Hydrogen BECCS Innovation Programme

Report

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1.0 Introduction

Biowise Limited (trading as Wastewise and owned by Urbaser Ltd) are an organic waste management service provider, processing some 200,000 tonnes per annum of garden, and mixed garden and food wastes through three composting sites in the North and East Yorkshire areas of England. Outputs of the composting process include a range of quality compost grades, and a 'compost over-size' (COS) fraction of which comprises biomass materials (such as twigs and sticks) which do not decompose easily during the composting process.

Biowise Limited are using the Hydrogen BECCs innovation funding to develop a project at their Willerby site that will process COS to produce a biogenic feedstock source for hydrogen gasifiers. Accessing stable, high value and sustainable outlets for the COS fraction is a challenge for the composting sector as the material is generally unsuitable for direct combustion in energy from waste applications. The present absence of established and stable high value fuel markets creates little incentive for compost site operators to invest in innovative processes to produce a higher quality fuel. This situation clearly overlooks the latent bioenergy opportunity that the material presents and provides the origin for this proposed innovation. The innovation will use sorting, grading and material handling techniques to produce a refined fuel that meets a hydrogen gasification feedstock specification. Therefore, not only does the proposed innovation provide a 100% biogenic feedstock source which can support hydrogen BECCS value chains, but it also provides an opportunity to elevate COS management within the waste hierarchy.

Phase I of the Hydrogen Bioenergy with Carbon Capture and Storage (BECCS) Innovation Programme requires a detailed technical description to be provided of the proposed Hydrogen BECCS innovation in order to provide confidence in the proposal. The overall project has a variety of stages in place in order to develop a project that will process COS to produce a full biogenic feedstock source for hydrogen gasifiers. To deliver the project, Biowise developed a staged approach which included the following, six distinct packages of work:

1. Determination of COS Fuel Specification
2. Outline COS Fuel Line Specification
3. Detailed COS Fuel Line Specification
4. Feasibility Modelling and Risk Assessment
5. Implementation and Commercialisation Plans
6. Project Report

Throughout the project, a series of assumptions have been made and these can be found in Appendix 1.

2.0 Determination of Common Fuel Specification

Defining the emerging fuel specification for hydrogen gasification technologies is an important element of the overall project. There are several biomass characteristics that significantly affect gasification performance so determining a fuel specification is essential in order to ensure that the fuel used in the hydrogen gasifiers is suitable and enables the gasification process to take place as efficiently as possible.

In order to successfully develop a biogenic feedstock source for hydrogen gasifiers using COS, a fuel specification is needed to ensure that the parameters or characteristics of the feedstock meet the requirements. As the hydrogen gasification industry is very much in its infancy and because a process has yet to be developed to use COS to produce a biogenic feedstock source, developing a common fuel specification for the purpose of this project has required significant amounts of primary and secondary research.

Firstly, developers and proponents of hydrogen gasification facilities were approached in order to gain an understanding of the feedstock parameters such as but not limited to, moisture content and physical form (e.g. particle size/pellet/chip). Several developers and proponents of hydrogen gasification systems were approached but as is discussed in more detail below, only a limited number of responses were obtained. A literature review was also carried out in order to further develop the common fuel specification and to gain an understanding of the parameters and characteristics of biomass feedstock that need to be considered in order to effectively use COS to produce a biogenic feedstock for hydrogen gasifiers. Finally, a review of existing biomass fuel and related standards was carried out to further contribute to the establishment of a common fuel specification.

All of the above has been viewed in the context of the laboratory analysis results of Biowise's COS material from sampling carried out previously and at the start of this project which demonstrated a hydrogen content of the COS material of approximately 5%. These results can be seen in Appendix 2.

2.1 Engagement with gasification operators

Developers and proponents of hydrogen gasification systems were approached in order to gain an understanding of the various feedstock parameters and characteristics that need to be met to ensure that the feedstock is appropriate for use in hydrogen gasifiers. WRM contacted seven companies in total and explained the project objectives and outlined the potential feedstock parameters that could be of interest based on background knowledge of gasification in order to develop the common fuel specification for COS to be used in hydrogen gasifiers. The parameters outlined in the correspondence sent by WRM included;

- Particle size (mm)
- Hydrogen content (%)
- Moisture content (%)
- Ash content (%)
- Sulphur concentration (%)
- Chlorine concentration (%)
- Heavy metals concentration (mg/kg)

WRM received positive responses from two of these companies from which discussion calls were undertaken and summarised below.

2.1.1 Wild Hydrogen Ltd

Wild Hydrogen are involved in the BEIS programme for gasification plants and have partnered up with another company called Helical. They currently have a lab gasification prototype which will convert organic waste into clear hydrogen whilst removing carbon from the atmosphere. Wild Hydrogen suggested that their gasification process would be able to take a wide range of wastes with a broad specification, however, they did go on to provide maximum thresholds for key parameters as follows:

Physical Parameter	Threshold	Chemical Parameter	Threshold
Particle size	<100mm	Sulphur content	<0.1%
Moisture content	10-60%	Chlorine content	<0.5%
Ash content	<5%	Hydrogen content	>5%

2.1.2 Powerhouse Energy Group PLC

A discussion also took place with a company called Powerhouse Energy Group PLC. They are seeking to deploy a thermal treatment process to produce hydrogen fuel via a rotary kiln gasifier. Again, their aim is that the process would be able to process a wide range of feedstocks with a broad specification. Specific thresholds for specific parameters were provided as follows:

Parameter	Threshold
Particle size	<80mm
Chlorine content	<2%

2.2 Literature Review of Hydrogen Fuel Specification

The first part of the review sought to understand why a fuel specification is important for a hydrogen gasification system. As stated by Materazzi et al.[1] in their article from July 2019, the key element for a consistent quantity of biohydrogen is the production of a high-quality syngas which is very rich in hydrogen and suitable for catalytic processing. They also state that ideally this syngas would be free of contaminants, such as sulphur and chlorine, tars, particulates, vapour phase metals and nitrogen. The presence of these contaminants could hinder the effective syngas utilisation downstream. As such, the cleaning from these problematic species down to values that are acceptable for different downstream catalysts are of crucial importance for successful implementation of particular biohydrogen applications.

Once it had been established why certain key parameters are of importance in the gasification process in terms of impurities in the syngas, the research then moved on to focus on the main biomass characteristics that affect gasification performance. In an article from July 2020 by Leichang Cao et al.[2], it is suggested that the four main characteristics of biomass that affect gasification performance are biomass type, particle size, water content and ash content. It is noted that high ash content will unfavourably increase the production of coke as well as the release of particulate matter that will need to be removed through downstream gas purification processes.

The particle size of the biomass is identified in numerous articles as being a key parameter of the feedstock fuel in a gasification system. The particle size can have an impact on the formation of undesirable char and tar. In their 2009 article, Kumar

[1] *Production of biohydrogen from gasification of waste fuels: Pilot plant results and deployment prospects* – Massimiliano Materazzi, Richard Taylor and Mike Cairns – Waste Management, Volume 94, 1 July 2019

[2] *Biorenewable hydrogen production through biomass gasification: A review and future prospects* – Leichang Cao et al. – Environmental Research, Volume 186, July 2020.

et al.[3] came state that low sulphur concentrations of <0.5% in clean biomass is low enough to keep the sulphur content in the syngas low enough to meet the needs of most applications.

Finally, the Advanced Gasification Technologies – Review and Benchmarking: Task report 2[4] produced on behalf of BEIS considers the factors that might affect gasification of different feedstock fuel types. For virgin wood, the main issues stated concerned the moisture content of the wood, the particle size, ash content, and chlorine, sodium, and potassium contents of the wood. The reason why chlorine, sodium and potassium are important is because they may cause increased corrosion and slagging, with high levels of sodium and potassium lowering ash melting points and potentially causing issues in fluidised bed-based systems. For waste wood, the same issues as virgin wood are likely to be a factor of concern in the gasification process. However, additional items of concern for waste wood are heavy metals such as zinc, lead and aluminium, nitrogen and chlorine from paint metal contamination.

2.3 Existing Standards

As discussed above, whilst detailed research has been conducted into hydrogen gasification providers, only a limited amount of information was provided which can be used to develop the specification. In the absence of sufficient detailed information being provided by gasification operators and attained through literature review, a variety of existing fuel standards for biomass have also been considered and used to inform the initial specification. These were Biomass wood fuel standards e.g. G50, PAS Standard and the EA's Biomass comparator report.

2.4 Common Fuel Specification

Based on the sources of information described above, a common COS fuel specification has been determined and can be seen in Appendix 3. They parameters included are particle size, moisture, ash, sulphur, chlorine, bromine, fluorine, hydrogen, aluminium, phosphorous and zinc.

3.0 COS Fuel Processing Line Specification Design

3.1 Outline Design

The COS fuel processing line was designed in two phases. Initially, an outline design was established. This process included a workshop involving Biowise, Walker Resource Management Limited (supporting consultants), hereon referred to as WRM and FBW Engineering Ltd (specialist engineering consultant), hereon referred to as FBW. The purpose of the workshop was to establish the outline items of technology required to achieve the designed COS fuel specification. This involved a detailed review of the analysis results from COS sampling already carried by Biowise, both prior to this project and at the start of this project, which identified the key parameters of concern. In the case of the COS material produced by Biowise at their Willerby site, the key parameters of concern are fines (ash), metals, stones and chlorine containing plastics. On the back of this and using Biowise and FBW's

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[3] *Thermochemical Biomass Gasification: A Review of the Current Status of the Technology* – Ajay Kumar, David Jones and Milford A Hanna – Energies, 2009.

[4] Advanced Gasification Technologies – Review and Benchmarking: Review of current status of advanced gasification technologies – Task 2 report – prepared for BEIS by AECOM & Fichtner Consulting Engineers, October 2021.

experience of waste treatment technologies, an outline design for the processing line was constructed. This can be seen as a process flow diagram in Appendix 4 below. The key processing technologies identified and their order are as follows:

1. Trommel (fines removal)
2. Overband Magnet (ferrous metal removal)
3. Eddy Current Separator (non-ferrous metal removal)
4. Air/ballistic Separator (removal of heavies)
5. NIR Separator (plastics removal)

The COS material requires processing via a variety of sorting, grading and material handling techniques, arranged in a unique, novel way to produce a new fuel that will meet the required fuel specification to be used in innovative gasification technologies. Each technique selected plays a specific role in the treatment to produce a fuel of the required quality. The trommel was selected to remove fines from the fuel as it is in these fines that undesired ash is present. Only the larger material that goes through the trommel passes through to the next stage. It is important that the trommel is located at the start of the line as this is where the largest mass of undesired material is removed. In doing this at the start, it is easier for the subsequent items of technology to perform at their optimum. The metals are then removed from the remaining COS by magnets and eddy current separators before stones and some plastics are removed by the ballistic separator. Finally, any remaining plastics are removed by the NIR Separator. This is located at the end of the line to improve its performance as many other undesirable materials will have been removed already.

3.2 Detailed Design

This outline design for the COS fuel processing line was developed into a detailed design, in order to fully establish the engineering and equipment requirements needed to process COS into a biogenic feedstock source for hydrogen gasifiers. For this detailed COS fuel line specification, individual items of proven plant and equipment have been configured as per the outline design and integrated to produce an innovative processing line which has the capability to generate outputs in line with the market fuel specification. Technology suppliers were engaged with to clearly identify specific items of equipment required for the COS fuel line specification. They were also requested to deliver all aspects of the treatment line. The technology suppliers need to have the capability to deliver a turnkey project for design, installation, testing and commissioning of the process equipment. Research and consideration of the additional balance of plant requirements for the COS fuel processing specification also took place.

The aim of contacting the suppliers was to test the market, understand the products available, their price, footprint and build schedule, before choosing a preferred bidder. Three technology suppliers were engaged with: Turmec UK (Turmec), OKAY Engineering Services Ltd (OKAY Engineering) and Eggersmann Anlagenbau UK Ltd (Eggersmann).

Turmec were chosen as the preferred technology supplier due to the greater level of interest shown, their willingness to engage in the project and the promptness of their responses to questions. They also supplied the required information in advance of the deadline imposed. Turmec has nearly 50 years of experience in the recycling industry. Originally specialising in general engineering, the company has evolved to design, manufacture and install market-leading, cost-effective, and high-quality facilities for customers in the recycling industry across varying streams including dry mixed recyclables; RDF/SRF fuel preparation; glass; compost; plastics and fines treatment. Turmec is OHSAS 18001, ISO 14001, ISO 9001, and OHSAS 45001 accredited, along with several other industry accreditations including EN1090. Turmec also offer complete solutions including design, manufacture, installation and servicing.

3.2.1 Design Parameters

Biowise receive approximately 90,000 tonnes of waste at their Willerby site each year. During the composting process the waste loses approximately 45% of its mass in the form of moisture loss, which equates to 38,700 tonnes. Of the remaining mass of material, approximately 20,880 tonnes of 0-10mm grade PAS 100 compost is produced and approximately 13,620 tonnes of 0-25mm grade PAS 100 compost is produced. Approximately 1,800 tonnes of non-compostable waste is removed from the waste during the screening process, resulting in approximately 15,000 tonnes of compost oversize remaining at the end of composting process.

The items of equipment that have been selected below have been sized to be able to process the full 15,000 tonnes per year. It is anticipated that the plant shall operate for 6 hours per day, allowing sufficient time (2 hours) for cleaning and routine maintenance. This equates to a plant throughput of nearly 10 tonnes per hour.

A full-scale demonstration plant is required for this process and as part of Phase II. A small-scale pilot demonstration plan is not applicable for this project. The items of equipment selected below are generally the smallest available on the market. A throughput of 15,000 tonnes per annum is considered very low for similar pieces of equipment in the wider waste treatment industry with throughputs upwards of 50,000 tonnes per annum and 50 tonnes per hour not uncommon.

3.3 Key Process Equipment Selection

The following sections detail the process equipment selected as part of the fuel processing line which will enable a suitable fuel for feedstock to a hydrogen gasification plant to be produced. The proposed plant layout can be seen in Appendix 5 with the Piping and Instrumentation Diagram shown in Appendix 6.

3.3.1 Feeder and Hopper

The Independent Feeder is installed to allow for the plant to feed COS material into the process line. The material is fed into the hopper and is transferred via the Independent Feeder Conveyor. The feeder's main function is to control the feed of material through the plant.

3.3.2 Trommel

The COS is screened by the trommel screen to remove material <25mm. The <25mm material falls through the mesh screen and into the concrete bay below for storage prior to onward use. This material would be released into the agricultural market as a PAS 100 product. The proposed 3 Series Trommel is 2.2m in diameter and 9m in length. The Trommel drum itself will be fully sealed.

3.3.3 Vibrating Feeder, Drum Magnet and Eddy Current Separator

The 25-80mm COS material is then passed via a vibrating feeder over an IFE INP Drum Magnet and Eddy Current Separator (ECS) to remove ferrous and non-ferrous metals. The ferrous and non-ferrous metals are discharged directly to storage bays located beneath the process equipment. Drum magnets and drum separators are self-cleaning, allowing for continuous removal of ferrous contaminants from a wide range of free-flowing bulk and granular materials in high-volume applications.

3.3.4 Overband Magnet

The overband separators are used to separate ferrous impurities from any kind of bulk material. In this instance a MPQ 900 F Overband Magnet will be used to recover magnetic particles from the COS material and will be utilised to protect downstream equipment from metallic tramp particles. It will improve the quality of the material being sent to the hydrogen gasifier as fuel, as well as capturing a material stream that may be of sufficient quality to be sent for onward recycling.

3.3.5 Single Drum Air Separator

Due to the tangling nature of the 25-80mm COS material, a NIHOT SDi 800 Single Drum Air Separator has been selected to allow light materials such as plastics and COS to pass forward for further treatment, with the removal of heavies, such as stones, from the process. The Single Drum Separator is a high volume, high-capacity system. The separation takes place with the heavy materials falling down into the residue bay before the rotating splitter drum and against the air flow. The light materials are aspirated and conveyed into the expansion room. The remaining COS material is passed to the optical sorter to remove plastics.

3.3.6 Optical Sorter

An Optical Sorter uses Near Infra-Red (NIR) technology to detect different types of material. Once the material has been detected, the optical sorter uses jets of compressed air to eject the selected products at high speed. The optical separators have a number of parameters that can be adjusted to achieve a ‘positive pick’ on the materials not desired to be in the required output fraction that will be sent to gasification. Each machine can either increase or decrease the number of materials it ejects.

It is proposed to utilise Pellenc Mistral + NIR sorters to remove plastics and also any remaining metals from the compost. The Mistral+ is a multi-material sorting machine and highly versatile to meet the requirements of the recycling industry. The Optical Sorter will also be equipped with a metal detector to detect and eject all metals which may have been missed by the Overband Magnet and ECS.

3.4 Ancillary Services Selection

Aside from the core processing machinery, the facility will also require ancillary services to ensure it presents a safe working environment for its operators and controls any potential emissions protecting the environment. These can be summarised as follows:

3.4.1 Air Handling and Extraction

It is intended to house the COS fuel treatment line in a dedicated new building. This will help to control the emissions of noise, odour and dust from the fuel treatment line. In order to control the environment within the building, high level air extract ductwork will be installed within the roof space of the building. Extract fans will facilitate a number of full building air changes per hour and will route any odorous air to the existing scrubber and biofilter which serve the existing in-vessel composting (IVC) facility.

3.4.2 Building Services

The new process building will also accommodate a building services system consisting of high-level lighting, emergency lighting and small power outlets to allow adequate servicing and maintenance of plant. A fire detection system will also be installed. A single line diagram has been produced for the fuel preparation Motor Control centre and the associated building services. An electrical distribution diagram for this can be seen in Appendix 7 below. A proposed building layout can also be seen in Appendix 8 below.

3.4.3 Building Location

It is proposed that the building in which the fuel treatment line would be housed is located immediately northwest of the existing IVC facility at Willerby. This land is an old railway line and Biowise own the stretch of land the extends beyond the IVC building by approximately 300m up to an old railway bridge. Planning permission that has since expired has previously been granted for a waste processing building on this site. The embankment on the western side of the old railway line would be cut into to provide the space for the new building whilst still leaving space on the eastern side for vehicle movements. The proposed building is 72m long, by 24m wide, by 12.25m high with access doors for vehicles at the northern and southern ends. The location of the proposed building can be seen in Appendix 9.

4.0 Environmental Benefit

This section provides details of carbon emissions associated with the treatment of the COS material, as well as the carbon benefits that are derived from the manufacture of the recycled COS material for use in hydrogen gasification.

4.1 Scope of Carbon Assessment

This report seeks to broadly quantify the carbon position of the COS fuel treatment line at Biowise.

Noting the above carbon assessment considerations, the evaluation of the COS fuel treatment line has been limited to the following aspects:

- Carbon emissions associated with the treatment of the COS material;
- The material and carbon emissions saved due to the material being used as hydrogen fuel, rather than being disposed of;
- The environmental and carbon benefits that are associated with producing a recycled hydrogen fuel from the COS material.

In applying this approach considering three distinct phases, it is recognised that the above list of factors is not exhaustive, although this list does cover the factors with the greatest sensitivity on the evaluation and comparison of options. As such the outputs from the modelling performed in this study should be viewed as a carbon assessment and not a carbon footprint which implies a full and detailed quantification of carbon in line with a recognised methodology.

4.1 Materials and Emissions Saved

The process of using COS material to produce a biogenic feedstock source for hydrogen gasifiers provides a significant opportunity to reduce the need for forms of disposal of waste, such as at landfill sites. Therefore, it is estimated that a significant amount of material and carbon emissions will be saved due to the COS material being used as hydrogen fuel, rather than being disposed of via landfill. This is primarily because the proposed valorisation of the COS material will improve the carbon performance of the material management in a variety of ways.

Accessing stable, high value outlets for the COS material is a challenge for both Biowise and the wider composting sector. Currently, some 30% of COS is presently disposed to landfill. The disposal of this material into landfill creates significant amounts of methane emissions and therefore, by using the COS material as a fuel for hydrogen gasification, these methane emissions shall be avoided. For means of comparison, greenhouse gases such as methane are converted into CO_2 equivalents. The table below presents the potential emissions factors for the gasification of the COS material compared with landfill.

Table 1 - Emissions Factors

Waste type	Gasification	Landfill
	kg CO2e/ tonne	kg CO2e/ tonne
Compost Oversize	21.280	587.326

Additionally, the hydrogen strategy identifies biomass as one of five energy inputs into the hydrogen economy and it is noted that Biomass along with ‘renewables’ perhaps provide low carbon energy inputs which support the UK’s net zero target delivery. The biomass derived from the COS material at Biowise also presents additional carbon reduction opportunities such as improvements in the thermal conversion efficiency compared to some mass burn incineration techniques.

The process of producing a hydrogen gasification fuel from COS material in itself does not provide direct capture of carbon. However, the feedstock is 100% biogenic and when used as a fuel for hydrogen gasification, carbon capture and storage can occur on the back of the gasification/pyrolysis and syngas processing phases. Moreover, the use of the COS material as a fuel source supports the Hydrogen BECCs value chain by providing a wholly biogenic source of feedstock from which hydrogen can be produced (with associated carbon capture). Furthermore, as a material stream which arises from the treatment of household waste collections, COS provides a biogenic feedstock opportunity without the requirement for cultivation of energy crops and the associate land use change impacts.

4.3 Environmental and Carbon Benefits

One of the main environmental benefits of using COS material as a fuel for hydrogen gasifiers is the opportunity to improve the level of the waste hierarchy at which COS is managed. The COS fraction presently has limited market appeal with compost site operators presently partially sending the material to landfill. Alternative options for end market application include treatment into producing a fuel known as 'Black Biomass' for combustion in non-WID biomass plants with varying levels of thermal efficiency and utilisation. This requires the separation of contaminants from COS, which can be associated with costs that could be higher than the market price of further treated COS that achieves a fuel specification.

Analysis by BEIS for the sixth carbon budget suggests that some 250-460TWh of hydrogen could be required in the UK by 2050, making up 20-35% of the UK's final energy consumption. There are several factors that shall determine the size of the hydrogen economy in 2050 in the UK, such as the cost and availability of hydrogen, relative to alternatives. The analysis conducted by BEIS identifies that biomass inputs in the hydrogen economy will be an important factor in the stability and size of future hydrogen supply chains. The default bioenergy feedstock for emerging gasification technologies is presently wood pellets or chips. The COS material presents a more-environmentally friendly and recycled fuel source for hydrogen gasification than virgin wood pellets/chips, reducing the impact on the environment.

Another important environmental benefit of using COS material as a fuel source for hydrogen gasification is that the COS material is being sourced from an established and stable segment of the waste management sector in the UK. The COS material provides a fuel source for hydrogen gasifier without the requirement for land-take for the cultivation of bioenergy feedstock. Therefore, the use of COS material as a fuel for hydrogen gasification avoids potential environmental concerns around indirect land use change and ecological impacts which are often associated with bioenergy fuel production.

5.0 Financial Feasibility Assessment

5.1 Financial Model

A mass balance and financial model has been produced for the detailed COS fuel processing line. It considers all of the costs associated with Site Development Capital Expenditure, the COS Processing Line Capital Expenditure, the overall facility Operational Expenditure and then any revenues associated with the processing line.

The main aspects of Site Development Capital Expenditure are as follows:

- Planning consent
- Project Management
- Building construction
- Air treatment system upgrade
- Land clearance / cutting
- Detailed M&E and Civils
- Principal Contractor fees

Identified Facility Operational Expenditure include, but is not limited to:

- Electricity
- Equipment maintenance and repair costs
- Costs to remove separated materials from site
- Business rates
- Insurance

Revenues for the site will consider a gate fee to process the COS material (£42.04 per tonne), sales of the non-ferrous metals separated by the COS fuel processing line (£400 per tonne) and sales of the COS fuel itself (£85 per tonne). All of these prices are based on Biowise's experience and current market rates.

The detailed financial model can be seen in Appendix 10. It demonstrates that over a 10-year financing period, the COS fuel processing line is a financially viable project.

5.2 Risk Assessment

An investment risk assessment for the development of the COS processing line at Biowise's Willerby site has been carried out. The assessment has been completed following a due diligence review of:

- Information provided by FBW Engineering Limited; and,
- Information provided by Turmec in their capacity as equipment supplier.

This risk assessment can be seen in Appendix 11.

6.0 Implementation Plan

The purpose of the Implementation Plan is to provide the framework for progressing the COS fuel processing line from techno-economic feasibility to development and commissioning of a full-scale plant. The full Implementation Plan including an implementation risk assessment can be seen in the accompanying large project report (Biowise_BEIS_Full_Report). However, this section covers the key points.

6.1 Scope of Works for Phase II

The first task of the implementation plan was to identify the scope of works required to install the COS fuel processing line for the delivery of Phase II of the BECCS project. The key aspects are as follows. A Gantt Chart setting out the expected delivery timescales for the Implementation Plan can be seen in Appendix 12.

6.1.1 Project Management

The Phase II project will be managed by Biowise, whilst ultimately controlled by Urbaser Ltd, the owners of Biowise. Biowise will employ a Principal Contractor who will oversee the civil engineering and construction work and the installation of the fuel processing line and will also be responsible for health and safety during civils and installation. The Principal Contractor will also be involved in the commissioning, performance testing and maintenance of the processing line. An Independent Certifier shall also be employed to provide specialist advice, monitor compliance with design, specification and statutory standards and ensure all project requirements are met.

6.1.2 Progress Reports

A project update report shall be produced every six months throughout the duration of the implementation of the COS fuel processing line detailing progress made. The first of these shall be produced in August 2023 with the final being produced in March 2025. The final report shall detail the success of the project programme and the implementation of the COS fuel processing line at Willerby.

6.1.3 Planning Permission

Biowise currently operate their composting facility at Willerby under planning reference numbers 09/04909/STPLF, 15/03404/STPLF, 16/03310/CM and 09/00417/STPLF. As indicated elsewhere, Biowise have previously had full planning permission for an additional building to clean up Grade C wood for a biomass facility due to be built in Hull but never was, to be constructed north of the IVC building but this was never acted upon and the permission has since lapsed. Therefore, the first task required for the delivery of Phase II is the submission of an application for planning permission for the construction of a new building to house the fuel processing line. This application will be submitted to the East Riding of Yorkshire Local Authority.

6.1.4 Site Clearance / Preparation

To begin the construction phase, the site will be required to be cleared and prepared to achieve the required levels for the concrete foundations and working concrete services.

Any topsoil removed of the working areas will be stored for use in the later landscaping works at the end of the build phase. Where cuts are required into the underlying subsoil to achieve flat area, this removed material will either be used for any required landscaping of the area or blended on site under the environmental permit.

Due to an area of the site having already been recently developed in the construction of an in-vessel composting unit, the ground conditions are well known. It is not anticipated there are any unknown subterranean services of features that will hold up the site stripping and build programme.

Power and water services already exist at the site, and calculations have indicated that the electrical distribution board at the site possesses sufficient capacity to provide the proposed load for the COS fuel processing line. Enabling works will include the digging of necessary trenches required for incoming power and water. These will ultimately serve the plant but are also necessary to provide power and water to the necessary welfare units required for the teams during the construction phase.

Drainage requirements for grey, surface or road water systems will also be dug, and necessary underground pipework installed. All underground water services shall be tested through the application of a leak test, and this process made available to the Independent Certifier. At the end of Practical Completion, evidence that underground draining piping is clear from debris shall be provided though CCTV inspection of the line.

6.1.5 Place Equipment Order

The next stage of the process is to place the order for the fuel processing line with the chosen equipment supplier. However, prior to doing this, risks associated with the equipment that have been highlighted in the Feasibility Risk Assessment phase need to be addressed. For the purposes of the project the equipment supplier shall be considered the Principal Designer, who is responsible for the delivery of the plant in terms its adherence to the Machinery Directive and relevant guidance that must be included in the plant.

Performance guarantees shall also be established and agreed prior to purchasing the equipment. A fuel specification has been established as part of the Phase I work and a mass balance model has also been produced which is based on process details supplied by Turmec. However, performance guarantees shall be established with the technology supplier prior to ordering to ensure both Biowise and supplier are clear on the performance requirements. This includes an allowance to refine further the mass balance, equipment specifications and capacities with the technology supplier.

Once all of the above has been carried out and should Biowise be satisfied with the outcome of the mitigation measures then the equipment associated with the fuel processing line shall be ordered. At this point, the expected delivery dates shall be established which will provide Biowise with added clarity on when the subsequent work stages need to be completed by.

6.1.6 Civils Works

Any necessary foundations will be dug to support the building. In the detailed design stage for the processing equipment, calculations will also be undertaken to establish whether any individual assets in the processing line require its own foundations or whether the thickness of the working area concrete pad is sufficient. This concrete will be subjected to Certified Quality Auditing (CQA) testing to ensure the concrete used is of sufficient quality to bear the designed loads required.

Following the casting of the necessary foundations the concrete pad will be cast that will ultimately serve as the roadways and covered working area for the processing plant. Concrete cast during this stage will also be subjected to CQA testing. The thickness of the concrete will be established at the detailed design phase, however it is anticipated that this thickness will be similar to that used in the recent In-vessel composting construction due to the similar ground conditions.

6.1.7 Building Construction

The steel portal frame for the building will initially be erected on a series of pads and bolt boxes/ The concrete slab will then be poured afterwards. This activity will involve the Principal Contractor and a specialist steel portal frame installation company. Together they will establish a safe system of work surrounding a lifting plan, whilst at the same time addressing the necessary safety requirements needed for teams working at height. The base plate and columns will be lifted and secured into place, followed by the rafters and purlins that will hold the steel cladding.

The roof surface shall consist of a number of clear or skylight sheets that will aid visibility within the building during daylight hours. The roof shall also house mounted solar panels to provide renewable electricity to the site.

6.1.8 Equipment Installation

In conjunction with each of the process asset suppliers, a delivery schedule will be determined during the detailed design phase to ensure each of the required assets arrive in a sequence whereby they can be lifted into place.

On completion of the installation of assets, the necessary access gantries will be installed alongside the guarding required by the Machinery Directive and relevant guidance.

Practical Completion will be said to have been reached when:

- CQA testing for all concrete pours has been received and demonstrated to have passed.
- The building is complete and able to be properly secured.
- A building control certificate has been received by Biowise.
- Fire safety certification has been achieved.
- Electrical test certificates have been received by Biowise.
- The roadways and working surfaces have been completed and passed their CQA tests.
- The ancillary building services such as building and emergency lighting have been installed and tested.
- The individual assets of the processing line have been positioned and secured,
- The linking conveyors have been positioned and secured.
- Grey, surface and road water drainage systems are connected, have been leak tested and evidence given that the drainage lines are clear and free from debris.

  An up to date set of as built drawings together with drawings of drainage and building services has been provided to Biowise.

6.1.9 Commissioning

The commissioning team will be the core members of the project, installing contractor, supporting consultant and Client as well as the support resources.

Commissioning documentation will be defined and prepared in advance of the commissioning phase. This will include the test plans and test procedures that will be specific to each asset that will be executed during commissioning, and checklists required, as well as drawings. The construction team will deliver an accurate set of drawings to the commissioning team in order that the correct installed configuration of equipment in the field is accurately documented.

As construction is completed and equipment installation is complete, the construction and commissioning teams will perform a weekly walkthrough, or more frequently if required, to identify any deviations or deficiencies and list all items on a deficiency tracking list.

Mechanical completion will occur at the end of the construction phase, once the individual assets of the processing line are installed. There will be a formal handover process confirming that the equipment is installed per the design. The construction, commissioning and Biowise Operation Team will perform a walkthrough together to inspect the installation and confirm there are no deficiencies. Should deficiencies be discovered they will be recorded as a defect against three different categories: A-Type, B-Type and C-Type, spanning from major to minor.

Following completion of pre-commissioning checklists, dry commissioning will begin.

Dry commissioning confirms proper function of mechanical systems without process inputs, while wet commissioning adds the process inputs confirm operation. Electrical commissioning consists first of pre-energization safety. Initially each item of equipment will be energised in isolation, with the surrounding assets being electrically isolated.

At the wet commissioning stage, the plant begins to receive the COS feedstock and the separation processes can be tested. Mechanical processes are slowly started and configured for the initial operating scenarios. The flow of material through the plant are monitored and measured against the design parameters to ensure correct operation. During this process electrical interfaces are verified, and the speed of the processing line is slowly ramped up to operating levels.

6.2 Performance Testing

In order to ensure that the facility meets its desired performance level and passes its performance guarantee stage, the capture of samples for testing will be undertaken. The input feedstock demonstrates large heterogeneity owing to the input particle size of the media ranging from 0.1-80mm, with the core fraction ranging from 25 to 80mm. The strategy for obtaining a representative sample will be undertaken through those methods specified in the PAS100 standard, the origin of this approach being based on BS EN 15442:2011 Solid Recovered Fuels – Methods for Sampling. One 25 litre sample (or two in the case of the plastic material) will be taken per day from the following materials:

- Feedstock material
- Trommeled material
- Ferrous material
- Non-ferrous material
- Heavy material
- Plastic material
- COS fuel

Presently the proposed Performance Guarantees tested through the performance testing period are as follows, although this is subject to change following the further engagement with the technology supplier prior to placing the order for the equipment:

Table 2 - Current Plant Throughput Performance Guarantees

Parameter	Design Mass Balance	Tested via:
Daily input tonnage	58 tonnes	On site mass balance, verification through weighing daily input tonnage over weighbridge.
Processing rate	9.7 tonnes per hour	When the plant runs continuously for 6 hours. Captured by IC and also verified by run time hours on the MCC HDMI.
Weekly input tonnage	290 tonnes	On site mass balance, verification through addition of daily processed weights captured over the weighbridge.

Process and performance guarantees within waste streams are notoriously difficult to establish due to the large particle size and heterogeneity of the material stream. A design mass balance to model separation of the wastes based on known input has been calculated, although again this is subject to change following the further engagement with the technology supplier prior to placing the order for the equipment.

Based on the current design mass balance the following Performance Guarantees shall be applied. Further details on how these are tested can be seen in Appendix 13.

Table 3 - Current Plant Performance Guarantees

Parameter	Design Mass Balance	Mass Balance Guarantee
Input material	100% at <80mm	N/A
Fines	27%	>27%
Ferrous	0.09%	>0.09%
Non-Ferrous	0.09%	>0.09%
Stones	7.2%	>7.2%
Plastic	0.9%	>0.9%
Fuel	64%	>64%

It should be noted that the sole reason for the processing line is to achieve a product that is suitable for onward gasification, therefore the greater the contamination removal the cleaner the product. Therefore, the Performance Guarantee looks at the design mass balance as being the minimum performance of separation required, with any increase in this performance directly impacting on the quality of the output fuel. The details of the Performance Guarantee will be confirmed prior to placing the equipment order.

6.3 Sampling Procedure

All sampling operations shall be carried out over a sufficiently short period of time and in such a way as to avoid any alteration in the characteristics of the product or the samples. During sampling all samples shall be stored in a manner that maintains their characteristics.

Representative samples shall be taken by taking seven incremental samples of the material, each of at least 25 litres. These shall be taken from the feedstock material or from the pile that has formed at the discharge point of the product being sampled. The incremental samples from each lot shall be combined to form a combined sample, which in turn shall be reduced in size by coning or quartering to produce a final analysis sample and a final storage sample, each of at least 25 litres and placed in separate container(s) suitable for transport to the laboratory.

6.4 Roles and Responsibilities

A clear structure has been established which sets out the hierarchy which would be present in Phase II and the roles and responsibilities of each organisation within this structure. A number of organisations would be involved in the delivery of Phase II as set out in Appendix 14. The organisations involved in the implementation of the processing line and their key responsibilities include:

- BEIS – owners of the Hydrogen BECCS Innovation Programme.
- Urbaser – owner of Biowise and thus they will ultimately control the project.
- Biowise – owner and operator of Willerby site.
- Consultant – additional external consultancy support.
- Principal Contractor – overseeing the civil engineering and construction work and the installation of the fuel processing line.
- Technology Supplier / Principal Designer – ensure that the equipment is designed to current safety design and environmental standards as designated by the WISH guidance and responsible for the installation, commissioning and performance testing.
- Independent Certifier – provide specialist advice, monitor compliance with design, specification and statutory standards and ensure all project requirements are met.

7.0 Commercialisation Plan

The detailed financial model has determined that the development and installation of the COS fuel production line at Biowise's Willerby site, processing the compost oversize produced by the composting activities that take place on that site, is a financially feasible project beyond Phase II.

This model sets out the defined routes for the materials separated by the COS fuel processing line. Clearly, the COS fuel market is the most important for this project, however, the production of this fuel is based on the separation and removal of undesired material in the compost oversize. Each of these materials has its own potential market, some of which will have an associated revenue.

The first category of material to be separated from the COS fuel stream is the PAS 100 0-25mm fines. These are removed from the fuel stream by a trommel screen at the front of the processing line. It is expected that approximately 4,050 tonnes of this material will be removed from the input feedstock each year. The main existing market option for this material is for it to enter the agricultural market as a PAS 100 product. Biowise would look to allow this to leave the site free of charge if collected from site by the customer.

Once the COS material has passed through the trommel screen, the ferrous and non-ferrous metals are removed from the material stream via an eddy current separator, overband magnet and a drum separator. Both of these types of metal will be sent off site for onward recycling. Due to the likely levels of dust etc expected in the collected ferrous metal and based on the current market, Biowise expect to send this off site free of charge. The non-ferrous metal would be sold at a cost of £400 per tonne based on current market rates. As such, this would bring in a revenue of £5,200 per year.

Following this, the heavies in the COS material stream are removed via ballistic separation. Current expectations are that this material would be removed from site for use in soil manufacture at a cost to Biowise of £16.50 per tonne. As such, the annual cost of this to Biowise would be £17,820 based on 1,020 tonnes being removed from the COS stream each year.

Finally, the plastics will be removed from the material stream by an optical sorter. Based on the performance guarantee of the plant, it is expected that 135 tonnes of plastics will be removed from the material stream per year and sent off site at an annual cost to Biowise of £18,900. The plastics will be removed from site for onward recycling or for use as RDF/SRF.

As is demonstrated above, there are existing markets available for all of the waste material removed from the COS material stream, some which will cost Biowise to remove on site and some which will be a revenue to Biowise. Currently, it costs Biowise approximately £55 per tonne to remove the compost oversize for use in Energy from Waste facilities. This equates to an annual cost of approximately £825,000. If the costs and revenues associated with the separated waste materials (excluding the final COS fuel) are applied, the annual cost to remove these from the site is £92,270.

It is expected that 9,708 tonnes of the COS fuel will be produced annually from the COS fuel processing line. The hydrogen gasification market is still in its infancy and as such, the market rate of the fuel that will feed the gasification plants is unknown. In the detailed financial model, it has been assumed that the COS fuel will be sold into the hydrogen gasification market at £85 per tonne. This figure was determined following initial discussions with gasification operators and an assessment of the cost of virgin wood fuel. The £85 per tonne figure is less than the market rate for virgin wood fuel which reflects the obvious fact that the COS fuel is not a virgin material and will contain some contaminants which will be detrimental to the gasification systems. It is therefore considered that the price assumed in the financial model is a reasonable one.

During the implementation of Phase II, Biowise will engage with hydrogen gasification operators across the country. The purpose of this shall be to agree the tonnage and price of the COS fuel with each operator. This will result in an agreement in principle for COS fuel to be supplied to a gasification operator once the implementation plan and process validation are complete and the fuel is demonstrated to be at the required quality. Once this has been done and Biowise have left BEIS's Hydrogen BECCS project, Biowise will be free to sell the COS fuel into the market as per the agreements with the hydrogen gasification operators.

7.1 Future opportunities to commercialise COS fuel processing line in England

Accessing stable, high value and sustainable outlets for the COS fraction is a challenge for the composting sector as the material is generally unsuitable for direct combustion in energy from waste applications. The present absence of established and stable high value fuel markets creates little incentive for compost site operators to invest in innovative processes to produce a higher quality fuel. Should the performance guarantees of the COS fuel processing line at Willerby be met and should the COS fuel meet the required quality for use as a fuel in hydrogen, then there will be a great opportunity to deploy the process technology across other composting sites and capitalise upon the full opportunity that COS offers as a 100% biogenic feedstock for hydrogen production.

According to the Environment Agency's Waste Data Interrogator tool, which details the waste received at permitted sites, approximately 4.7 million tonnes of non-hazardous household/industrial/commercial waste was received at sites across England for composting in 2021. According to Biowise statistics, approximately 16.3% of the waste received is removed from site as compost oversize. This figure could be applied to all waste received for composting across England to produce a total compost oversize figure of approximately 769,000 tonnes. To this figure, the expected COS fuel recovery rate of the fuel processing line at Biowise of 64.7% can be applied to calculate a predicted potential COS fuel availability across England of approximately 500,000 tonnes. According to research carried out by Mustafa, Calay and Mustafa[5] at the Arctic University of Norway, approximately 0.03 tonnes of bio-hydrogen is produced from 1 tonne of biomass. This would equate to approximately 14,900 tonnes of bio-hydrogen being produced from the COS fuel that could be recovered from composting facilities in England. Even if a 20% reduction in bio-hydrogen production was factored into account for the fact that the COS fuel is not a clean biomass fuel, this would still equate to approximately 12,000 tonnes of bio-hydrogen being supplied to the hydrogen fuel chain if all the compost oversize in England was processed in this way.

It currently costs approximately £150/tonne (includes gate fee, tax and delivery) to dispose COS material in landfill. Therefore, across the industry it could be estimated that it costs up to £34,605,000 per year to dispose of the COS material in this way based on 30% of COS material being disposed of via landfill. By processing the COS material to produce a fuel, selling it into the market and disposing of the separated materials in the ways and costs described in Section 7.0, it can be estimated that this would result in a revenue of approximately £12,000,000. This means the net increase in revenue to the sector of processing the COS material to produce a fuel would be approximately £46,605,000 per year.

The COS fuel processing line that would be developed at Willerby would be able to process approximately 15,000 tonnes of compost oversize each year. However, the specific items of equipment chosen for this line are generally the smallest models available for that technology in terms of throughput. Therefore, it is conceivable that the processing line technology could be uprated when installed at other sites by choosing larger models of each equipment type. Following discussions with the technology supplier it has been determined that the maximum throughput of the designed line would be 15 tonnes per hour. The pinch point would be the optical sorter. Based on the predicted operating hours at Willerby of 6 hours a day, 5 days a week, this would equate to 23,400 tonnes per year. Based on this, 34 COS fuel processing lines would need to be installed across the country to process all of the COS material produced in England. This can be viewed in the context of there being 176 composting operators in England.

[5] *A Techno-Economic Study of a Biomass Gasification Plant for the Production of Transport Biofuel for Small Communities* – Albara Mustafa, Rajinish Kaur Calay & Mohamad Y. Mustafa – Sustainable Solutions for Energy and Environment, EENVIRO 2016, 26-28 October 2016.

8.0 Conclusions

The sections above, detail the processes that were followed to deliver a comprehensive and robust Phase I project. The fact that the hydrogen fuel market is in its infancy meant that a brand-new COS fuel specification had to be established, largely via engagement with potential hydrogen gasification operators and literature review. This specification was then carried through the remainder of the project.

The real source of innovation on this project lies with the specific layout of the individual items of technology in the proposed COS fuel processing line and the proposed use of the end material. Whilst the individual items of selected technology are currently well-established items in the waste industry, the combination and proposed layout is unique, as is the end use of the “clean” compost oversize as a fuel in hydrogen gasification plants. The proposed processing line combines trommels, magnets, eddy current separators, air separators and near infra-red separators to remove ash, metals, heavies and plastics from the COS material.

The environmental benefits of this processing line are clear to see. The separation of the COS material into its constituent parts would enable greater levels of recycling and a significant reduction in the amount of material going to landfill or being burnt in energy from waste facilities. Compost oversize is a significant problem in the composting industry and the current market position for compost oversize is that without any further processing or treatment, the material is sent to landfill.

The detailed financial assessment of the COS fuel processing line that has been carried out demonstrates that the project is financially feasible beyond Phase II at Biowise’s Willerby site. This is based on detailed costs for the technology, current exchange rates and current market rates for things such as gate fees and construction costs to name a few.

A detailed implementation plan has been produced which details the framework for progressing from techno-economic feasibility to development and commissioning of a full-scale plant. This defines the scope of works required for the delivery of Phase II of the BEIS programme.

The commercialisation plan focuses on deployment of the unique COS fuel processing line to capitalise on the full opportunity that the COS material offers as a 100% biogenic feedstock for hydrogen fuel production. It is estimated that there are approximately 769,000 tonnes of COS material produced each year by composters in England, which if treated through COS fuel processing lines could yield approximately 500,000 tonnes of COS fuel. This equates to approximately 12,000 tonnes of bio-hydrogen that could be supplied into the hydrogen fuel chain. It is estimated that there would need to be approximately 34 COS fuel processing lines installed across the country in order to recover all of the COS fuel available, with each region of England only needing up to a maximum of six processing lines based on the maximum throughput of the proposed technology.

APPENDIX 1 – PROJECT ASSUMPTIONS

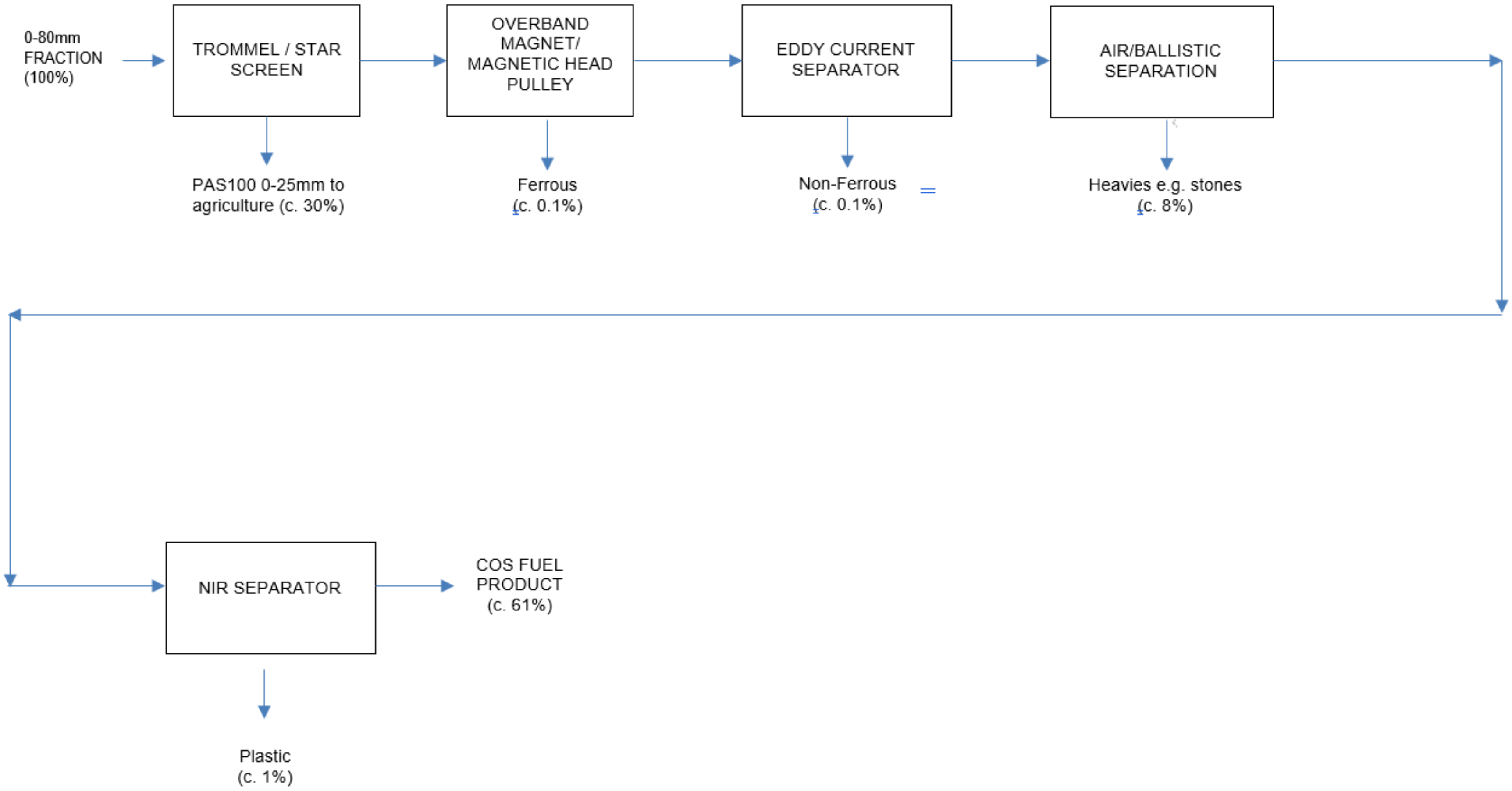
- Processing line will operate for up to 6 hours a day, 5 days a week, 52 weeks per year.
- CO2 equivalent figure for gasification of Biomass the same as that for combustion.
- For Mass Balance / Financial Model
  - Euro/Pound exchange rate of 0.87.
  - Financing period of 10 years.
  - Financing rate of 7%.
  - Process Line annual maintenance and lifecycle costs of 5.1% of CAPEX.
  - Process line efficiency of 90%.
  - 0-80mm COS consists of (by mass):
  - 30% 0-25mm fines
  - 0.1% ferrous metal
  - 0.1% non-ferrous metal
  - 8% heavies
  - 1% plastics
  - All costs in Site development CAPEX tab
  - No import duties apply to equipment purchased
  - All costs in facility OPEX tab
  - Price per tonne for sales of non-ferrous metals
  - Price per tonne for sales of COS fuel
- Fuel recovery rate of processing line at Biowise applied to all composting sites on Waste Data Interrogator tool in England.
- 0.03 tonnes of biohydrogen produced from 1 tonne of COS with assumed 20% reduction to account for contaminants.
- Cost of £150/tonne (gate fee, tax and delivery) to dispose COS material in landfill.
- 30% of COS material disposed of in landfill in England.

APPENDIX 2 – LABORATORY ANALYSIS RESULTS

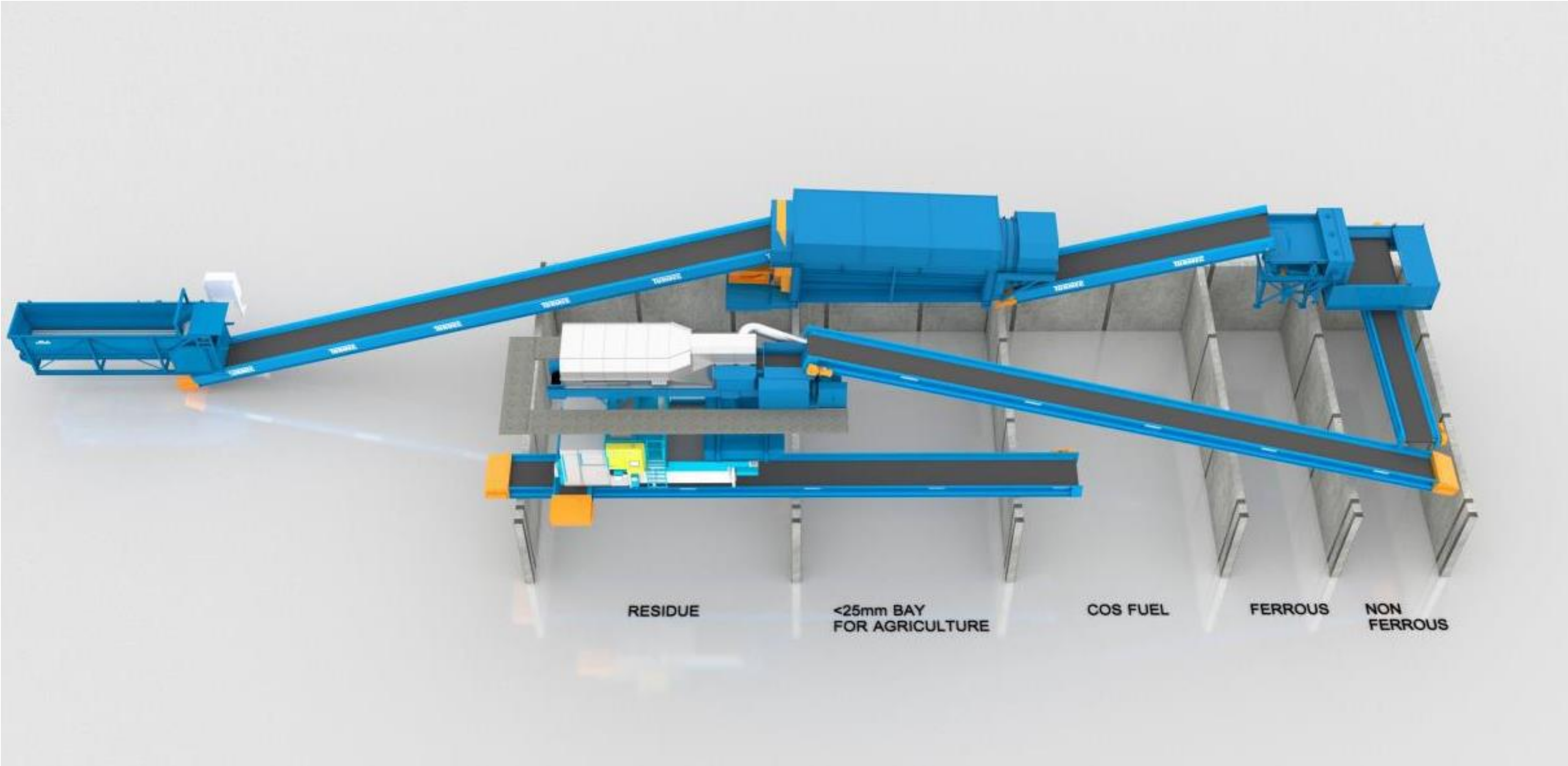
APPENDIX 3 – COMMON FUEL SPECIFICATION

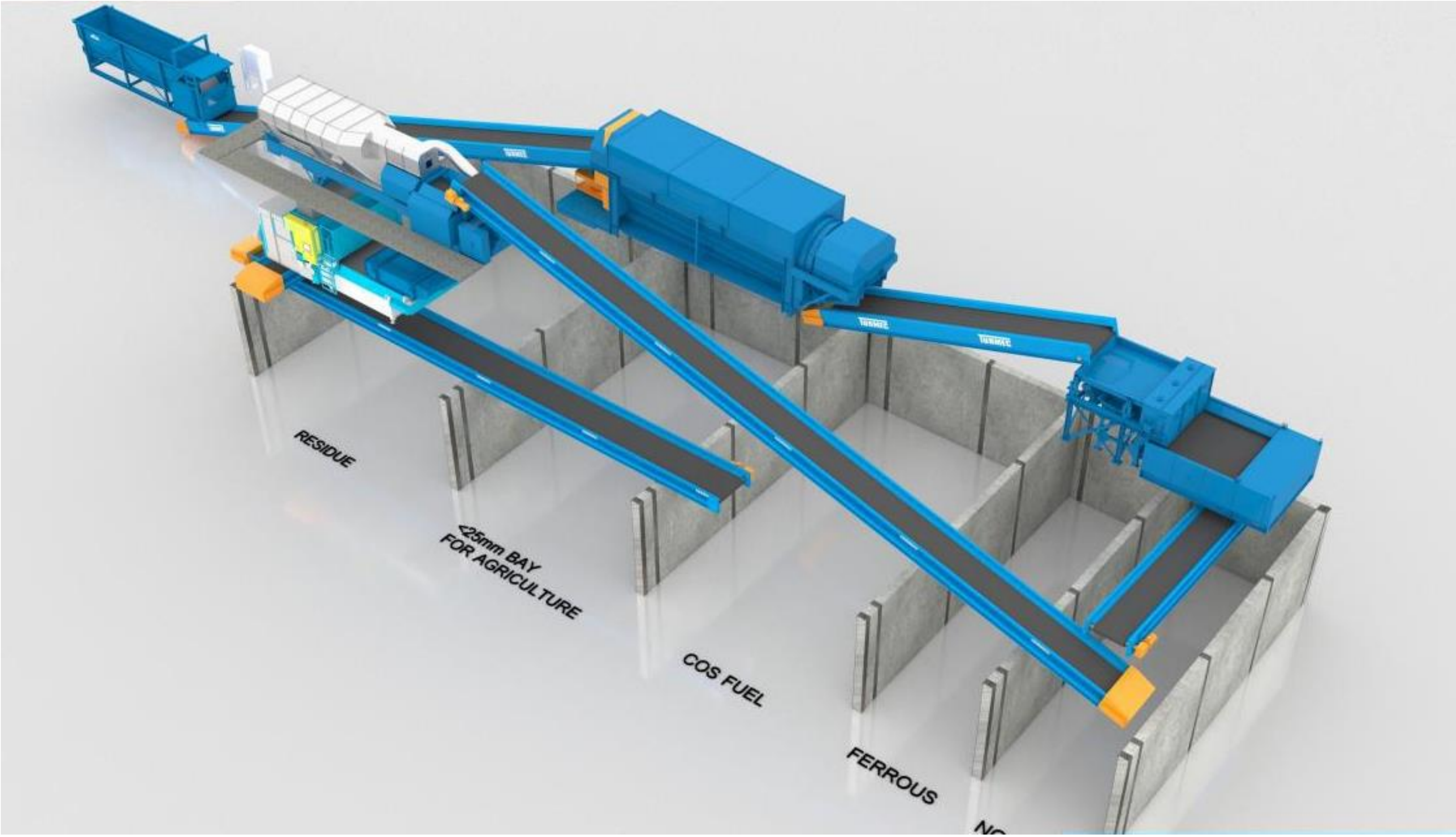
Parameter	Selected value	Unit	Tested via:
Particle size	<80	mm	Laboratory Analysis
Moisture content	10-60	%	Laboratory Analysis
Ash content (DW)	<5	%	Laboratory Analysis
Sulphur (DW)	<0.1	%	Laboratory Analysis
Chlorine (DW)	<0.5	%	Laboratory Analysis
Bromine (DW)	<100	mg/kg	Laboratory Analysis
Fluorine (DW)	<87.9	mg/kg	Laboratory Analysis
Hydrogen (DW)	>4.58	%	Laboratory Analysis
Aluminium (DW)	<100	mg/kg	Laboratory Analysis
Phosphorous (DW)	<100	mg/kg	Laboratory Analysis
Zinc (DW)	<10	mg/kg	Laboratory Analysis

APPENDIX 4 – OUTLINE COS FUEL PROCESSING DESIGN

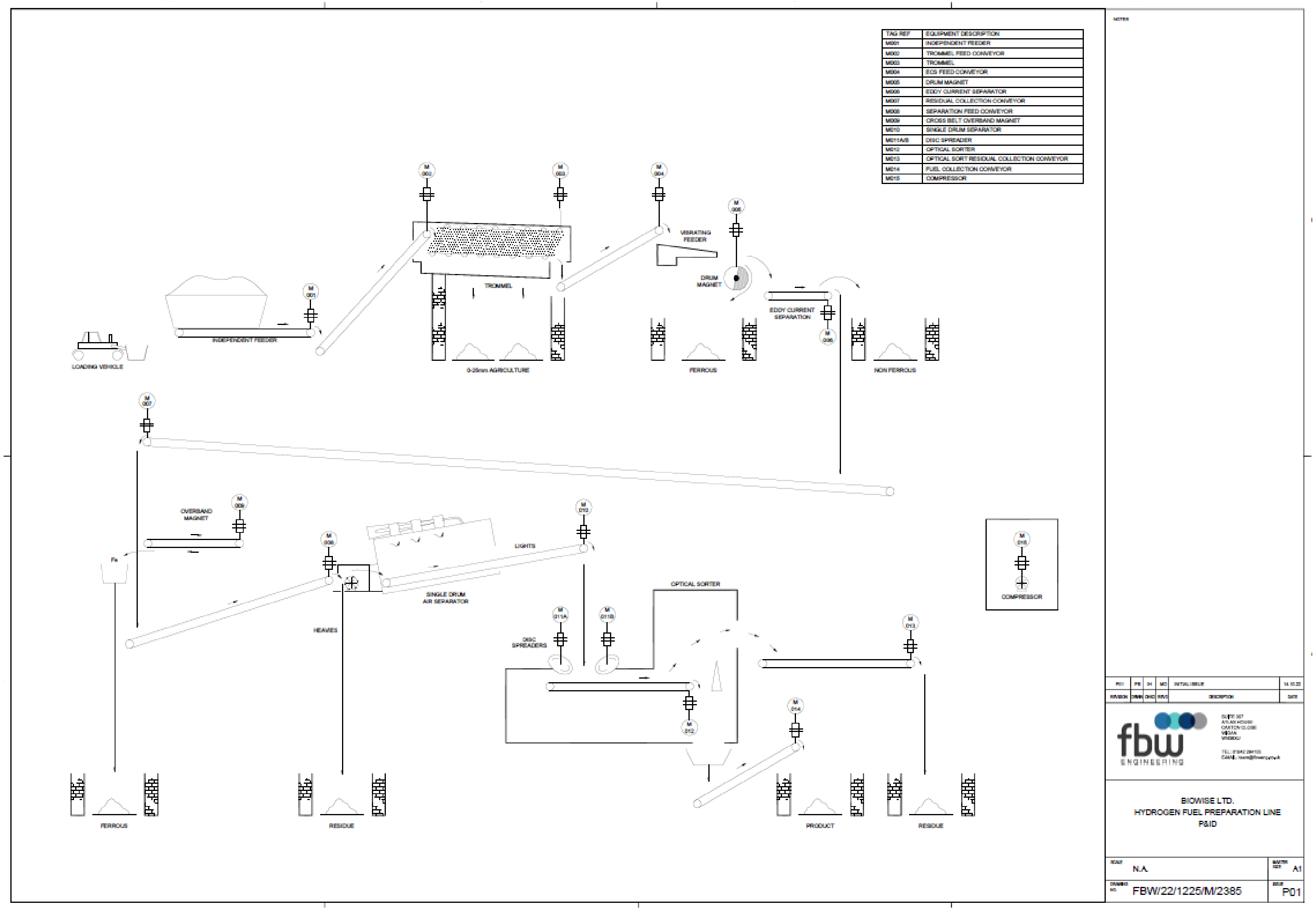

0-80mm FRACTION (100%)
TROMMEL / STAR SCREEN
OVERBAND MAGNET/ MAGNETIC HEAD PULLEY
EDDY CURRENT SEPARATOR
AIR/BALLISTIC SEPARATION
PAS100 0-25mm to agriculture (c. 30%)
Ferrous (c. 0.1%)
Non-Ferrous (c. 0.1%)
Heavies e.g. stones (c. 8%)
NIR SEPARATOR
COS FUEL PRODUCT (c. 61%)
Plastic (c. 1%)

APPENDIX 5 – PROPOSED PLANT LAYOUT


RESIDUE
<25mm BAY
FOR AGRICULTURE
COS FUEL
FERROUS
NON
FERROUS

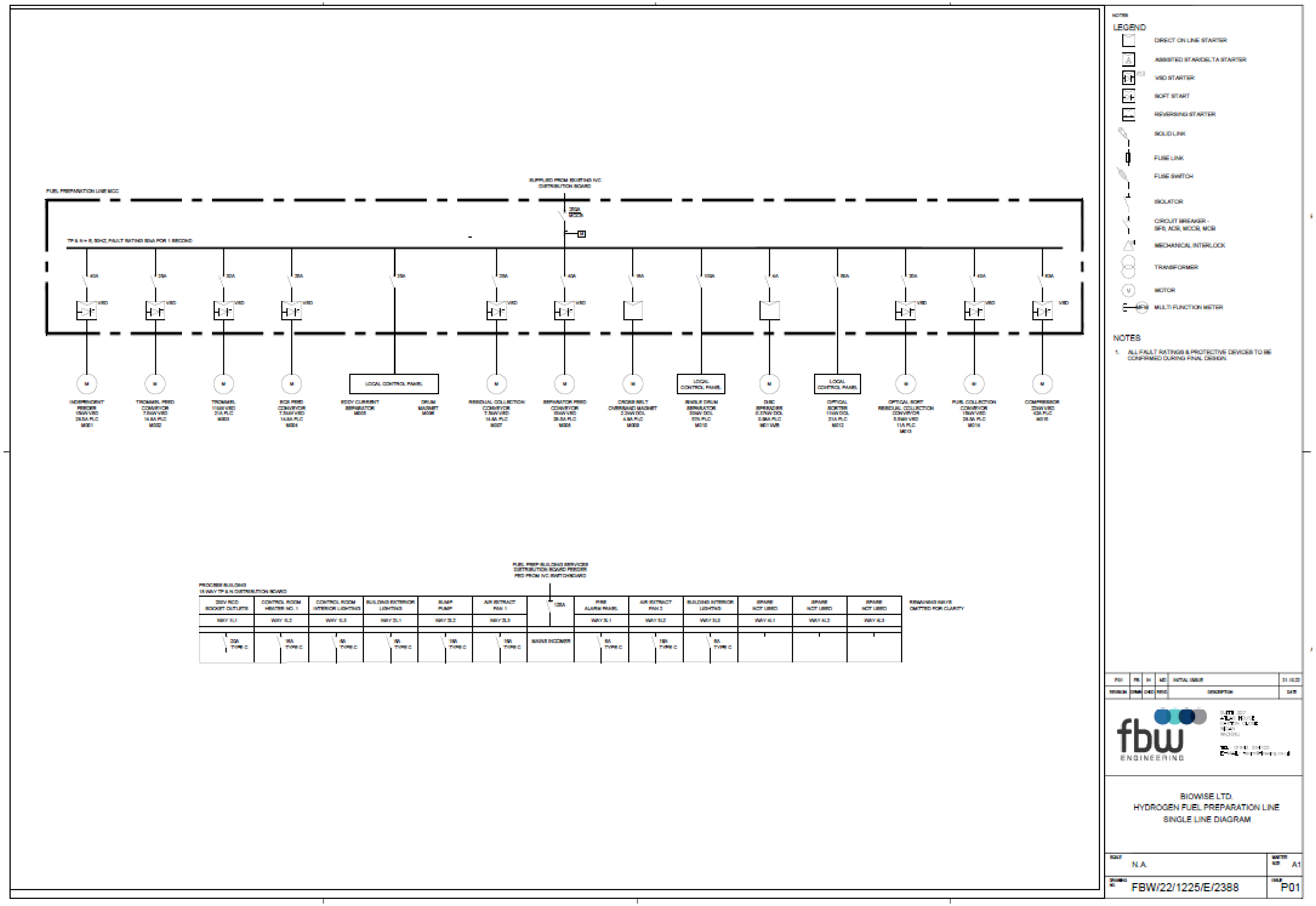

RESIDUE
<25mm BAY
FOR AGRICULTURE
COS FUEL
FERROUS

APPENDIX 6 – PIPING AND INSTRUMENTATION DIAGRAM

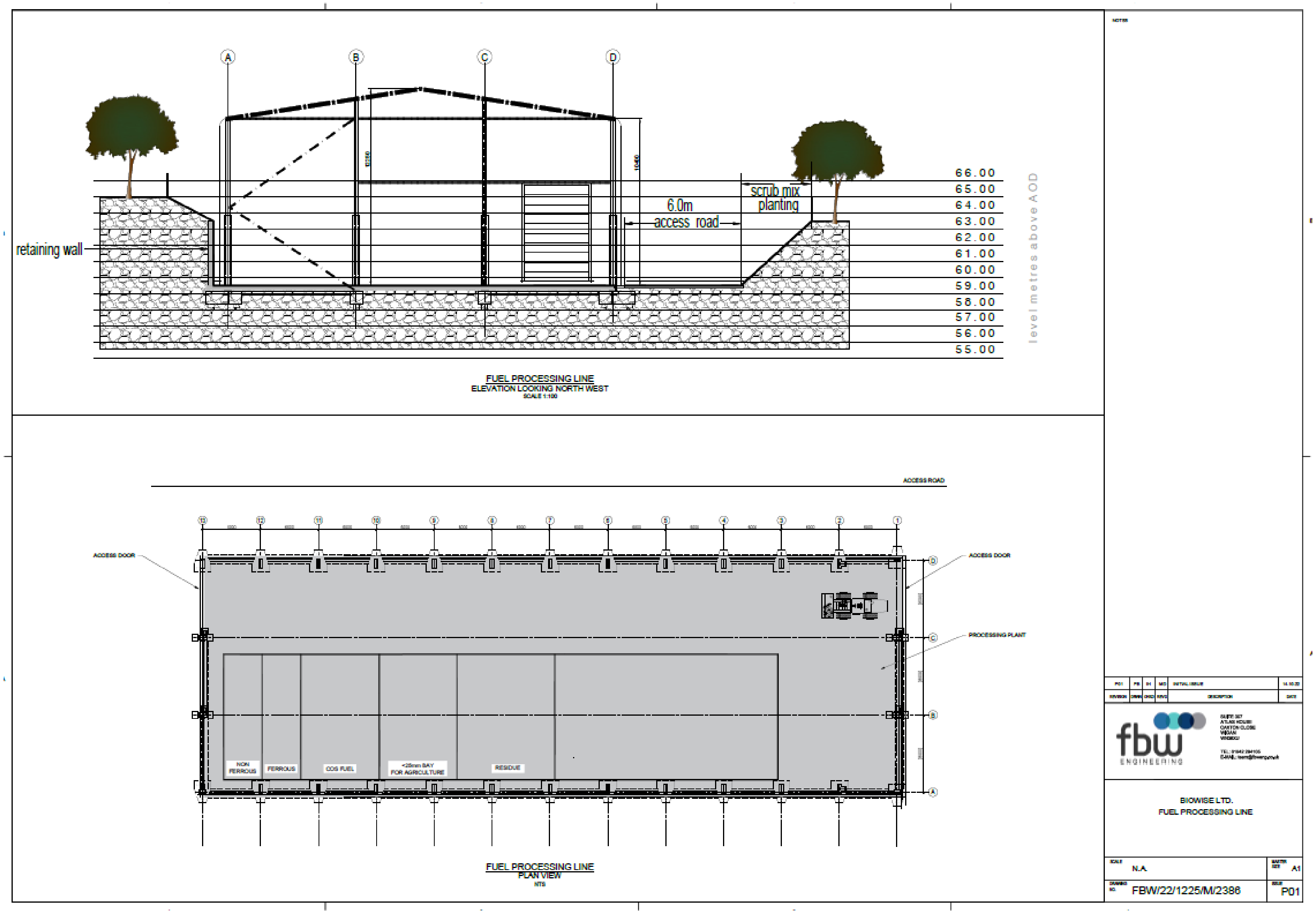


TAG REF | EQUIPMENT DESCRIPTION
M001 | INDEPENDENT FEEDER
M002 | TROMMEL FEED CONVEYOR
M003 | TROMMEL
M004 | ECS FEED CONVEYOR
M005 | DRUM MAGNET
M006 | EDDY CURRENT SEPARATOR
M007 | RESIDUAL COLLECTION CONVEYOR
M008 | SEPARATION FEED CONVEYOR
M009 | CROSS BELT OVERBAND MAGNET
M010 | SINGLE DRUM SEPARATOR
M011A/B | DISC SPREADER
M012 | OPTICAL SORTER
M013 | OPTICAL SORT RESIDUAL COLLECTION CONVEYOR
M014 | FUEL COLLECTION CONVEYOR
M015 | COMPRESSOR
LOADING VEHICLE
INDEPENDENT FEEDER
TROMMEL
0-25mm AGRICULTURE
VIBRATING FEEDER
DRUM MAGNET
FERROUS
EDDY CURRENT SEPARATION
NON FERROUS
OVERBAND MAGNET
Fe
LIGHTS
HEAVIES
SINGLE DRUM AIR SEPARATOR
OPTICAL SORTER
DISC SPREADERS
COMPRESSOR
FERROUS
RESIDUE
PRODUCT
RESIDUE
BIOWISE LTD.
HYDROGEN FUEL PREPARATION LINE
P&ID
N.A.
A1
FBW/22/1225/M/2385
P01

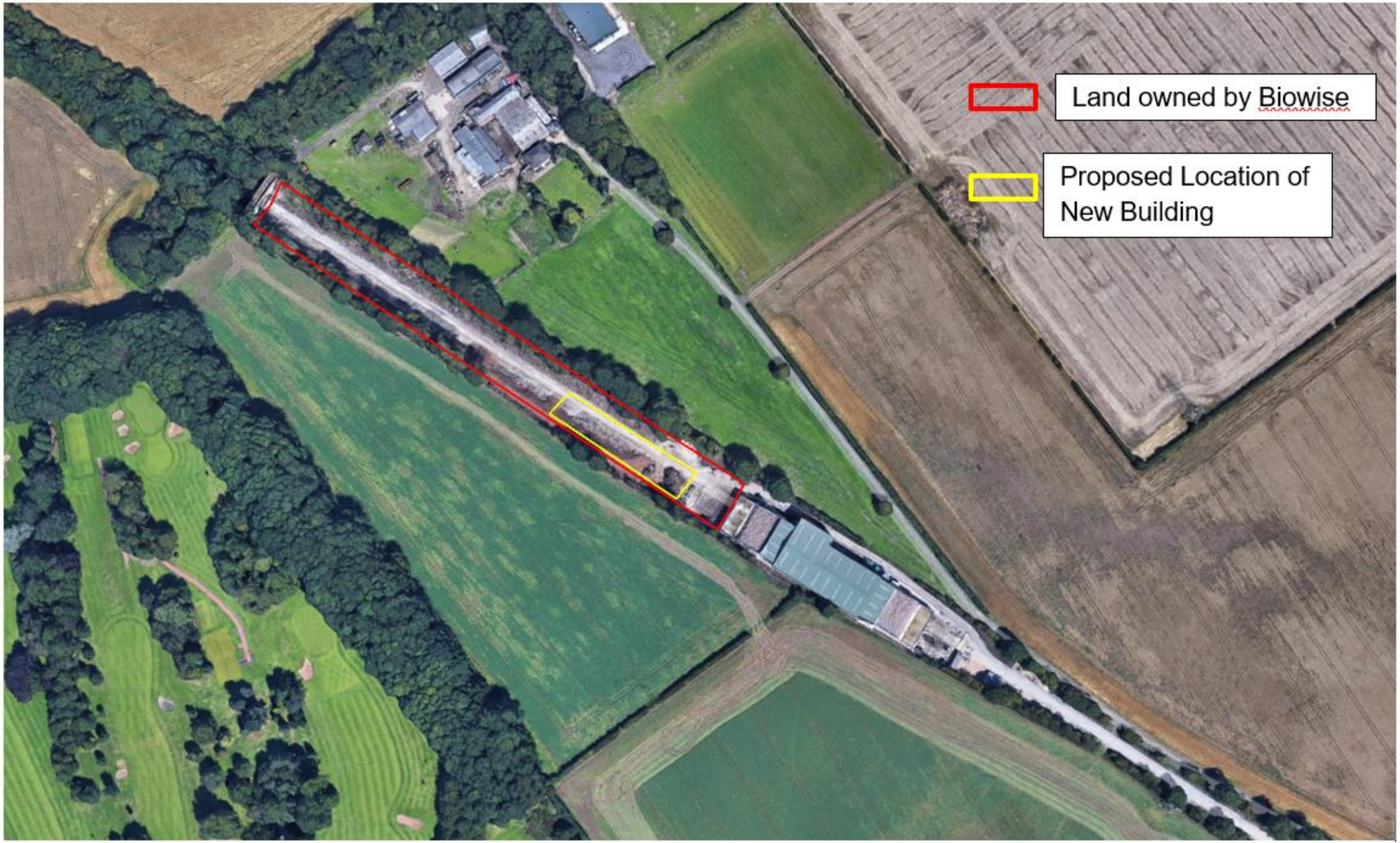
APPENDIX 7 – SINGLE LINE ELECTRICAL DISTRIBUTION DIAGRAM


LEGEND
DIRECT ON LINE STARTER
ASSISTED STAR/DELTA STARTER
VSD STARTER
SOFT START
REVERSING STARTER
SOLID LINK
FUSE LINK
FUSE SWITCH
ISOLATOR
MECHANICAL INTERLOCK
TRANSFORMER
MOTOR
MULTI FUNCTION METER
NOTES
1. ALL FAULT RATINGS & PROTECTIVE DEVICES TO BE CONFIRMED DURING FINAL DESIGN.
fbw ENGINEERING
BIOWISE LTD.
HYDROGEN FUEL PREPARATION LINE
SINGLE LINE DIAGRAM
N.A.
A1
FBW/22/1225/E/2388
P01

APPENDIX 8 – PROPOSED BUILDING LAYOUT


retaining wall
6.0m access road
scrub mix planting
66.00
65.00
64.00
63.00
62.00
61.00
60.00
59.00
58.00
57.00
56.00
55.00
level metres above AOD
FUEL PROCESSING LINE
ELEVATION LOOKING NORTH WEST
SCALE 1:100
ACCESS ROAD
ACCESS DOOR
ACCESS DOOR
PROCESSING PLANT
NON FERROUS
FERROUS
CDS FUEL
<25mm BAY FOR AGRICULTURE
RESIDUE
FUEL PROCESSING LINE
PLAN VIEW
NTS
BIOWISE LTD.
FUEL PROCESSING LINE
N.A.
A1
FBW/22/1225/M/2386
P01

APPENDIX 9 – PROPOSED LOCATION OF NEW BUILDING


Land owned by Biowise
Proposed Location of New Building

APPENDIX 10 – DETAILED FINANCIAL MODEL

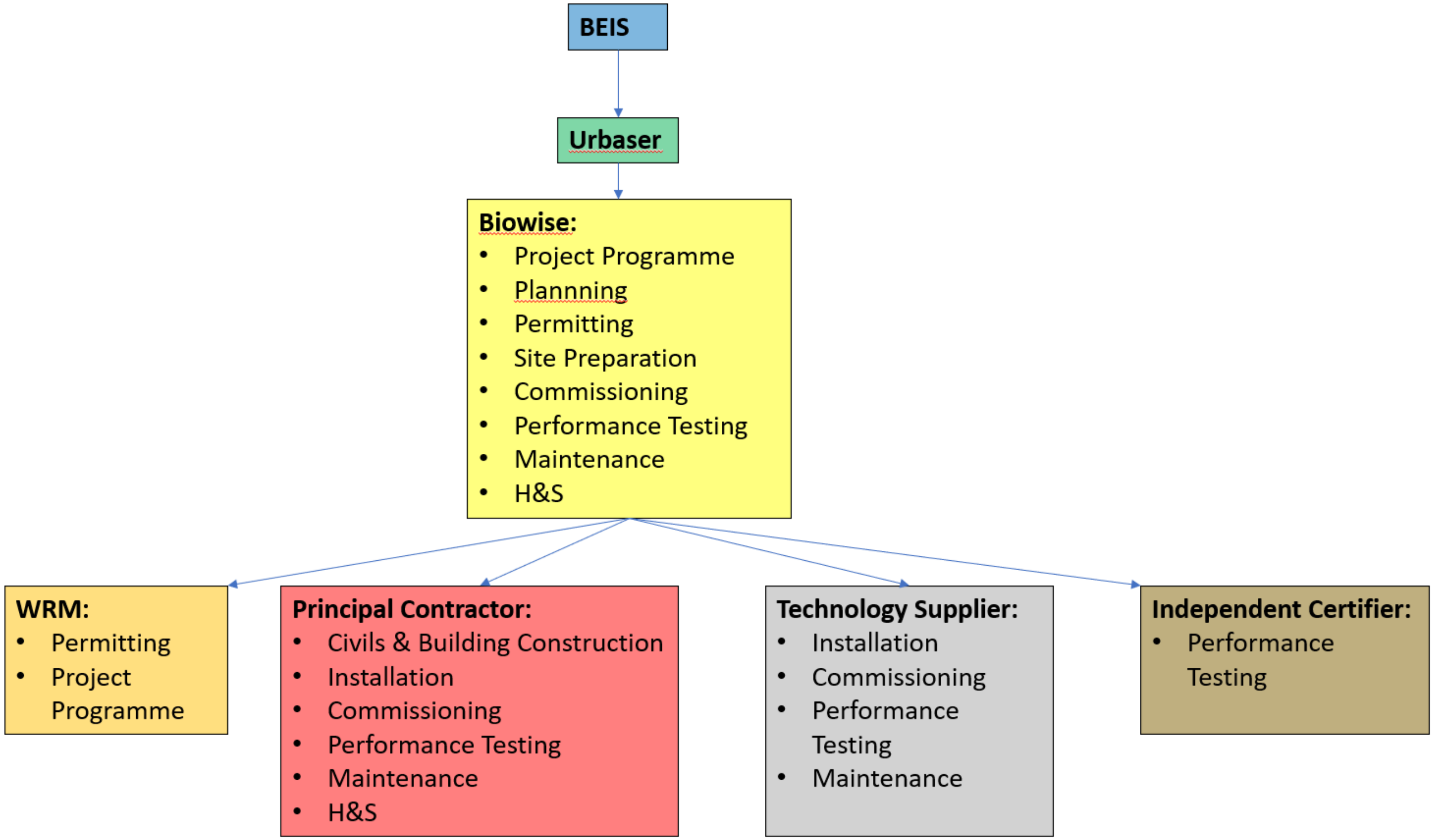
APPENDIX 11 – INVESTMENT RISK ASSESSMENT

APPENDIX 12 – IMPLEMENTATION PLAN GANTT CHART

APPENDIX 13 – CURRENT PLANT PERFORMANCE GUARANTEES

Parameter	Design Mass Balance	Mass Balance Guarantee	Tested via:	Unit
Input material	100% at <80mm	N/A	On site mass balance, verification though weighing daily input tonnage. <80mm captured via lab analysis	Tonnes
Fines	27%	>27%	On site mass balance, verification though weighing daily weight captured vs input tonnage	Tonnage of fines captured vs input tonnage to plant per day averaged over the week
Ferrous	0.09%	>0.09%	On site mass balance, verification though weighing daily weight captured vs input tonnage	Tonnage of ferrous captured vs input tonnage to plant per day averaged over the week
Non-Ferrous	0.09%	>0.09%	On site mass balance, verification though weighing daily weight captured vs input tonnage	Tonnage of non - ferrous captured per day vs input tonnage to plant per day averaged over the week
Stones	7.2%	>7.2%	On site mass balance, verification though weighing daily weight captured vs input tonnage	Tonnage of stones captured per day vs input tonnage to plant per day averaged over the week
Plastic	0.9%	>0.9%	On site mass balance, verification though weighing daily weight captured vs input tonnage	Tonnage of plastic captured per day vs input tonnage to plant per day averaged over the week
Fuel	64%	>64%	On site mass balance, verification though weighing daily weight captured vs input tonnage	Tonnage of fuel captured per day vs input tonnage to plant per day averaged over the week

APPENDIX 14 – ROLES AND RESPONSIBILITIES ORGANOGRAM


BEIS
Urbaser
Biowise:
• Project Programme
• Plannning
• Permitting
• Site Preparation
• Commissioning
• Performance Testing
• Maintenance
• H&S
WRM:
• Permitting
• Project Programme
Principal Contractor:
• Civils & Building Construction
• Installation
• Commissioning
• Performance Testing
• Maintenance
• H&S
Technology Supplier:
• Installation
• Commissioning
• Performance Testing
• Maintenance
Independent Certifier:
• Performance Testing

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