Power site has been calculated to be in the range of 1.8 – 2 GJ/tonne CO_2 captured. This is below the industry recognised energy requirement for amine-based systems of >2.5 GJ/tonne CO_2 capture.

Dependencies to Ensure a Carbon Capture Commercial Scale Plant at Ince Bio Power will be a Success

The project team recognises the importance of BECCS deployment to achieve the UK government's net zero ambition and believe the Ince BECCS Pilot Plant and subsequent installation of a commercial scale plant at the IBP site can help achieve this. There are however a number of dependencies which will be paramount to enable a commercial scale carbon capture plant to be implemented at the Ince Bio Power site. What we believe to be the primary dependencies have been outlined below:

- C-Capture's continued technology development, through the testing regime of the Pilot Plant and ongoing independent development activities.
- Continued progress with the HyNet industrial cluster and the proposed business models[7] to create the required infrastructure and supporting network to promote collaboration with surrounding emitters.
- Continued development of suitable supporting framework and business models[8] to enable individual emitters to invest in carbon capture projects.
- Development of long-term commercial relationships with third party suppliers who are providing proprietary design for C-Capture's technology, to ensure de-risking and cost reductions in future scale-ups and commercial scale plants.

[7] Transport & Storage Company (T&SCo) framework
[8] Industrial Carbon Capture, Dispatchable Power, Hydrogen, Bioenergy with Carbon Capture & Storage (BECCS), etc

- Stabilisation of currently volatile material / supply chain costs.
- Progress on the interpretation of environmental permitting regulations for carbon capture solutions to enable technology to be deployed.

8.5 Future Commercialisation of BIG Assets

As mentioned above, Mersey Bio Energy (MBE), located on the other side of the Mersey at Widnes, within reasonable proximity to the HyNet industrial cluster, is an 22MWe waste wood power plant that could equally have a carbon capture plant retrofitted to deliver negative emissions if connected to HyNet infrastructure.

Energy Works Hull (EWH), another BIG asset on the east coast, has entered into a Memorandum of Understanding with the East Coast Cluster which has also been selected as a Track-1 cluster. Unlike IBP, EWH is included as an expansion project in the East Coast Cluster. The timetable for expansion projects is likely to see emitters such as EWH connect to the East Coast Cluster after 2030. In addition, EWH features in C-Capture's application to CCUS Innovation 2.0 for a carbon capture solvent compatibility unit, which if successful will see this installed at EWH in 2022 to gain a further understanding of the C-Capture solvent on flue gas from a waste to energy facility.

BIG is also actively considering how carbon capture plants can be integrated into EFW plants which have not been constructed, offering the opportunity to deliver an optimised solution from first commercial operations as opposed to retrofitting afterwards. This promotes new development opportunities to bring forward new facilities to deliver negative emissions.

ABBREVIATIONS

Abbreviations	
AACE	Association for the Advancement of Cost Engineering
AIL	Abnormal Indivisible Load
BAT	Best Available Techniques
BECCS	Bioenergy with Carbon Capture and Storage
BEIS	Department of Business, Energy and Industrial Strategy
BIG	Bioenergy Infrastructure Group
C&I	Control and Instrumentation
CAPEX	Capital Expenditure
CCS	Carbon Capture and Storage
CDM	Construction (Design and Management) Regulations
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
COSHH	Control of Substances Hazardous to Health
DSEAR	Dangerous Substances and Explosive Atmospheres Regulations
EA	Environmental Agency
ELV	Emission Limit Value
EWH	Energy Works Hull
FEED	Front-End Engineering Design
FTIR	Fourier Transform Infrared Spectroscopy
GGR	Greenhouse Gas Removal
HAZID	Hazard Identification
IBP	Ince Bio Power
IBPL	Ince Bio Power Limited
ISBL	Inside Battery Limits
LPA	Local Planning Authority
MBE	Mersey Bio Energy
MCC	Motor Control Centre
MEA	Monoethanolamine
OPEX	Operating Expenditure
OSBL	Outside Battery Limits
P&ID	Piping and Instrumentation Diagram
PLC	Programmable Logic Controller
PZ	Piperazine
SBRI	Small Business Research Initiative
TRL	Technology Readiness Level
VOC	Volatile Organic Compound