Department for
Business, Energy
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Public Project Final Report

Hydrogen BECCS Innovation Programme: Phase 1

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Project Lead Organisation:	Advanced Biofuel Solutions Ltd
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Contents

1 Executive Summary

ABSL and UCL are collaborating to enhance biomass gasification through the development of novel techniques to deal with tar and ash contaminants.

Fluidised bed oxy-steam gasification is a key pathway to produce BECCS biohydrogen. Feedstocks are converted into a syngas comprising hydrogen, carbon monoxide and carbon dioxide which is reacted with steam to increase its hydrogen content. Carbon dioxide is then stripped from the gas stream using a chemical or physical solvent for sequestration, leaving a low carbon hydrogen for use as a fuel or chemical feedstock.

Biomass contains ash components that can bind with the fluidised bed and impair the gasification process. This means that gasification must take place at low temperatures resulting in the formation of tars, long chain hydrocarbons that are a vapour at gasification temperatures but condense at lower temperatures, fouling equipment. In addition, some components of the feedstock vaporise during gasification and then condense as the gas cools, creating lumps of accreting material that block ducts and corrode downstream equipment.

This project explores novel solutions to remove these contaminants from a syngas:

a. It has been demonstrated that tars can be reformed high temperatures (1,200°C or higher) using a plasma arc to catalyse the reformation reactions. The project will explore the use of plasma at lower temperatures (800°C to 1,100°C), investigating the impact on tar reformation and required residence times.
b. The gasifier can be controlled to reduce the release of volatile material.

Phase 1 of the project carried out a literature search on gasifier control. Experimental work and modelling was used to assess both gasifier control and low temperature plasma tar reformation. Phase 1 also produced an initial design of the equipment required to test both solutions at the ABSL gasification plant, prepared an experimental test plan for Phase 2 trials and carried out a preliminary safety assessment of that plan. Finally, Phase 1 evaluated key parts of a commercialisation plan for the technology.

Phase 2 of this project consists of the following work packages which will implement the test plan developed in Phase 1 of the project:

WP1	Modification to the plant to allow testing.
WP2	Operation of the plant to establish a base line performance.
WP3	Preparatory testing to ensure the modification to the plant are functioning in line with the design.
WP4	Functional testing of gasifier control techniques.
WP5	Functional testing of low temperature furnace operation.
WP6	Performance testing of the modifications developed in WP4 and WP5.
WP7	Development of plans for commercialising the technology.
WP8	Project management.

The key parameters that the Phase 2 project aims to improve are the cold gas conversion efficiency, power consumption and system availability of a gasification system. This builds upon Phase 1 work that showed that the improvements work at a laboratory scale and developed the test plan to investigate them at a large scale.

The project will be delivered by a combined ABSL and UCL team in line with the ABSL project management procedures. These cover governance, reporting, document management, risk management and budgetary control. The current forecast of the cost of the project is £4.8m.

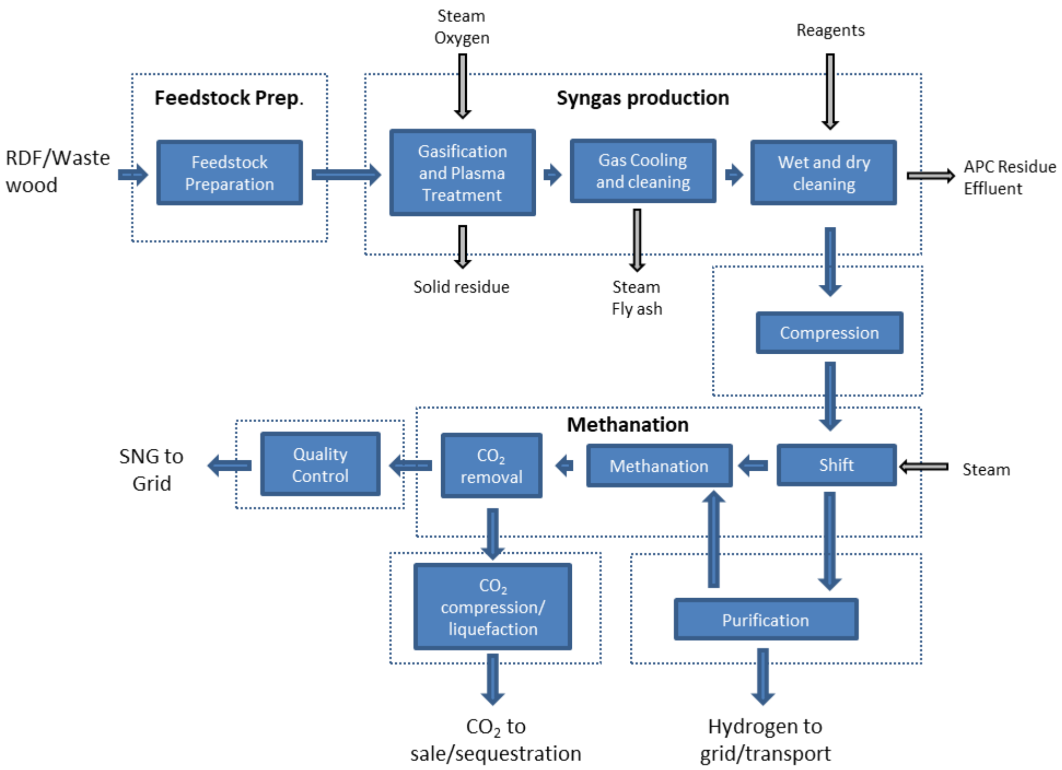
The key project risks are the technical performance of the Swindon demonstration plant, the availability of qualified staff and completing all activities within the 23 month programme.

The results of the project will significantly improve the efficiency and reliability of biomass gasification resulting in a reduction in the cost of hydrogen production with BECCS.

2 Technology

RadGas Technology

ABSL's RadGas solution converts waste into low carbon fuels while capturing carbon dioxide for sequestration. The process is summarised in the following diagram.



The process operates as follows:

- Pre-prepared waste is brought to the plant in moving floor trailers.
- It is shredded and dried.
- The dried feedstock is metered into a fluidised bed gasifier to produce a crude synthesis gas (syngas).
- Tars in the syngas are reformed using a direct current electric arc furnace. This also vitrifies ash components of the syngas.
- The gas is cooled in a waste heat boiler and then filtered and scrubbed to remove any remaining ash, acid gases and alkali gases.

- The cool, clean syngas is compressed.
- The compressed gas is catalytically converted into biohydrogen and/or biomethane.
- Carbon dioxide in the gas is removed using a chemical scrubbing system and then either stored for onward sale or injected into a transport and sequestration network.
- The biohydrogen or biomethane is metered into the gas grid for onward sale.

The process was developed at a pilot plant in Swindon that operated for 3,500 hours over the course of five years. This showed that the underlying chemistry of the process works. The next stage in the development of the technology is to operate a demonstration plant that will work on a full-time basis in a fully commercial environment.

ABSL are in the process of bringing a demonstration plant at Swindon into operation. The plant will convert one tonne per hour of household waste into 3MW of biomethane, enough to heat 1,500 homes.

Construction, cold commissioning, and wet commissioning of the Swindon plant are complete, and it is fully staffed by around 30 trained engineers. All regulatory consents are in place. The facility is currently in hot commissioning and the plan is that it will produce good quality syngas early in 2023.

The Swindon facility is the only plant in the world to convert household waste into a low carbon fuel while capturing carbon dioxide. It provides a unique reference for the RadGas process at scale that is large enough to give stakeholders confidence in the technology but small enough to allow challenges that arise to be resolved relatively quickly and cost-effectively.

The key technical challenges faced by gasification plants are:

- Fouling of the system by tars generated in the gasification process. These tars are gaseous at gasification temperatures but when cooled they form sticky liquids and solids that coat and foul downstream equipment. In a RadGas plant tars are reformed at high temperatures with plasma being used to catalyse reformation reactions.
- Blockage of ducts by contaminants found in the biomass feedstocks. These contaminants are vapourised by the high temperatures in the plasma furnace but coalesce in downstream equipment as they cool, blocking ducts. The deposits can build up very quickly. In the pilot plant ducts would become blocked within one day of operation. The demonstration plant is designed to cool gas rapidly so that it forms a dust that does not adhere to duct walls.

Project Aims

The aim of this project is to explore:

- Reformation of tars at lower temperatures in the plasma furnace. Lower temperature operation improves system efficiency because less syngas energy is required to raise syngas temperature and because thermal losses are reduced at lower temperatures.
- Methods of controlling the gasifier to reduce the build-up of contaminants in downstream equipment.

Both solutions were tested experimentally in Phase 1 of the project.

Low Temperature Plasma Operation

A laboratory scale plasma furnace was used to explore the impact of syngas temperature and composition on tar reformation in a plasma environment. The test apparatus comprised gas bottles, syringe pumps for injecting water and n-dodecane, a gas pre-heater, a plasma furnace, gas coolers and gas analysis equipment.

Tests were run over a period of eight hours which included two hours of plasma operation. Four sets of tests were run with varying gas compositions ranging from 99% argon and 1% n-dodecane to 20% hydrogen, 9% carbon dioxide, 14% carbon monoxide, 10% water, 46% argon and 1% n-dodecane. These results were used to validate a kinetic model of plasma tar reformation and evaluate the impact of gas temperature on tar reformation.

This showed that reformation of tar at 800°C is too limited to be useful in industrial applications but that 97% of the tar is reformed at 1,000°C which is significantly lower than the 1,200°C operating temperature for the Swindon demonstration plant. This shows that it may be possible to reduce the operating temperature of the furnace and still reduce tar contamination to an acceptable level.

Phase 2 of the project will explore the operation of the plasma furnace at low temperatures in a demonstration environment. The target will be to reduce the operating temperature to 1100°C.

A 100°C reduction in furnace operating temperatures increasing process efficiency by 1.5 percentage points. Identifying an operating plan that allows lower temperature tar reformation will increase efficiency and the amount of low carbon fuel produced. This improves economic performance and the likelihood of the technology being commercially deployed.

Gasifier Fluxing

Phase 1 of the project carried out a literature search to identify methods that could be used to reduce the release of contaminants from the gasifier. This showed that there has not been a significant amount of work in the area because gasifier research tends to focus on tar reformation rather than ash management. UCL then set up a laboratory scale experiment to test various methods to control the release of contaminants in the gasifier. This identified the preferred method for further testing which will be tested in Phase 2 of the project.

3 Engineering Design

The Phase 2 project will be carried out at the Swindon demonstration plant described in Section 2. This plant requires the following modifications to carry out the Phase 2 test plan:

- The gasifier will be adapted to allow the techniques developed in Phase 1 to be tested to control the release of contaminants.
- A syngas sampling system will be added to the exit of gasifier. This will require specialised equipment that allows a sample of tar and ash laden hot (800°C) syngas to be taken for external analysis.
- A syngas sampling system will be added to the exit of the plasma furnace. The gas exiting the plasma furnace will have lower levels of tar and ash than the gas exiting the gasifier, but temperatures will be higher (up to 1300°C).

The functional requirements for each of these modification and safety implications have been assessed in Phase 1 of the project and reported in Phase 1 deliverables 2.1 and 3.1. The detailed design and implementation of the changes will be carried out at the start of Phase 2.

The modifications are relatively minor and should be implemented within 6 months of start of Phase 2.

4 Test Plan

A detailed test plant was developed in Phase 1 of the project and is set out in Deliverables 2.2 and 4.2. Key activities for testing are:

- A period of operation under normal conditions to establish the baseline system performance.
- Preparatory testing to ensure that the additional equipment that has been added to the system is working in line with design specification and to test and refine operating procedures.
- Functional testing of the changes to gasifier operation.
- Functional testing of the impact of low temperature operation of the plasma furnace. Phase 1 of the project showed that low temperature tar reformation is feasible.
- Performance testing of the preferred gasifier control and furnace low temperature environment.

These tests will be carried out on waste wood and then refuse derived fuel. The key differences between these feedstocks are the higher levels of ash and contaminants (sulphur and chlorine) in refuse derived fuel. These may have a significant impact on performance and so the results from each feedstock could be very different.

The key performance parameters that will be measured during testing are:

- Cold gas conversion efficiency – the ratio of chemical energy in the syngas to the energy in the waste feedstock.
- Power consumption.
- Availability – the ratio of time in normal operation to the total time of the run.
- Molar proportion of tars and their composition in the syngas after the gasifier and after the plasma furnace.
- Mass proportion of alkali salts in the feedstock and in the syngas after the gasifier.
- The ratio of mass of alkali salts removed in the bed media system to mass of the feedstock.

The purpose of the testing under normal operating conditions is to establish the baseline performance on each parameter.

The functional test of gasifier operation will require several test periods of 24 hours of stable operation taking measurements of the bed media system and compositions of syngas. The gasifier will be brought to a steady state under normal operations and then new control strategies will be tested. Samples will be taken of bed media together with syngas from various points in the system. This data will be analysed to determine system performance.

The functional test of low temperature operation will require several test periods of 96 hours of stable operation. The system will be run under normal operating conditions and then the operating temperature will be changed. Measurement of slag chemistry and conditions will be taken together with measurement of system performance. The objective of the testing is to determine the lowest temperature operation that gives adequate tar reformation.

The results from the functional testing will be used to develop a new operating plan for the gasifier and plasma furnace. This will be tested over 1,000 hours in performance tests on waste wood and then refuse derived fuel. The data that will be collected are the key performance parameters set out above. Results will be compared to baseline testing. Successful testing will result in:

- An increase in cold gas conversion efficiency.
- A reduction in power consumption.
- Higher levels of system availability.
- No reduction in levels of tar reformation.

If the project delivers material improvement in each of these parameters, it will significantly improve performance of the RadGas technology and its likelihood of successful commercialisation.

A preliminary safety assessment of both the gasifier fluxing and low temperature plasma furnace operation was carried out in Phase 1 of the project and reported in Deliverables 2.3 and 4.3. This did not reveal any major safety concerns but identified risks around flux handling and syngas sampling that will require mitigation in Phase 2 of the project.

5 Project Plan

5.1 Project Team, Project Management and Dissemination

Phase 2 of the project will be delivered by the same organisations that delivered Phase 1. ABSL will provide the demonstration plant and the team to define, manage and carry our testing. UCL will provide technical advice and independent reviews of results.

The key members of the project team and their roles are set out in the following table.

Job Title	**Project Role**
CEO	Project director
CTO	Technical director
Project Developments Manager	Project manager
Plant Manager	Project deliver manager
Engineering Director	Quality control
CFO	Financial control
Document Administrator	Document control
Research Fellow of RAEng	Results analysis and review

This core team will be supported by an operational team of 30 engineers who operate the plant and collect data. ABSL also has a team of 5 process, mechanical and electrical engineers who will design the plant modifications required for the plant and assist in data collation and analysis.

The project team collaborated on the design, construction and commissioning of the ABSL demonstration plant and are currently delivering a major project under the BEIS Greenhouse Gas Removal programme. They have extensive experience of delivering complex capital projects.

The project will be managed in line with ABSL standard project management procedures. These are summarised as follows:

- The project will be governed by a project board comprising of one member from each partner and chaired by the project director, who will have the casting vote. Governance rules will be set out on the collaboration agreement.
- The project board will meet on a monthly basis to review project progress, update the risk register and discuss and resolve project issues.
- Day to day responsibility for managing the project will rest with the project manager who will co-ordinate activity between partners and check and chase progress.
- The project manager will issue a monthly report covering project progress, risks and financial performance. The project director will review this report and provide a summary for BEIS.
- Project documents will be managed by the ABSL document administrator using the ABSL document management system.
- Each work package will be managed by the project manager.
- A risk-based approach will be used for project management and the risk register will be reviewed and updated regularly.

ABSL operates a quality management system. All project documents will be reviewed and approved before issue. Quality procedures will be independently reviewed by ABSL's engineering director.

The project director will take responsibility for dissemination of project results. ABSL will disseminate non-confidential information through:

- Updates on its website and social media.
- Visits to the plant by organisations interested in the technology such as government, fuel companies, chemical companies and waste companies.
- Presentations to conferences and exhibitions.
- Press releases for the completion of major project milestones.

ABSL will notify BEIS of dissemination activities and ensure that they are happy with any references to the project.

5.2 Work Packages and Timetable

The work packages for the project are summarise in the following table.

Work Package	Title	Description	Key Deliverables	Due Date
WP1	Plant Modifications	Design, installation and commissioning of equipment required to carry out tests.	Design documents Procurement documents Safety assessment Equipment delivery notes	Oct-23
WP2	Baseline testing	Operation of plant on waste wood and refuse derived fuel to establish baseline performance.	Wood plant operating data Wood baseline performance measurements RDF plant operating data RDF baseline performance measurements	Nov-23
WP3	Preparatory testing	Preparatory testing of system modification to	Operational reports Test results	Feb-24

		test performance and operating procedures.		
WP4	Gasifier functional testing	Functional testing of gasifier operation	Operational reports Test results	May-24
WP5	Low temperature functional testing	Functional testing of low temperature plasma operation.	Operational reports Intermittent operation results	Sep-24
WP6	Performance testing	1000 hour performance test using procedures developed in functional testing.	Operation reports Test results	Dec-24
WP7	Commercialisation	Commercialisation of technology through development of commercial project at selected site.	Detailed site report. Summary of off-take agreements. Report on hydrogen business model. Report on GGR business model.	Oct-24
WP8	Project management	Ongoing project management in line with ABSL project management process. Dissemination of results.	Monthly reports. Risk register. 6-monthly project reports. Final project report. Social media and website updates.	Feb-25

Work package and work package 2 can be carried out in parallel. Work packages 2, 3, 4, 5 and 6 rely on the demonstration plant and so must be carried out sequentially with some overlap for system set up and analysis of results. Work package 7 will be started once there is more certainty around the BEIS business models for greenhouse gas removals and low carbon hydrogen. Project management will take place across the entire project. The final report is expected to be delivered in February 2025.

5.3 Project Costs

The overall cost of the project is currently forecast at £4.8m. This is made up of:

- The cost of the equipment required to modify the Swindon plant to allow the work to be carried out.
- Subcontractor costs for making those modifications; analysing solids and gases; calibrating sensors and other activities associated with plant operation.
- Consumables which are primarily made up of the power used by the plant, chemicals used in gas treatment, fluxing materials and disposal of waste products generated by the process.
- ABSL and UCL labour costs for carrying out the project activities.

5.4 Risks and risk management

An initial risk register has been prepared for Phase 2 of the project. The top three risks identified in the register are:

- Performance of the ABSL demonstration plant. The demonstration plant that will host the project is currently in hot commissioning. The key components use in the project have been operated individually but will not be tested together until the end of 2022. There is a risk

that delays to plant commissioning may delay the project. It should be noted that plant performance risk is significantly lower than projects that rely on completely new equipment. The risk is mitigated through careful management of the commissioning process and the provision of a three-month contingency between the planned completion of hot commissioning and the date it is required for the projects.
- Staffing. There is a shortage of qualified staff in the UK at present and it is difficult to recruit the technical personnel required to carry out complex engineering projects. ABSL and UCL both have sufficient resources to carry out the project at present but there is a risk that staff will leave and then be difficult to replace. The risk will be mitigated by recruiting new staff early in the project to provide a contingency against others leaving.
- Programme. The time available to carry out the testing is very short at 23 months and there is a risk that there will not be sufficient time to complete all the tests. This will be mitigated through careful management of the project and prioritisation of work if it won't be possible. For example, it would be possible to prioritise testing on waste wood rather than refuse derived fuel.

The risk register will be reviewed regularly by the project team and used to prioritise project activities.

6 Commercialisation Plan

6.1 Target Markets

ABSL's RadGas H_2BECCS solution targets two separate markets – low carbon hydrogen and negative emissions. These are discussed below.

Low Carbon Hydrogen Market

The low carbon hydrogen market is explored in detail in Deliverable 4.2. The key features of the market are:

- It is immature with high levels of uncertainty around the timing and quantum of supply and demand.
- It is driven by Government regulations on the emission trading scheme and support for low carbon hydrogen.
- There are many organisations looking to switch to hydrogen for heat and transport to meet decarbonisation targets. However, switching will involve capital costs and disruption which act as a barrier to adoption. Furthermore, risks around the availability and cost of low carbon hydrogen also discourage its adoption. Government intervention is required to encourage switching.
- There is very limited low carbon hydrogen production at present. There are only small amounts of green hydrogen being produced and no blue hydrogen. Projects are under development that will significantly increase blue and green hydrogen production.
- Blue and green hydrogen production is supported by Government backed business models. Currently there isn't any support for biohydrogen.
- Transport of hydrogen to end users is challenging. It can be transported by road, but this is expensive and requires many vehicle movements. Transport by pipeline is more cost effective but requires the consumer to be close to the point of production. Public hydrogen networks are under development but are unlikely to be widely available until the late

2020’s. This means that it is preferable for supply and demand to be in close proximity for an offtake to work.

- Overall, it is highly likely that there will be high levels of demand in future but currently it is difficult to find counterparties willing to enter into long term hydrogen off-take contracts. This is particularly true for biohydrogen because it is not supported by government business model.

Greenhouse Gas Removal Market

The key features of the GGR market are:

- It is immature with very high levels of uncertainty around pricing, supply, demand and regulation.
- It is driven by Government policy and corporate decarbonisation objectives. Governments recognise that they need GGRs to offset residual emissions and achieve net zero objectives. Corporates that are committed to decarbonising require GGRs for similar reasons.
- Currently, platforms such as Puro trade GGRs generated from afforestation, biochar or timber products. These offer sequestration of 10’s or 100’s of years and trade at around €30-€150/tonne. Companies such as Microsoft or Swiss Re will buy credits to offset their positive emissions. Long term geological storage with sequester carbon dioxide for 1,000’s of years and should trade at a significant premium to shorter term solutions.
- The UK Government is consulting on support for GGRs through contracts for difference or a guaranteed price. It intends to introduce a scheme in 2023 to help provide certainty to the market.
- The regulation of the market is currently carried out by voluntary bodies such as Puro, CDP or the Greenhouse Gas Protocol. There isn’t an agreed set of standards to give confidence to the market. Some companies will use unregulated negative emissions to claim they are low carbon, bringing the market into disrepute. There may be a role for Government to help set standards.
- Voluntary standards currently focus on land-based carbon sequestration but there is a growing awareness of engineered solutions.
- Companies such as Microsoft are willing to enter into long term offtake agreements to help develop the sector because they recognise its importance in delivering net zero.
- GGR trading is virtual and so does not suffer from the same delivery logistics issues as low carbon hydrogen.
- Overall, it is possible to secure offtake agreements and Government regulation appears to be heading in the right direction. However, there are high levels of uncertainty around the value of GGRs.

6.2 Intended scale and deployment locations

The RadGas solution is described in Section 2. For biohydrogen, the solution has the following features:

- Around 110ktpa of waste is accepted by the facility by road in moving floor trailers.

- It produces 313GWh of low carbon hydrogen that can be exported to a hydrogen grid or metered into tube trailers for road transport.
- It captures 147ktpa of carbon dioxide that can be injected into a transport and sequestration network.

The plant requires around 6 hectares of land and is designed to operate in a standard industrial setting. It requires access to power, gas and water infrastructure to meet its utility requirements.

The facility provides a solution to three separate problems:

- Environmentally friendly treatment of waste with no emissions to air.
- Production of a low carbon fuel.
- Capture of carbon dioxide to generate negative emissions through injection of carbon dioxide into a sequestration network.

It provides good solutions to all three challenges, but its key advantage is that it addresses all three at the same time in an integrated plant.

6.3 Commercialisation Plan

ABSL has begun the development of its first commercial plant, Protos Biofuels, in the Northwest. This facility, described below, will act as a template for future development.

The company's commercialisation plan is to act as developer, owner and operator of H_2BECCs plants in the UK and overseas. This will involve:

- Identifying sites and securing options on them to allow project development.
- Obtaining planning permission for the plants.
- Engaging a large engineering contractor to produce a detailed design of the facility.
- Agreeing long term off-takes for biohydrogen and GGRs.
- Securing utility supply agreements.
- Raising debt and equity financing for the plants.

ABSL is developing the skills to carry out these activities through the Protos project.

Protos Development

The Protos plant will convert 16.1 tonnes per hour of waste wood into 42MW of biomethane or biohydrogen, enough to heat 21,000 homes. The plant can produce a slipstream of transport grade biohydrogen and is capable of being converted to produce 100% biohydrogen as that market develops.

The status of the development is as follows:

- Petrofac have been appointed to carry out the engineering design of the facility. They expect to produce a price and delivery programme for the plant in June 2023. Sumitomo Heavy Industries have been selected to supply the gasifier and Wood Group have been selected to supply the hydrogen production, methanation and carbon capture technology.
- A site has been secured from Peel and draft agreements are in place for utility supplies. A route to the National Transmission System has been identified for export of gas and a route to the Hynet network has been identified for the export of carbon dioxide.

- Planning permission has been granted for the facility but requires refreshing because of changes to the design arising for the FEED. The new permission is expected to be granted in July 2023.
- Greenergy have agreed to purchase the green credits (dRTFCs) produced by the plant. Discussions are underway for the off-take of the biomethane and credits for carbon dioxide sequestration.
- ABSL is being advised on funding by Jefferies and JP Morgan and there is a short list of 40 interested organisations. A process to select funders will be run in the first half of 2023.

The plan is to reach financial close on the facility in December 2023. This would allow it to enter operation in June 2026.

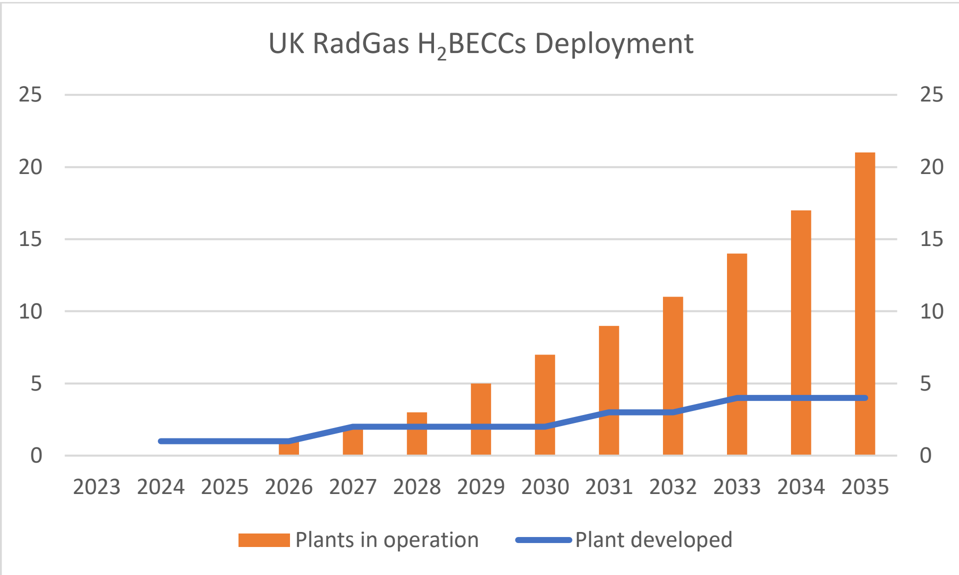
The Protos project is ready to be converted to biohydrogen production if BEIS develops a suitable business model.

6.4 Integration with H2BESS and Alignment with Net Zero

ABSL is forecasting that there will be 21 plants in operation by 2035. These would:

- Process 2.5 million tonnes of waste. Broadly equivalent to the amount currently exported from the UK to Europe for incineration and a small proportion of total UK waste arisings.
- Produce 6.6TWh of hydrogen, around 4% of expected 2035 demand.
- Capture and sequestrate 3 million tonnes of carbon dioxide, a significant proportion of UK Government target.

The growth plan is shown in the following chart.



The plants will produce low carbon hydrogen to replace fossil natural gas and will sequestrate carbon dioxide from the biomass fraction of the waste. This will make a significant contribution to targets for low carbon hydrogen, greenhouse gas removal and net zero.

7 Lifecycle Assessment

The Project carried out a detailed assessment of the greenhouse gas (GHG) emissions from the process. This was reported in Deliverable 5.1.

The waste feedstocks are made up of a biomass and fossil fraction. The proportions vary by waste type with further variations geographically and over time as consumer behaviour varies and waste treatment technologies evolve. Typically, residual household waste contains 60% biomass by energy while waste wood is 95% biomass. There are different GHG approaches for waste made from the biomass fraction and waste made from the fossil fraction.

Biohydrogen made from the biomass fraction has carbon intensity of $13gCO_2/MJ$, significantly lower than the $20gCO_2/MJ$ threshold set out in the low carbon hydrogen standard. This reduces to minus $116gCO_2/MJ$ if the biogenic carbon dioxide is captured.

The fossil fraction has a carbon intensity of $19gCO_2/MJ$, below the low carbon hydrogen threshold. This requires the fossil carbon dioxide to be captured. The hydrogen from the fossil fraction would not be low carbon If the carbon dioxide is not captured.

The largest contribution to the carbon intensity of the hydrogen is the electricity used in the process to prepare waste, clean up tars and compress gases. The carbon intensity of biohydrogen will reduce as the UK decarbonise its electricity grid. The emissions associated with the transport of the waste to the plant are the next largest contributor. For fossil gas, the uncaptured carbon dioxide emitted to atmosphere is around a quarter of the hydrogens carbon intensity.

The RadGas process is focussed on using waste materials such as refuse derived fuel or waste wood. The materials converted into hydrogen are unsuitable for recycling or reuse and are at the end of their life. This means that there are no negative effects from using them to produce fuels and that there aren’t any direct or indirect land use impacts.