AUSTRALIAN MEAT PROCESSOR CORPORATION

Final Report

Integrated Bioresource Recovery Facility. Novel FEED Study, Stage 2

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Contents

1.0 Abstract

AMPC recently collaborated with Tessele Consultants and ARENA to conduct a thorough feasibility study on establishing an integrated Bioresource Recovery Facility (BRRF) at a red meat facility in NSW. The BRRF aims to maximise the value of by-product streams through wastewater treatment, biogas production, CO_2 recovery, and biofertiliser production. The study included a front-end engineering design (FEED) for each component:

- The Wastewater Treatment Plant (WWTP) processes the facility's wastewater to produce recycled water for irrigation and non-potable uses onsite.
- The Biogas Plant converts red meat processing by-products and WWTP sludge into thermal and electrical energy using Combined Heat and Power (CHP) units.
- The CO_2 Recovery Plant extracts and purifies CO_2 from biogas and CHP unit combustion for food-grade liquid CO_2 used in meat cooling processes.
- The Biofertiliser Plant utilises nutrient-rich digestate from the biogas process to produce biofertilisers.

The project highlighted the renewable energy potential of using red meat by-products for biogas production, estimating a yield of 1.4 GJ per tonne of hot standard carcass weight (HSCW) at a facility capacity of 135,200 t.HSCW/yr. The Combined Heat and Power (CHP) units in the biogas plant generate 2.37 MWh of electrical energy and 2.42 MWh of thermal energy, supplying the BRRF's energy needs while providing surplus energy to the red meat facility.

Financially, the project promises significant returns, with a Net Present Value (NPV) of $225.3 million over a 25-year lifespan and a payback period of 7 years. It positions the red meat sector as a significant contributor to renewable energy production and exemplifies sustainability and circular economy practices for other industries.

A webinar for the project will be held on September 19th. You can register here.

2.0 Acknowledgements

This Study received funding from the Australian Renewable Energy Agency (ARENA) as part of ARENA's Industrial Energy Transformation Studies Program.

The views expressed herein are not necessarily the views of the Australian Government, and the Australian Government does not accept responsibility for any information or advice contained herein.

3.0 Executive Summary

A beef processing facility in NSW is looking to adopt innovation in the way their wastewater and solid wastes are managed, aiming to (i) improve the removal of nitrogen and phosphorus, maintain an effective nutrient balance on irrigation of crops, (ii) recycle water on allowed operations, (iii) recover bioresources including biogas, biomethane, CO_2, biofertiliser, and (iv) reduce their overall carbon footprint.

The studied beef processing plant was part of the case studies that served for the development of the Digital Tool (Core Project 2021-1142) and the preliminary assessment showed that there is a potential for implementing an integrated system that can produce a positive financial return while attending to the nutrient removal requirements and carbon emission reduction. This study will also inform the completion of the core project Bio-resource Recovery - Centres of Excellence (Core Project 2023-1013).

In this context, this project aims to develop an Integrated Bio-Resource Recovery Facility Novel FEED Study, Stage 2, to be implemented at the NSW case study facility to inform a technical and economic decision on the way forward for project implementation and the required stages.

The innovative plant design considers aspects such as nutrients (nitrogen, phosphorus) and other compounds recovery from wastewater, with the possibility of irrigation and recycling uses, within compliance limits. Solid streams will be processed onsite for recovering thermal and electric energy as well as food-grade liquid CO_2 from biogas. Moreover, a biofertiliser processing plant adds value to the digestate.

The FEED Study, Stage 2, will inform the NSW beef processing facility on adequate technologies, concept design (layouts & process flow diagram) and optimal implementation stages. The documentation produced in the FEED will also support the Environmental Licensing application process (works approval), required for the implementation of the integrated Bio-resource recovery facility.

This project will help establish the Bio-resource Recovery - Centres of Excellence (Core Project 2023-1013) through the following actions:

- Solid streams ‘waste’ audit and characterisation (quantities and quality).
- Biogas and biofertiliser potential production study.
- The facility’s energy use and demand profile analysis.
- Development of a design of an Integrated Bio-resource recovery facility (biogas, biomethane, CO_2 recovery and biomass processing plant), excluding the wastewater treatment plant (WWTP) component, which was completed in FEED Stage 1 for the NSW case study facility.
- Preparation of equipment lists to be used in the procurement stage.
- Development of a cost estimate for the biogas, biomethane, CO_2 recovery and biomass processing plants.
- Development of an economic analysis including CAPEX and OPEX, which will support the decision-making process for the Bio-resource recovery facility implementation.

This Final Report details the outcomes of the Integrated Bioresource Recovery Facility Novel FEED Study for the NSW beef processing plant, which integrates resource recovery via several components, including wastewater treatment, biogas, CO_2 recovery, and biofertiliser plants. The design is centred around the principles of resource recovery and circular economy. The selection of wastewater treatment equipment aimed to maximise recycled water recovery, producing treated water suitable for irrigation and other non-potable uses within the facility. For the biogas plant, organic solid by-products from the NSW beef processing site were evaluated for their biomethane potential, to form a feedstock that enhances energy production. Biogas production occurs in anaerobic digesters, where substrate, combined with specific microorganisms and controlled conditions like temperature and pH, is converted into biogas, and liquid digestate. A biogas composition of 60% methane (CH4) and 40% carbon dioxide (CO_2) was assumed for the biogas in this project. The generated biomethane (CH4) will provide thermal and electrical energy to the BRRF through combined heat and power (CHP) units (Figure 1).

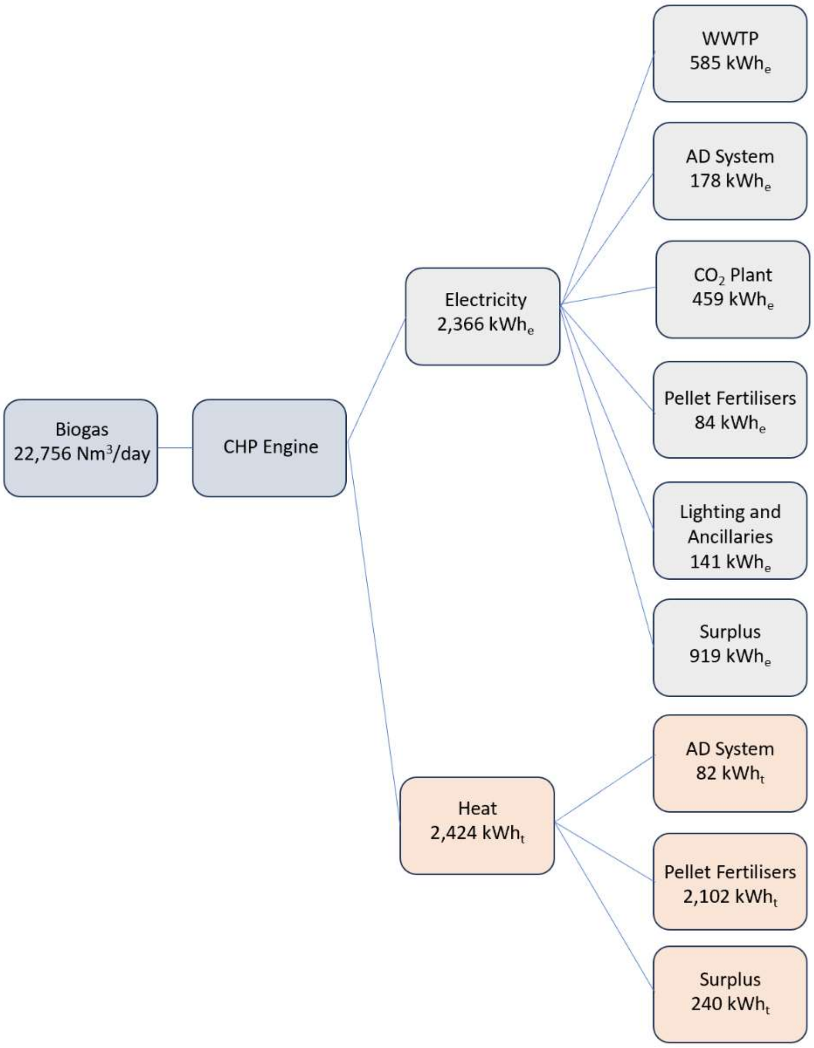


Figure 1. BRRF energy supply diagram.

Additionally, a CO_2 plant was designed to recover the carbon dioxide gas portion of the biogas, along with CO_2 from the biogas combustion in the CHP units. It treats the recovered CO_2 to food-grade liquid CO_2 which is used as dry ice for storage and transport of the NSW case study facility's final product, processed meat. A thorough technology assessment was done and identified that amine technology is widely used and economically sound technology for this CO_2 capture application.

After a high level digestate characterisation assessment, using a combination of assumptions from literature and raw wastewater samples from the NSW beef processing facility, it is anticipated that the liquid digestate byproduct from anaerobic digestion will meet the high nutrient requirements for producing a valuable bio-based fertiliser product. Consequently, the digestate is directed to the biofertiliser plant, where it is converted to biofertiliser through a dewatering, drying and pelleting process, effectively avoiding waste disposal and adding a valuable income stream. According to a thorough biofertiliser technology and application study, pelleted biofertiliser was identified as the most suitable option for the NSW case study facility, due to its higher nutrient retention compared to other types of biofertilisers (such as biochar), and its alignment with the organic fertiliser demand in the local area of the NSW case study facility.

The cost analysis of the proposed Bioresource Recovery Facility (BRRF) includes the assessment of capital and operational costs of the plants, as well as revenue from potential commodity offsets, such as treated water, energy,

CO_2, biofertiliser, and carbon credits. Net Present Value (NPV) and Return on Investment (ROI) have been analysed for various scenarios, considering the implementation of one or more resource recovery plants and staged capital investments. Implementing the full BRRF in 2026, including all recovery plants, shows the highest ROI and fastest payback. Table 1 below illustrates the profitability measurements for the best BRRF implementation scenario where the resource unit per plant CAPEX was calculated assuming a 25-year effective life.

Table 1. Profitability measurements for the best BRRF implementation scenario.

Profitability Measurements	Full BRRF implementation in 2026
NPV (Million AU$)	225.3
Water CAPEX (AU$/ ML)	8,156
Energy CAPEX (AU$/GJ)	5
CO_2 CAPEX (AU$/tonne)	76
Biofertiliser CAPEX (AU$/tonne)	60
ROI (%)	492
Annualised ROI (%)	7.4
Payback Period (years)	7

4.0 Introduction

The implementation of a Bio-resource Recovery Facility (BRRF) at the NSW case study facility promises well-managed resource recovery and robust environmental compliance. This initiative not only aligns with circular economy principles but also future proofs their production site, contributing to the red meat sector's commitment to sustainability. Additionally, the facility stands to gain from potential offsets such as treated water, energy, food-grade liquid CO_2, biofertiliser, and carbon credits.

The Integrated Bioresource Recovery Facility's Novel FEED Study, Stage 2, builds from the Stage 1 FEED Study, which included the design of a Wastewater Treatment Plant (WWTP). Stage 2 includes biogas production from anaerobic digestion of underutilised solid byproducts and wastewater sludges. The biogas provides thermal and electrical energy to the facility via combustion in combined heat and power (CHP) engines. This approach ensures that the wastewater, biogas, CO_2 recovery and biofertiliser plants can operate self-sufficiently on the renewable energy produced from the biogas. This reduces the NSW case study facility’s reliance on external fossil-fuel derived energy providers, increasing reliability of power supply, reducing their carbon footprint and mitigating the impact of rising electricity costs. Additionally, the study explores innovative CO_2 recovery of the carbon dioxide produced from the biogas plant, along with CO_2 from the biogas combustion exhaust in the CHP units. The CO_2 recovery plant will purify the captured carbon dioxide gas to food-grade liquid CO_2 which is used as dry ice for storage and transport of the NSW case study facility’s final product, processed meat. Producing this valuable resource onsite will generate significant revenue for the facility since the market price for this resource has considerably increased due to market instabilities.

To close the loop of the bioresource recovery facility and minimise waste disposal, the liquid digestate from the biogas plant can be used as a valuable product for fertiliser or soil amendment application. Through a dewatering, drying and pelleting process, the biofertiliser plant converts the digestate into pelletised biofertiliser. Pelletised biofertiliser retains a higher nutrient content than other product options (such as biochar), and is logistically easier and cheaper to store, transport and apply to land, particularly during winter. The significant agricultural land use in the NSW case study facility region creates a high local demand for biofertiliser, exceeding the NSW case study facility’s biofertiliser production capacity, facilitating a favourable market for product offtake. When commercialised, this recovered resource adds meaningful income to the facility.

In addition to Front End Engineering Designs (FEED) for the Bio-resource Recovery Facility components of wastewater, biogas, CO_2 recovery and biofertiliser production plants, the cost analysis of the BRRF was carried out through the evaluation of the capital and operational cost of the plants as well as the revenue from potential offsets such as treated water, energy, CO_2, biofertiliser and carbon credits. Profitability measurements were analysed for various scenarios, considering the implementation of one or more resource recovery plants and staged capital investment, identifying the best investment option.

To source information for the project, a desktop review of relevant documentation and communication via phone calls and emails with the NSW beef processing plant team was undertaken. This Final Report presents the outcomes of the Front-End Engineering Design, Integrated Bioresource Recovery Facility Stage 2 for the NSW case study facility. The design and assumptions were conceived based on the concepts of recovering resources and approaching a circular economy.

5.0 Project Objectives

The objective of this project is to prepare Stage 2 of the Front-End Engineering Design for the integrated wastewater, biogas, CO_2 recovery and biofertiliser plant for the management of the red meat processor wastewater and organic solid ‘waste’. The final report will be used for the licensing application, decision-making process, procurement and funding of further stages of the system implementation.

The objectives to be achieved in Stage 2 include:

- Solid streams ‘waste’ audit and characterisation (quantities and quality).
- Biogas and biofertiliser potential production study.
- The facility’s energy use and demand profile analysis.
- Development of a design of an Integrated Bio-resource recovery facility (biogas, biomethane, CO_2 recovery and biomass processing plant), excluding the WWTP component, which was completed in FEED Stage 1 for NSW case study facility.
- Preparation of equipment lists to be used in the procurement stage.
- Development of a cost estimate for the biogas, biomethane, CO_2 recovery and biomass processing plants.

6.0 Methodology

To undertake the design of the integrated facility and cover all aspects required for a successful and concise outcome, the project comprises the following methodology:

Wastewater Treatment Plant Design: The methodology for developing the Wastewater Treatment Plant Concept Design in Stage 1, involved an Excel-based process and hydraulic calculations, followed by BioWin modelling. Real sampling data was used, and the BioWin model, validated through sensitivity analyses, informed the selection of major equipment sizes and process components. Concept design drawings and an equipment list were created.

Organic By-Products Characterisation and Quantification: Organic by-products produced at the NSW beef processing plant underwent physicochemical analysis by a certified laboratory to determine Biomethane Potential (BMP), Volatile Solids (VS), and Total Solids (TS). The results were compared with existing data from literature and other red meat facility case studies. Additionally, the volume of organic by-products was reported by NWS beef processing plant personnel. The laboratory results, combined with the substrate production volumes, were used to estimate the quantity of biogas production for the biogas plant design.

Biogas Plant Design: Using feedstock characteristics from information provided by the NSW case study facility, a set of process calculations has been undertaken to develop the Front-End Engineering Design for the anaerobic digestion plant. This process included the production of FEED drawings and a comprehensive equipment list, detailing equipment specification, design and quantities.

CO_2 Recovery Plant Design: Given that the NSW case study facility aims to implement the innovative approach of recovering and purifying CO_2 in the BRRF, an in-depth analysis of technologies for CO_2 recovery from biogas production and combustion was undertaken. After analysing each CO_2 recovery system, one shortlisted process for capturing and purifying carbon dioxide to food-grade quality at the NSW beef processing plant was identified. In collaboration with an equipment manufacturer of CO_2 recovery, the concept design of the CO_2 recovery plant was created along with technical drawings, an equipment list and a feasibility study.

Biofertiliser Plant Design: Environmental regulation studies regarding bio-based solids application were undertaken, ensuring full compliance with the biofertiliser plant final product. To identify an optimal process design to convert the anaerobic digestate to a valuable resource, a technical evaluation of various commercial digestate recovery systems was performed. Criteria for this assessment encompassed not only technical performance but also environmental impact, energy consumption, and economic viability. Based on this evaluation, a specific process for the dewatering and drying of digestate was selected. Drafting of the biomass processing plant and components were undertaken along with a list of equipment and ancillary parts.

Cost Estimate: The cost estimate methodology included a quoting process in which the plant equipment lists were shared with reliable vendors. Prices from up to three suppliers were considered for each equipment item for the BRRF. Additionally, in collaboration with a cost estimator, an analysis of the BRRF implementation costs, such as civil works, was undertaken. For instance, it was assumed that most of the site will be paved with crushed limestone rather than concrete, which helps to reduce civil works costs. For equipment, the methodology assumed that the client would directly engage with equipment suppliers, thereby avoiding builders' costs. A 5% contingency factor included equipment installation and delivery costs. The BRRF amenity was planned to be centralised in one control room, featuring a containerised laboratory. Electrical works were considered to integrate with equipment that already contains control panels, while pipework considered both above and below ground pipes. Project management (10%), contractor preliminaries (18%) including supervision, safety, insurance, and escalation for tender in 2026 (10%) were all factored in to refine the CAPEX costs.

Economic Analysis: The economic analysis included different scenarios considering the implementation of one or more resource recovery plants (wastewater treatment, biogas, CO_2 and biofertiliser plant) and staged capital investments. Regarding the staged implementation scenarios, a 60% CAPEX investment was considered for building bioresource recovery plants that cope with the planned facility expansion for 67,600 t.HSCW/yr, expected to occur within a two-year timeframe. The remaining amount of 40% CAPEX was allocated for the capacity upgrades needed for the long-term facility expansion to 135,200 t.HSCW/yr, projected to take place in 7 years. Additionally, a detailed analysis was conducted to identify the flowrates and volumes of both upstream and downstream products at each plant of the BRRF in stages 1 and 2. Following this, an assessment of the recovered bioresource quantities and potential revenues was undertaken. Personnel from the NSW case study facility supplied cost data for resources currently paid for onsite. This information played a crucial role in the economic analysis by contributing to the calculations for potential revenue offsets such as treated water, energy, CO_2, biofertiliser and carbon credits.

7.0 Project Outcomes

Table 2 below summarises the key elements of each scope of work item and the respective outcomes achieved in this final report.

Table 2. Report summary table.

Item	Scope of Works	Outcome
Wastewater Treatment Plant Concept Design, Equipment List, Recommended Suppliers, and Cost Estimate – Package 1	Site Assessment. Wastewater audit and characterisation. WWTP design. Equipment list and recommended suppliers. Cost estimate.	WWTP design with high process control flexibility, focusing on improved nutrient removal, recycling for other uses, environmental compliance and resolving current wastewater disposal issues. Design considers nutrient and other compound removal from wastewater, with the possibility of irrigation and cattle wash. Cost estimate and design will be used for the decision-making process for further stages of the plant implementation, and the Environmental Licencing application process.
Mobilisation Package 2	Inception meeting, mobilisation.	Stage 2 includes Packages 2 and 3. Steps to complete concept designs for a biogas plant (including CO_2 recovery) and a biomass processing plant (biofertiliser).
Solid Streams Audit and Characterisation	Site audit and BMP tests for all solid streams.	Pre-selected solid organic streams on-site exhibit potential as substrates for anaerobic digestion, offering prospects for biogas production. Generated biogas holds the potential to offset a portion of the facility's energy consumption and contribute towards the NSW case study facility's carbon neutrality objectives.
Anaerobic Digestion Plant Concept Design	Anaerobic Digestion FEED. 3 drawings (PFD, general arrangement, elevations). Anaerobic Digestion Plant Equipment List and Preferred Suppliers Cost Estimate of Anaerobic Digestion Plant	Developed a Biogas Plant Design. Front-End Engineering Design (FEED) based on data from the NSW beef processing plant, literature and Tessele Consultants' assumptions. Modular units chosen for redundancy and expansion capability. Planned expansion aligns with increased feedstock availability. AD plant produces 1.4 GJ per t.HSCW processed. Total energy production: 4.79 MWh (2.37 MWh electrical, 2.42 MWh thermal). Equipment list and preferred suppliers for Biogas Plant design.
CO_2 Recovery Plant Concept Design	CO_2 Recovery Plant Concept Design CO_2 Recovery Plant Equipment List and Cost Estimate Assessment of CO_2 recovery alternatives for producing dry ice from both biogas and existing boiler stack.	Concept Design for CO_2 recovery plant by Evo Energy Technologies. Evaluation of technology choices for producing dry ice from pre or post combustion biogas, or recovery from the existing coal boiler stack Assessed CO_2 production for different scenarios: implementation of one or more resource recovery plants (wastewater treatment, biogas, CO_2 and biofertiliser plant) and staged capital investments. The recommended method is amine-based chemical absorption for biogas combustion exhaust post-CHP engine.
Digestate Management Concept Design	3 drawings (PFD, general arrangement, elevations). Digestate Management Equipment List and Preferred Suppliers Cost Estimate of Digestate Management Plant	The processed biomass was characterised and quantified at 279 kL/day of 5% TS digestate. Adopted municipal biosolids guidelines for bio-based fertiliser. Recommended recovery technology is mechanical dewatering, drying and pelletising digestate into bio-based fertiliser pellets for third-party offtake.

Item	Scope of Works	Outcome
Economic Analysis	Economic analysis of packages 1, 2, and 3, including 3 staging alternatives (as agreed with the NSW case study facility).	Implementing the full BRRF with all components (wastewater, biogas, CO_2 recovery, and biofertiliser plants) yields highest return on investment. The payback time difference is only two years whether implemented all at once, or in two stages. Optimisation potential includes reviewing and optimising quantities and prices of recovered bioresources, and increasing recycled water use and biofertiliser price to enhance ROI.

The project outcomes for the Stage 2 Novel FEED Study are presented in the following sections.

7.1. Wastewater Treatment Plant

This section provides an overview of the Front-End Engineering Design (FEED) – Integrated Bio-resource Recovery Facility – Stage 1 project, which served as a predecessor to the Stage 2 Novel FEED Study. In Stage 1, modular wastewater treatment plant for the NSW case study facility was developed to address current wastewater disposal issues and accommodate future expansion. The focus was on nutrient removal and reuse opportunities. Existing infrastructure will remain operational until the new plant is fully installed.

This section includes:

- Site assessment.
- Design flow rate definition.
- Wastewater characterisation.
- Wastewater production and off-take potential.
- Wastewater Treatment Plant (WWTP) concept design and equipment list.
- Cost estimate for the WWTP.

7.1.1. Site Assessment

The NSW case study facility operates 260 days per year, typically running 24 hours on weekdays. According to data from 2022, the site processes an average of 166,816 cattle heads per year, equivalent to a production of 43,368 t.HSCW annually. The NSW beef processing plant has identified an approximately 2.6 ha greenfield site near the existing wastewater treatment plant as the potential location for the new Bio-resource Recovery Facility (Figure 2). It is recommended that topographical and geotechnical surveys be conducted at the site prior to further stages of the project.

Figure 2. Area available for the new Bio-resource Recovery Facility, including wastewater treatment, biogas plant, CO_2 recovery and biofertiliser plants.

Table 3 shows relevant findings from the case study facility in NSW.

Table 3. Relevant findings from the case study facility in NSW.

Aspect	Details
Irrigation area	320 hectares of adjacent agricultural land.
Current treated wastewater use	Utilise existing network for irrigation; continue to use as an alternative disposal option when treated effluent is not reused at the facility.
Environment Protection License (EPL) #809	Requires monitoring and recording of nutrient concentrations in effluents and solids (total phosphorus, total nitrogen, potassium); baseline of 70 kg of total nitrogen per hectare per year based on optimal crop uptake.
Potable water supply	Supplied by a local provider.
Current water usage	Estimated at approximately 542 ML/year (based on 2022 data).
Future water demand	There is the drive to reuse treated wastewater to support current operations and future expansion.

7.1.2. Design Flowrate Definition

The NSW case study facility’s current and projected water usage and wastewater production are shown in Table 4, where the current information is based on 2022 data.

Table 4. Water usage projection and estimated wastewater production.

Timeline	Facility Production (t.HSWC/ year)	Water Usage* (kL/year)	Wastewater Production** (kL/year)
Current	51,687	541,794	487,615
2 years	62,400	692,308	623,077
5 years	78,000	865,385	778,846
10 years	104,000	1,153,846	1,038,462

*Assuming 3 kL of water used per head.
**Assuming up to 90% of the water used is converted into wastewater.

The plant's modular implementation allows for flexible expansion and equipment redundancy, starting with three modules totalling 2,520 kL/day. A fourth module will be implemented to reach 3,360 kL/day when capacity exceeds 90% (Table 5).

Table 5. Proposed treatment capacity stages

Number of Modules	Total Capacity (kL/day)	Total Capacity (kL/year)
1	840	306,600
2	1,680	613,200
3	2,520	919,800
4	3,360	1,226,400

Table 6 shows the WWTP average, minimum and maximum flow rates.

Table 6. Wastewater treatment plant design flow rates

Parameter	Average	Minimum	Maximum
Flowrate	2,520 kL/d	540$_a$ kL/d	3,024$_b$ kL/d

a. Minimum flow rate was estimated using a correlation between average and minimum flow rates seen at another red meat processing facility.
b. Peak flow rate based on 120% of average flow rate.

7.1.3 Design Flowrate Clarifications

The WWTP was designed for 2,520 kL/day to handle approximately 92,092 t.HSCW/yr with an interim expansion time of 7 years. It was assumed that the average wastewater production for cattle is 7.1 kL/t.HSCW, requiring 2,023 kL/day for 104,000 t.HSCW/year (10 years). New information from the NSW beef processing plant indicates that increased throughput does not linearly correlate with wastewater production. Thus, a BioWin sensitivity analysis confirmed the design's robustness under various scenarios, including a scenario using the design wastewater flow rate and concentration, half the current flow rate, and half the flow rate at double the concentration. The design and half-design flow rate scenarios proved robust. The half-design flowrate scenario, with double the concentration, can meet target effluent quality with additional filtration, chemical dosing, and operational adjustments (e.g., return activated sludge ratio). Table 7 shows the BioWin sensitivity analysis outcomes.

Table 7. BioWin sensitivity analysis outcomes.

Scenario Description	Comments	BioWin Outcome
The design wastewater flow rate at current concentrations	WWTP design - conservative	Proved robust
Approximately half the design flow rate at current concentrations	Overdesign check	Proved robust
Approximately half the design flow rate at double the current concentrations	Possible scenario	With additional chemical dosing, increased filtration and adjustment of operational parameters, target effluent quality can be achieved

Accurate flow measurement and future flow rate confirmation are critical for detailed design, with the WWTP design conservatively overdesigned for potential increases in wastewater throughput.

7.1.4 Wastewater Characterisation

The average wastewater quality characteristics are shown in Table 8. It includes the results of the Save-All stream (combined red and green stream before the existing anaerobic pond) sample provided by the NSW beef processing plant. A more detailed analysis is in Appendix 1.

Table 8. Raw wastewater quality characteristics.

Parameter	Average	Load	Minimum	Maximum
BOD	6,360 mg/L	16,040 kg/d	975 mg/L	14,830 mg/L
COD[a]	9,090 mg/L	22,900 kg/d	1,390 mg/L	21,190 mg/L
TKN	350 mg/L	880 kg/d	180 mg/L	590 mg/L
TP	50 mg/L	120 kg/d	21 mg/L	71 mg/L

[a] COD results of the save-all stream were unavailable. A factor derived from the COD to BOD ratio in the red stream was applied to the BOD values of the combined save-all stream to estimate its COD values.

The COD ratio is higher than optimal for nutrient removal due to fat, oils, and grease. The NSW case study facility reports the existing primary DAF underperforms due to insufficient coagulant / flocculant dosing. Tessele's jar testing confirmed adequate dosing significantly improves TSS and O&G removal, thus it is assumed about 50% of total COD will be removed in the primary DAF, resulting in more suitable C:N ratios for biological nutrient removal.

7.1.5 Treated Effluent Quality Targets

Assuming the treated wastewater will be used for irrigation, cattle wash (other than final wash) and non-potable uses at the facility, treated final effluent quality requirements according to the Australian Guideline for Water Recycling (Environment Protection and Heritage Council et al 2006) and the Water Reuse Guideline from NSW Food Authority are shown in Table 9.

Table 9. Treated final effluent quality requirements.

Parameter	Unit	Requirements
Soluble BOD	mg/L	<20
TSS	mg/L	<30
TDS	ppm	N/A
pH	---	6.5 - 8.5
Turbidity	NTU	<5
UV dose (mJ per cm2)	-	*
Residual chlorine	mg/L	*
E.coli	cfu per 100 mL	<1
Virus	log reduction	6
Protozoa	log reduction	5
Bacteria	log reduction	5
TN	mg/L	<19**
TP	mg/L	<1.4***

*Minimum disinfection that aims to demonstrate reliability to achieve microbial quality consistently. It is recommended to add a 2 mg/L chlorination dose.

**TN concentration estimated based on calculation for 70kg TN/hectare provided by the NSW case study facility.

***TP concentration was estimated using the TP/TN ratio from another red meat facility and applying this factor to the NSW case study facility's TN.

According to AQIS Meat Notice No: 2008/06 – The Efficient Use of Water in Export Establishments (DAFF, 2008), meat processors establishments can use potable recycled water for any potable processing purpose on the establishment apart from a direct ingredient in meat products or use it for drinking. Selling the recycled water will require the approval of the relevant domestic authorities.

Regarding non-potable recycled water applications in the red meat processing industry,

Table 10 shows the potential uses divided by required AQIS approval.

Table 10. Applications for non-potable recycled water in the red meat processing industry according to AQIS approval.

(i) Applications that require AQIS risk assessment through HACCP*.	(ii) Applications that don't require special approval just a reference in the water procedures within the Approved Arrangement.
Steam production (other than steam used or to be used in direct or indirect contact with meat and meat products), fire control, the cleaning of yards, the washing of animals (other than the final wash) and other similar purposes not connected with meat and meat products.	Irrigation, watering gardens, flushing toilets, washing down external areas.

Note that not requiring an AQIS HACCP does not mean that the water quality for the specific application is inferior to a water application that needs an AQIS HACCP application.

Besides attending to the Australian market, the NSW case study facility exports its products to China and the European Union. For export-registered establishments, any applications that use recycled or reused water should be directly reported to the AQIS On Plant Supervisor if one is stationed at the establishment or the Area Technical Manager if there isn't an AQIS On Plant Supervisor. AQIS will inform the relevant state food safety authority of the proposal to ensure any concerns of the local authority are identified and addressed.

7.1.6 Wastewater Equipment Selection and Concept Design

The wastewater treatment plant concept design is based on a future average flow rate of 2,520 kL/day for biological and physicochemical processes. Hydraulic components were calculated for a peak flow of 3,024 kL/day (120% of the average). The treatment sequence, shown in Figure 3, combines unit operations to achieve contaminant removal.

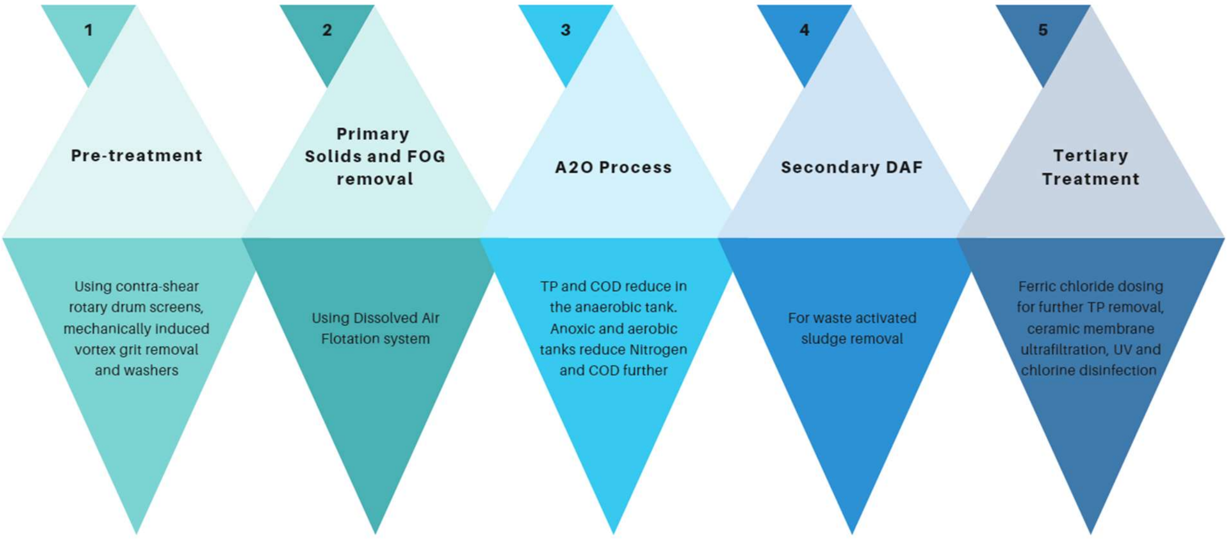


Figure 3. Summary of steps considered in the WWTP concept design.

The following sections describe the specifications of individual equipment and processes. Refer to Appendix 2 for the WWTP technical drawings. The wastewater treatment plant uses equalisation tanks to balance daily effluent flow and operates continuously at a balanced flow rate, with three parallel, independent modules for enhanced robustness and reliability. Design conditions and equipment specifications are detailed below.

Pre-treatment

Three rotary drum screens with 0.75 mm apertures, suitable for high fat, oil, and grease red meat processing wastewater, were selected to prevent solids from entering the WWTP, improving efficiency. Designed for a peak flow of 302 kL/hr (120% of the average daily design flowrate) and 5,200 mg/L total solids concentration, they remove approximately 30% of suspended solids and allow for easy in-situ maintenance without halting operations. Table 11 summarises the screens' specifications.

Table 11. Screen specifications.

Tags	Design Conditions	Preliminary Specifications
RS.001A RS.001B RS.001C	Peak flowrate design = 3,024 kL/day total Peak flowrate design = 1,008 kL/day per screen Operational hours = 10 hours Design flow: 300 kL/h total Design flow: 100kL/h per screen	Fine screens Aperture = 0.75 mm screening Material = SS 304 Channel details to be specified with screen manufacturer

Solids from the rotary screen will be collected in skip bins and transported to a future biogas plant for energy recovery, with the option for automated transport via a screw conveyor to be defined in the design stage. Three mechanically induced vortex tanks and two grit classifiers were selected for consistent grit removal at varying flow rates, operating in parallel to maintain circulation and remove grit, designed for a peak flow of 302 kL/hr. Table 12 shows these equipment specifications.

Table 12. Grit removal equipment specifications.

Tags	Design Conditions	Basic Specifications
GS.001A GS.001B GS.001C	Peak flowrate design = 3,024 kL/day total Peak flowrate design = 1,008 kL/day per grit tank Operational hours = 10 hours Design flow: 300 kL/h total Design flow: 100kL/h per grit tank Duty/Duty/Duty	Volume per tank: ~1 m3 for a 30s detention times Material = SS 304 Details to be specified with grit tank manufacturer
GW.001A GW.001B	Peak flowrate design = 41 kL/day total Peak flowrate design = 21 kL/day per grit classifier/washer Operational hours = 10 hours Design flow: 4 kL/h total Design flow: 2 kL/h per grit washer Duty/Duty-Standby	Specifications per grit washer: Width: 2.3 m Total Height: 3.1 m Discharge Height: 2.5 m Inlet DN: 80 Outlet DN: 150 Installed Mixer Power: 0.37 kW Drive Power: 1.1 kW Material = SS 304

Screened and de-gritted wastewater flows by gravity to the pump station TK.001, where it is pumped to the equalisation tanks via a set of submersible pumps, (3 duty and 3 standby). The wastewater will be pumped to a flow splitter before entering the equalisation tanks. The specifications for the transfer pumping station and pump sets are presented in Table 13 below.

Table 13. Transfer pumping station specification.

Tags	Design Conditions	Preliminary Specifications
TK.001	Peak flowrate design = 3,024 kL/day Operational hours = 10 hours peak and 14 hours non-peak 1-2 minutes holding capacity	Diameter = 1.8 m Depth = 3 m Operational depth assumed = 1.5 m Operational volume = 3.8 kL
P.001A P.001B P.001C P.001D P.001E P.001F	Pump set (total flows) Peak flowrates (total) = 300 kL/h Average flowrates (total) = 252 kL/h Duty/Duty/Duty/Standby/Standby/Standby Pump number of starts and operational settings to be confirmed with supplier and electrical engineers	Flow range total = 20 to 400 kL/h Flow range per pump = 20 to 140kL/hr Operating in parallel on VSDs to maintain a level setpoint Pump power and head to be confirmed during detailed design, based on site location and elevations

Equalisation tanks

Three parallel balancing tanks, each with an operational volume of 1,512 kL, manage fluctuations in influent wastewater flow and quality, improving treatment performance and reducing costs. These mixed and slightly aerated tanks, designed for 1.5 days hydraulic retention, balance weekday and weekend flows, allow for pH adjustment, and prevent anaerobic processes, feeding wastewater continuously to the WWTP at 105 kL/h (Table 14).

Table 14. Equalisation tanks specifications.

Tags	Design Conditions	Basic Specifications
TK.002A TK.002B TK.002C	Total balancing volume = 4,536 kL Balancing volume per tank 1,512 kL Operational hours = 24 hours Minimum Holding Capacity = 1.5 days	Specifications per tank: Diameter: 15.4 Total Height: 8.5 m Operational Height: 8.2 m Operational Volume: 1,512 kL Material Glass Fused Steel with epoxy coating – covered top Coarse bubble diffuser shared between all tanks = 90 kW blower

After the equalisation tanks, three treatment trains operate independently in parallel, each with an average flowrate of 35 kL/h. Transfer pumps at the outlet of each tank, ranging from 16 kL/h to 42 kL/h, direct the equalised wastewater to the next treatment stage (DAF.001), regulating flow and stabilising the process.

Primary treatment

The DAF system uses fine air bubbles, coagulants and flocculants to separate fats, oils, grease, and suspended solids, removing BOD and nutrients, and is designed to remove approximately 75% of total solids. Located downstream of the equalisation tanks, it treats wastewater using air-saturated water, with primary sludge sent to anaerobic digesters. One DAF unit (DAF.001) will handle 105 m3/h with optimised chemical dosing and improved effluent quality. Chemicals for coagulation and flocculation are stored in IBC containers and connected to dosing pumps. The primary DAF sludge pit collects sludge for the Biogas Plant, and pH adjustment is included. Table 15 summarises the DAF specifications.

Table 15. Primary DAF design parameters.

Tags	Design Conditions	Basic Specifications
DAF.001A	Inlet average flow rate = 105 kL/h Inlet peak flow rate = 126 kL/h Hydraulic Flocculation time = 1 to 2 min Recirculation rate = 10 - 30% Application rate/Hydraulic Surface Loading Rate = 2.7 – 3.3 m/h for average and peak flows respectively Solids Loading Rate = 8.7 to 10.4 kg/m2.h for average and peak flows respectively Average flowrate design = 137 kL/h (incl. recirculation) Minimum surface area required = 50 m^2	The following specifications are for the existing DAF unit which will be utilised: Flotation Length: 14.4 m Total Height: 3.7 m Flotation Width: 3.5 m Material: Stainless Steel
Chemical dosing	Flocculant dosing Polymer dosing Ph adjustment (acid) Ph adjustment (base)	Two dosing pumps allocated for each chemical required, per train – in duty/standby configuration for each train (Pump range from 0 to 200 L/hr)
TK.006	Inlet average flowrate of DAF sludge = 13kL/h Inlet peak flowrate of DAF sludge = 16kL/h Hydraulic retention time = 2-3 minutes 2 pumps (1 duty 1 standby)	Total Depth: 1.3 m Diameter: 1.8 m Operational volume: 0.5 m^3 Actual tank volume: 3.3 m^3 Freeboard: 1.1m Material: Concrete

The primary effluent from the DAF system flows by gravity to a distribution chamber with a maximum 15-minute HRT, operating 24/7 at 105 kL/h, with up to 7 kL/h returned from the Biogas Plant dewatering processes. Six submerged pump sets (duty/standby) pump effluent to Anaerobic Tanks at an average of 35 kL/h per module, handing 16 to 42 kL/h. Table 16 presents the details of the primary effluent distribution chamber.

Table 16. Primary effluent distribution chamber.

Tags	Design Conditions	Basic Specifications
TK.003	Inlet flow rate, from DAF = 105 kL/h Additional 7 kL/h Design flow rate = 112 kL/h Maximum holding capacity = 15 min	Total Height: 4.0 m Diameter: 3.6 m Operational volume: 28 m^3 Actual tank volume: 41 m^3 Freeboard: 1.3m Material: Concrete
Pump set P.002A/B/C/D/E/F	Flow rate = 16 to 42 kL/h per pump Duty/Duty/Duty/Standby/Standby/Standby	6 x submersible pumps

Secondary treatment

The A2O reactor, a variation of the activated sludge process, has anaerobic, anoxic, and aerobic zones to remove BOD, SS, nitrogen, and phosphorus. It offers operational flexibility and includes three modular stages:

- Anaerobic: Biological phosphorus removal and COD reduction.
- Anoxic: Pre-denitrification (nitrate to nitrogen gas).
- Aerobic: Nitrification (ammonia to nitrite and nitrate).

Two recirculation lines optimise the process:

- Return Activated Sludge (RAS) from secondary DAF to anaerobic zone.
- Mixed liquor recirculation from aerobic to anoxic zone.

Anaerobic bioreactors – biological phosphorus removal

After DAF treatment, primary effluent enters three anaerobic reactors for biological phosphorous removal and COD reduction, achieving optimal C:N ratios for aerobic treatment and reducing downstream chemical phosphorous removal and costs.

Table 17 summarises the anaerobic reactor design.

Table 17. Anaerobic reactors design.

Tags	Design Conditions	Basic Specifications
R.001A R.001B R.001C	Anaerobic Reactor primary effluent in = 120kL/h Anaerobic Reactor flowrate in (per reactor) = 40kL/h Average HRT = 2h Operational hours = 24 hours	Diameter: 4.5 m Total Height: 5.7 m Operational Height: 5.1 m Operational Volume: 80 kL Freeboard: 0.5 m Material Glass Fused Steel with epoxy coating – open top Top entry submerged mixer with VSD – mixer power 0.9 kW

Anoxic bioreactors – pre-denitrification

Three anoxic tanks are proposed for denitrification, totalling a 2,640 kL operational volume. Table 18 summarises the anoxic reactor design.

Table 18. Anoxic reactor design.

Tags	Design Conditions	Basic Specifications
R.002A R.002B R.002C	Operational hours = 24 hours Average HRT = 6h	Specifications per tank: Diameter: 14.5 m Total Height: 5.7 m Operational Height: 5.4 m Operational Volume: 880 kL Freeboard: 0.3 m Material Glass Fused Steel with epoxy coating – open top Top entry submerged mixer with VSD – mixer power = 2 x 1 kW per tank

Aerobic bioreactors - nitrification

The aerobic zone removes soluble BOD and enables nitrification. It includes three tanks for a total operational volume of 3,474 kL. The system requires ~24,000 kg of O2/day, using four 260kW blowers (3 duty, 1 standby) delivering ~620,000 Nm³ air/day. Table 19 summarises the aerobic reactor design.

Table 19. Aerobic reactor design.

Tags	Design Conditions	Basic Specifications
R.003A R.003B R.003C	Operational hours = 24 hours Average HRT = 8h	Specifications per tank: Diameter: 17 m Total Height: 5.7 m Operational Height: 5.1 m Operational Volume: 1,158 kL Freeboard: 0.6 m Material Glass Fused Steel with epoxy coating – open top Segmented with baffle curtains Equipped with bottom air diffusors connected to blower system
Air diffusors	Air flow rate per diffusers = 4.5 Nm^3/h Diffuser density in the tank = up to 6 diffusers per square meter	Disc Diameter = 229 mm Disc Material = EPDM Total number of diffusers ~6,000
Blowers	Air flow rate = 620,000 Nm^3/day	4 blowers with 260 kW each (3 duty +1 stand-by)

BNR Recirculation and RAS pumps

The biological nutrient removal process requires recirculation of nitrified mixed liquor and return activated sludge (RAS). Mixed liquor recirculates from the aerobic stage to the anoxic stage. RAS recirculates from the secondary DAF to the anaerobic zone. Specifications are detailed in Table 20.

Table 20. Internal recirculation pumps and RAS pumps design.

Tags	Design Conditions	Basic Specifications
IN-Recirc from R.003A to R.002A IN-Recirc. R.003B to R.002B IN-Recirc. R.003C to R.002C	Average design flowrate = 315 kL/h total (for the design of 3x recirculation rate) Average design flowrate per pump = 105kL/h Range from 22 kL/h to 756 kL/h total Range per pump = 7 kL/h to 252 kL/h Recirculation from 1 to 6 times influent 3 pipelines total (pumps running in parallel)	Number of pumps: 6 (3 duty + 3 standby; 1 duty and 1 standby are dedicated to each train)
RAS from DAF.002A to R.001A RAS from DAF.002B to R.001B RAS from DAF.002C to R.001C	Average design flow rate = 105 kL/h total Average design flow rate per pump = 35 kL/h total Range per pump = 3 kL/h to 42 kL/h RAS from 50 to 100% 3 pipelines total (pumps running in parallel)	Number of pumps: 6 (3 duty + 3 standby; 1 duty and 1 standby are dedicated to each train)

Secondary DAF

Mixed liquor is pumped from aerobic reactors to secondary DAF tanks. Three DAF units (one per train) separate, thicken, and remove activated sludge, offering a smaller footprint and fewer operational issues than conventional clarifiers. A chemical dosing skid aids in sludge thickening. Sludge is collected in a pit (TK.007), from which RAS recirculates to the anaerobic reactors, while Excess Activated Sludge (EAS) is sent to the Biogas Plant. Clarified effluent transfers via gravity to a buffer tank (TK.004) before advanced treatment. Table 21 summarises the Secondary DAF system design.

Table 21. Secondary DAF system design.

Tags	Design Conditions	Basic Specifications
DAF.002A DAF.002B DAF.002C	Design conditions per DAF unit: Inlet average flow rate per DAF = 78 kL/h Recirculation rate = 10 - 30% Application rate/Hydraulic Surface Loading Rate = 4.6 – 5.5 m/h	Length: 10.0 m Total Height: 2.5 m Width: 2.2 m Material: Stainless Steel

Tags	Design Conditions	Basic Specifications
	Solids Loading Rate = 13.2 - 15.8 kg/m2.h Average flow rate design = 100 kL/h (including recirculation) Minimum surface area required per DAF unit = 22 m2	
Chemical dosing	Polymer dosing	Two dosing pumps allocated per train – in duty/standby configuration (Pump range from 0 to 200 L/hr)
TK.007	Inlet average flowrate of DAF (and UF backwash) sludge = 16kL/h Inlet peak flowrate of DAF sludge = 19kL/h Hydraulic retention time = 2-3 minutes 2 pumps (1 duty 1 standby)	Total Depth: 1.3 m Diameter: 1.8 m Operational volume: 0.7 m^3 Actual tank volume: 3.3 m^3 Freeboard: 1.1m Material: Concrete

Tertiary treatment

Buffer tank and chemical dosing

One buffer tank (TK.004) allows for chemical dosing to remove residual phosphorus, supplementing the biological phosphorus removal process. Phosphorus is removed by ferric chloride precipitation mixed via an in-line static mixer. Table 22 presents the details of the buffer tank and chemical dosing design.

Table 22. Buffer tank and chemical dosing design.

Tags	Design Conditions	Basic Specifications
TK.004	Total operational volume = 2,634 kL/day Operational volume = 56 kL Operational hours = 24 hours Holding Capacity = 25 – 30 minutes; design can be tuned pending on specific water reuse requirements	Diameter = 4.5 m Height = 4.5 m Operational Volume: 56 kL Actual Tank Volume: 72 kL Freeboard: 1.0 m Material Concrete; spaced with baffles
	Ferric Dosing Sodium Hydroxide dosing Chlorine liquid (for biofouling prevention)	Provision for up to 1.4kL/day of 44% Ferric Chloride Solution (contingency alternative to anaerobic tank) TBD by supplier during the detailed design process 0.5ppm – 1.14 ppm

Ceramic membranes as ultra filtration (UF.001A, UF.001B, UF.001C)

Ceramic membranes were chosen for ultrafiltration as part of the tertiary treatment process. The ceramic membranes specified in this design will be used as a tertiary polishing step, to remove the remaining excess solids from the treated wastewater, ensuring suitability for water reuse for the desired applications of on-site irrigation, and potentially cattle washing (other than final) and non-potable uses at the facility.

If required, ferric chloride dosing will take place before the membrane system for ultimate phosphorus removal. The membranes are periodically back-flushed with filter permeate water; then back-flush water is sent back to the treatment process. Table 23 describes the ceramic membrane design conditions and specifications.

Table 23. Ceramic membrane ultrafiltration design.

Tags	Design Conditions	Basic Specifications
UF.001A UF.001B UF.001C	Average inlet flow = 2,520 kL/d total Average inlet flow per UF skid = 840 kL/d Filtration rate = 118 LMH per skid Rejection (backwash requirements/phosphorous removal) = 2 -5%	Number of towers per train = 6 Number of modules per tower = 7 Total modules per train = 43 Filtration area per module = 258 m^2
Chemical dosing	Including = filtration, backwash, blower and cleaning	Including = filtration, backwash, blower and cleaning

Double-barrier disinfection

Further removal of pathogens is ensured by using a double disinfection process. Following UV irradiation, a chlorination for disinfection will occur before entering the storage tank (Table 24).

Table 24. Disinfection systems.

Technology	Description
UV Radiation	Effective, rapid, chemical free, does not require much space, avoid by-products formation.
Chlorination	Use of sodium hypochlorite to improve elimination of remaining microorganisms. It is simple cost effective. Required a minimal total chlorine residual > 2.0mg/L for water storage and further reuse (NRMMC, 2006).

Considering the UF system, the UV system and the chlorination, combined processes will guarantee the required treated water quality parameters. Table 25 summarises the tertiary treatment log removal rates.

Table 25. Tertiary treatment log removal rates.

Technology	Virus	Bacteria	Protozoa
Ceramic UF	1	5	5
Ultraviolet	2	5	4.5
Chlorination	3	3	3
Total	6	13	12.5

After disinfection and chlorination, the treated water will be stored in a covered treated water tank. The tank will have a low-level alarm offering at least 30 minutes of hydraulic retention time to achieve the minimum contact time for chlorination. From the storage tank, the water can be pumped to the NSW case study facility's existing dam for additional storage capacity, before being conveyed to the various end-uses. Table 26 describes the storage tank design conditions and specifications.

Table 26. Storage tank specifications.

Tags	Design Conditions	Basic Specifications
TK.005	Total balancing volume = 1,473 kL Operational hours = 24 hours Minimum Holding Capacity = 12 hours	Specifications per tank: Diameter: 15.4 Total Height: 8.5 m Operational Height: 8.0 m Actual Tank Volume: 1,566 kL Freeboard: 0.5 m Operational Volume: 1,473 kL Material Glass Fused Steel with epoxy coating – covered top

Sludge handling

The design assumes the implementation of a Biogas Plant, which includes anaerobic digestion of sludge. The liquid digestate can be applied to land directly in NSW (if certain conditions have been met) or processed further into a high-value, solid biofertiliser product. However, if the decision is made to implement only the WWTP in isolation, an allowance should be made for sludge handling. In this case, mechanical dewatering equipment should be installed to dewater combined sludge from the primary and secondary DAF and UF backwash streams.

The design conditions and specifications for the sludge blending tank, pumps and centrifuges in the sludge handling process are shown in Table 27 below.

Table 27. Equipment specifications for the sludge handling process.

Tags	Design Conditions	Basic Specifications
TK.008	Sludge blending tank operational volume = 200kL Residence time = 6.5 hours	Diameter: 6.8 m Total Height: 5.7 m Operational Height: 5.5 m Actual Tank Volume: 207 kL Freeboard: 0.2 m
LSS feed pumps	Average total design flowrate = 123 kL/h Average design flowrate per pump = 50kL/h Range from 22 kL/h to 148 kL/h total Range per pump = 7 kL/h to 50 kL/h	Pumps with VSDs Number of pumps: 4 (3 duty + 1 standby; 1 duty is dedicated to each train with 1 standby on the shelf to share between the trains)
LSS.001A LSS.001B LSS.001C	Average hydraulic loading = 730kL/d total Average hydraulic loading per centrifuge = 243kL/d =10kL/h Solids content of influent = 2.5%TS Dry solids loading per centrifuge = 6t/d total = 260kg/h Operation = 24h	Dimensions per centrifuge: Length = 2.98m Width = 0.94 m Height = 0.89 m
Dosing point within unit	Polymer Dosing	Polymer to be adjusted during operation dosing volume TBC with centrifuge supplier
Skip bin	Sludge skip bin	Volume sufficient to store waste from primary and secondary DAFs and filtration systems for minimum of 10 hours.

7.1.7 WWTP cost estimate

Based on quotes from up to three suppliers for each piece of equipment and cost estimate methodologies, a cost estimate was accomplished for the implementation of the WWTP (Table 28). The equipment list and recommended suppliers have been outlined in Appendix 3.

Table 28. Summary of the cost estimate for the WWTP implementation.

Description	Cost (Million AU$)
Contract preliminaries including supervision, safety, insurance etc (18% excluding equipment cost)	0.4
Contingency for installation and delivery (5%)	0.6
Design and Project Management WWTP (10%)	1.3
Wastewater Treatment Plant Breakdown	
Civil Works	1
Amenities Lab/Control Room	0.3
Equipment Supply	9.7
Pipework	0.3
Electrical	0.5
Subtotal	**14.2**
Escalation (10%)	1.4
Total for full implementation of the Wastewater Treatment Plant	**15.6**

7.2. By-products, characteristics, quantities and biogas plant inputs

To identify relevant organic by-products to utilise as feedstock for the biogas plant, the selection of the organic streams considered the anticipated carbon content and substrate availability at the facility, focusing on an operation independent of external substrate additions. In order to obtain a realistic BMP, VS and TS for the future substrate that will be directed to the biogas plant, a co-digestion sample was prepared and sent to a certified laboratory for testing. The chosen composition is grounded in a collaborative estimation of practical proportions of available feedstock (Table 29).

Table 29. Co-digestion batch composition by weight percentage.

Sample ID	Name	%
CS-RM	Contra-shear rendering material	5
TC-RM	Red Tricanter Bin to Render	10
TC-T	Red Tricanter to Tallow	10
BP	Beef Paunch	35
MA	Manure	5
B-CS	Crop stubble	5
BY-P	Other Solid By-Products	30

Note that the NSW case study facility indicated (after the BMP tests were already underway) that sample Red Tricanter to Tallow (TC-T) would likely not be included as one of the full-scale co-digestion feedstocks because it is currently commercialised for a reasonably high price. The co-digestion sample result is shown in Table 30.

Table 30. Co-digestion sample results.

Sample ID	Name	TS (%)	VS (%)	BMP (ml$_N$ CH$_4$/g VS$_{Added}$)	BMP (m^3 CH$_4$/tonne of original feedstock)
CD	Co-Digestion	29	23	602	137

The Co-Digestion sample total solids value (29% TS) is significantly higher than the recommended range of total solids content for wet anaerobic digestion (ideally 10 to 15% TS). Therefore, it is advisable to include screened wastewater along with the anticipated secondary DAF sludge. This addition will dilute the feedstock for the anaerobic digester, which consists of organic solid by-products, to attain an optimal total solids content of 12% TS. Optimising the total solids content ensures smooth anaerobic digestion operation, allowing the digesters to maintain the necessary homogeneity, fluidity, and mixability.

Thus, in order to enhance the accuracy of the biogas production estimate, two extra streams were assumed. Their description and parameters are based on well-educated estimates and data obtained from a southwest red meat processor, as shown in Table 31 below.

Table 31. Additional assumed substrates.

Sample ID	Name	Description	TS (%)	VS (%)	BMP (ml$_N$ CH$_4$/g VS$_{Added}$)	BMP (m^3 CH$_4$/tonne of original feedstock)
DAF-S	Secondary DAF sludge	Assumed composition based on calculations for domestic wastewater secondary sludge.	4	4	200	7
SWW	Screened Wastewater	Based on samples from a southwest red meat processor, primarily used for dilution water as it contributes little to BMP; required if primary DAF sludge continues to be dewatered for tallow before sending the remaining portion to the biogas plant.	0.2	0.1	176	0.2

Given the current by-product quantities reported by the case study facility personnel, the quantities of the organic streams that form the co-digestion sample were estimated according to a projection of 135,200 t.HSCW/yr (Table 32).

Table 32. Estimated biogas production of each organic by-product with potential for anaerobic digestion.

Sample	Name	Future Substrate (tonnes/yr)	Future Biogas Production @ 60% CH4 (kNm^3 per year)
CS-RM	Contra-shear rendering material	2,555	1,026
TC-RM	Red Tricanter Bin to Render	165,345	2,992
TC-T	Red Tricanter to Tallow	-	-
BP	Paunch	6,935	344
MA	Manure	1,095	19
B-CS	Crop Stubble	5,110	58
BY-P	Other Solid By-Products	5,840	356
CD	Co-digestion	33,945	7,737
N/A - estimated	Secondary DAF Sludge*	47,815	563
N/A - estimated	Screened Wastewater*	20,075	7
Realistic CoDigest Compilation	**CoDigest + Secondary Sludge + Wastewater**	**101,835**	**8,306**

Thus, Table 33 shows the estimated biogas production of the considered samples that will form the biogas substrate.

Table 33. Estimated biogas production.

Sample ID	Name	Future Substrate (tonnes/yr)	Future Biogas Production @ 60% CH4 (kNm3/yr)
CD	Co-digestion	33,945	7,737
DAF-S	Secondary DAF Sludge	47,815	563
SWW	Screened Wastewater	20,075	7
Realistic CoDigest Compilation	**CoDigest + Secondary Sludge + Wastewater**	**101,835**	**8,306**

Table 34 shows the biogas and energy potential derived from the updated Realistic CoDigest Compilation. This compilation integrates the BMP, TS and VS values provided by the certified laboratory, along with the expected secondary DAF sludge and screened wastewater required for dilution. The quantities used in the biogas calculations are based on the realistic availabilities of substrate. The presented biogas production value will be utilised for the Integrated Bioresource Recovery Facility Novel FEED Study Stage 2 project, leading to design capacities for biogas generated from the by-products of processing up 135,200 t.HSCW/yr red meat.

Table 34. Energy production of Realistic CoDigest Compilation anaerobic digester feedstock.

Item	Realistic CoDigest Compilation
Daily Biogas Production (kNm^3/year)	8,306
Energy Production per year (GJ/year)	182,733
Energy Production per t.HSCW (GJ/t.HSCW)	1.4
Electrical Energy (MWhe)	2.37
Thermal Energy (MWht)	2.42

In summary, the pre-selected solid organic streams on-site exhibit potential as substrates for anaerobic digestion, offering prospects for biogas production. The generated biogas holds the potential to offset a portion, if not the entirety, of the facility's energy consumption and contribute towards the NSW beef processing plant's carbon neutrality objectives. The forecast biogas and energy production from solids audit is depicted in Figure 4 below.

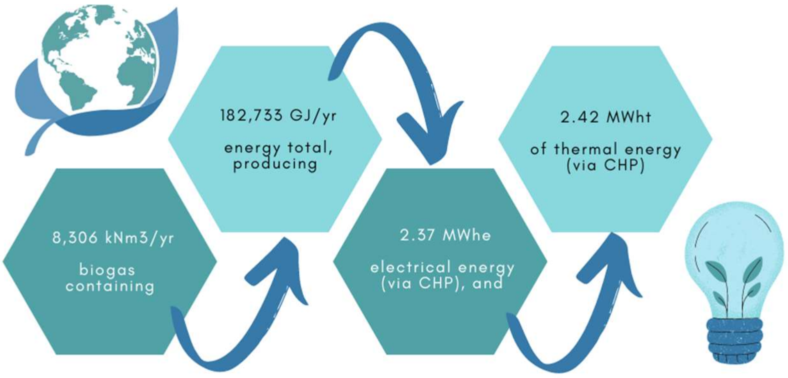


Figure 4. Forecast biogas and energy production from solids audit.

It is recommended that the NSW case study facility continues to undertake BMP tests for various likely ratios of co-digestion feedstock that will be available for the full-scale Bioresource Recovery Centre implementation. It is therefore advised to actively respond to the expression of interest for laboratory-scale pilot anaerobic digestion trials in collaboration with Tessele Consultants, Griffith University and the AMPC as part of the RACE for 2030 study.

7.3. Biogas Plant

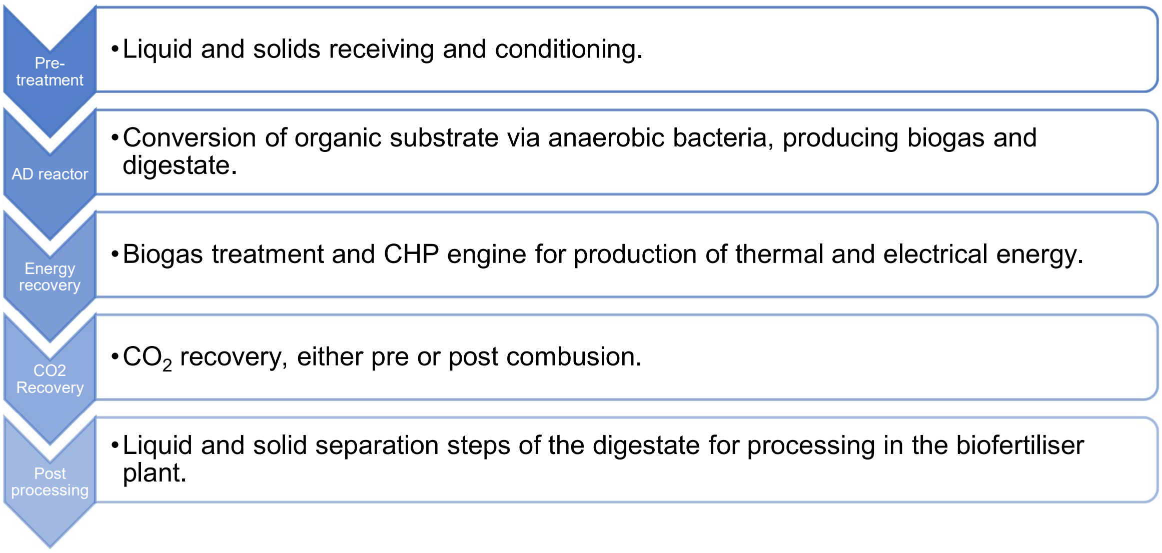
This section provides the anaerobic digestion plant Front-End Engineering Design to be implemented at the NSW case study facility, the required equipment and suppliers, and a cost estimate. This section also encompasses technical drawings for the anaerobic digestion plant.

7.3.1 Design

Following the waste-to-energy concept, the future biogas plant at the NSW case study facility will be comprised of anaerobic digesters, which will receive organic by-products produced in the facility and yield energy and heat, fostering bio-resource recovery. Besides contributing to reducing the facility's carbon emissions, it promotes a circular economy and reduces dependency on fossil fuels.

The core technology to be installed in the biogas plant is the anaerobic digesters. The design also includes ancillary equipment and will receive the sludge by-product streams from the red meat processor wastewater treatment plant as well as the solid feedstock from the red meat processing facility and leftover parts of harvested crops on the NSW beef processing plant land.

The biogas plant contains a pre-treatment step for the conditioning of the substrate and post-processing steps to deal with the renewable by-products of the process: biogas (energy), CO_2 (food grade) and digestate (nutrients and carbon). The process stages of the biogas plant are outlined in Figure 5.



- Liquid and solids receiving and conditioning.
- Conversion of organic substrate via anaerobic bacteria, producing biogas and digestate.
- Biogas treatment and CHP engine for production of thermal and electrical energy.
- CO_2 recovery, either pre or post combustion.
- Liquid and solid separation steps of the digestate for processing in the biofertiliser plant.

Figure 5. Summary of the process stages of the biogas plant.

The following subsections present the summary design of each stage in the biogas plant. Please refer to Appendix 4 for the biogas plant technical drawings.

Pre-treatment and substrate conditioning

The biogas plant’s enclosed shed for solid substrate receiving includes an odour treatment system and protects organic substrates from environmental conditions while allowing flexible handling and mixing of different organic streams for AD reactor feeding, where liquid and solid substrates are mixed to become pumpable for subsequent processing steps.

Solids receiving

Solid organic substrates, which are not pumpable, are transported from the red meat facility to the receiving bay using either an automatic system like a screw conveyor or manual loading. This combined material is transferred to the biogas plant solids receival area at a rate of ~93 tonnes per day (~130 tonnes per production day, assuming a 5-day week), where it is then gradually transported to the feeding hopper.

Liquids Receiving

The liquid streams (secondary sludge from the DAF units and dilution water from the wastewater treatment plant) represent a total volume of ~186 kL per day (7 day/week wastewater treatment plant operation). These streams will be pumped at a continuous flow rate into a liquid receiving tank of 404 kL volume, equipped with two side entry mixers, and then pumped to the substrate mixing tank (Table 35).

Table 35. Liquids receival equipment design conditions and basic specifications.

Tag	Design conditions	Basic Specifications
TK.008	Tank Volume: 404 kL Operational Volume: 375 kL Diameter: 8.5 m Height: 7.1 m Material: Glass fused steel	Receiving tank including camlock fitting for rapid connection and flexibility to receive liquid effluent from external sources. Fixed roof.
A-001 A-002	Side entry mixer: 10W per kL 2 mixers of 1.9 kW each	Side entry substrate mixing at the tank bottom
P.001 P-002	Liquid Receiving Tank Transfer Pumps	Progressive Cavity Pump Capacity: 3 to 8 kL/h Pump power and head to be confirmed during detailed design, based on site location and elevations (1 Duty + 1 Standby)

Substrate Mixing

Solid streams are conveyed into a feeding hopper, which uses a paddle drum to loosen and macerate the material. A rotating auger advances solids to a grinder that reduces them to approximately 5mm for efficient digestion (Table 36). A liquid-to-solid ratio of 10:1 is maintained to prevent blockages in the pipes feeding the blending tank.

Table 36. Substrate mixing equipment design conditions and basic specifications.

Tag	Design conditions	Basic Specifications
U.001	Hopper Capacity: 15.45 kL per load	Solids content: 15% to 60% TS Rotating auger shaft at its bottom allows solids to move forward to the substrate homogenisation tank.
IG-001	Shaft Grinder	Inline shaft grinder to guarantee an average solids particle size of 5mm in the AD process

Substrate Homogenisation

Substrates are homogenised in a 404kL blending tank equipped with mixers and recirculation pumps to achieve optimal homogeneity and total solids content before introduction into the AD reactors (Table 37), ensuring fluidity and reduced sedimentation. The blending tank provides up to two days of buffer capacity.

Table 37. Substrate homogenisation equipment design conditions and basic specifications.

Tag	Design conditions	Basic Specifications
TK.009	Tank Volume: 404 kL Operational Volume: 375 kL Diameter: 8.5 m Height: 7.1 m Material: Glass fused steel	Receiving tank including camlock fitting for rapid connection and liquid effluent receival from occasional external sources. Tank includes a cover which feeds the biogas collection system.
A-004 A-005	Side entry mixer: 10W per kL of the tank 2 mixers of 1.9 kW each	Side entry substrate mixing at the tank bottom
P.003 P.004	Recirculation Pumps	Open impellor or grinder pump Capacity: 7 to 62 kL/h Pump power and head to be confirmed during detailed design, based on site location and elevations (1 Duty + 1 Standby)
P-005 to P-012	Transfer Pumps	Progressive Capacity Pump Capacity: 3 kL/h Pump power and head to be confirmed during detailed design, based on site location and elevations (4 Duty + 4 Standby)

Anaerobic digesters in series

The biogas plant uses a wet co-digestion process in a continuous stirred tank reactor (CSTR) setup, operating at a mesophilic temperature of 37°C with a total hydraulic retention time (HRT) of 40 days. The digesters have an organic loading rate (OLR) of 2.6 VSS/m3 and receive substrates with a total solids content of approximately 12% TS. The plant includes eight anaerobic digesters arranged in four modules of two reactors each, working in series. The system features two stages of digestion, hydrolysis and methanogenesis, each taking 20 days.

Each of the AD reactors has an equal volume of 1,566 kL. The reactors will include a biogas double membrane holder dome that will have a holding capacity of approximately 550 Nm^3 of biogas per digester, providing an average of just over 4 hours of gas storage per digester. However, the secondary digesters are expected to generate significantly more biogas than the primary digesters, which should be considered during subsequent detailed design phases of the project. The digesters are also equipped with external blowers to maintain adequate pressure in the double membrane gas holder domes. The anaerobic digestion equipment design conditions and basic specifications are shown in Table 38 below.

Table 38. Anaerobic digestion equipment design conditions and basic specification.

Tag	Design conditions	Basic Specifications
R.004 (A-H)	Total solids substrate inlet: 12% Total solids substrate inlet acceptable range: 8% to 15% TS Hydraulic retention time: 20 days per digester, 40 days per train (two digesters in series) Operational hours: 24 hours OLR: 2.6 kg VSS/m^3 Acceptable OLR range: 1 to 4 kg VSS/m^3 Capacity (per digester): 1,566 kL Operational Volume (per digester): 1,474 kL Diameter: 15.36 m Height: 8.46 m	Material: Glass fused steel
A-006 to A-021	R.004 (A-H) mixers	Two side-entry mixers of 7kW each, per reactor
P-013 P-014 P-017 P-018 P-021 P-022 P-025 P-026	R.004 (A/C/E/G) (hydrolysis reactors) transfer pumps	Progressive Capacity Pumps Pump duty: 3 kL/h Pump power and head to be confirmed during detailed design, based on site location and elevations (4 Duty + 4 Standby)
P-015 P-016 P-019 P-020 P-023 P-024 P-027 P-028	R.004 (B/D/F/H) (secondary reactors for gasification) transfer pumps	Centrifugal Pumps Pump duty: 3 kL/h Pump power and head to be confirmed during detailed design, based on site location and elevations (4 Duty + 4 Standby)
B.001 to B.004	Air flowrate and required pressure TBD by suppliers	4 blowers (2 duty, 2 standby) to be shared across all modules. Power TBD by suppliers.

Digestate storage and processing

After treatment, the digestate produced is to be stored in a covered tank with 892 kL of operational volume (Table 39) offering up to 3 days buffer capacity to the system (based on a daily production of 279 kL of digestate). The digestate is to be further processed in the biofertiliser plant.

Table 39. Digestate storage equipment design conditions and basic specifications.

Tag	Design conditions	Basic Specifications
TK.010	Holding Capacity = 3 days Tank Volume: 948 kL Tank Operational Volume: 892kL Diameter: 11.94 m Height: 8.46 m Material: Glass fused steel	Post-digester Buffer / Storage Dome roof double-membrane gas collection system
A-022 A-023	Side entry mixer: 10W per kL of the tank 2 mixers of 4.5 kW each	Side entry substrate mixing at the tank bottom
P.029 P.030	Digestate storage tank transfer pumps	Centrifugal pump Pump duty of 11.6 kL/h Pump power and head to be confirmed during detailed design, based on site location and elevations (1 Duty + 1 Standby)

Biogas Treatment

As the raw biogas is expected to significantly exceed 2,000 ppm H_2S concentration, it must undergo pre-treatment to remove H_2S, siloxanes and humidity before it can be used in boilers or CHP engines. This involves dehumidification of the ~38 – 40°C biogas via chilling to 3-5°C, integrated with a heat exchanger and knockout drum filter for condensate removal (Table 40). The biogas pressure is boosted to feed either CHP engines/boilers at adequate pressure and flow rates. Yearly biogas production is expected to be approximately 8,306 kNm^3.

Table 40. Biogas treatment design conditions and basic specifications.

Tag	Design conditions	Basic Specifications
GT.001 (A-D)	Average biogas flowrate: 253 Nm^3 per hour per module (four modules of two digesters in series) Maximum biogas flowrate: 300 Nm^3 of biogas per hour per module	Biogas relative humidity: 100% (saturated) Biogas source: AD system Average CH_4 content: 60% Biogas inlet Temp: 38˚C Biogas outlet Temp: 3˚C Biogas conditions after blower: 20˚C @ 120 mBar Biogas inlet pressure ± 5 mBar H_2S inlet: >2,000 ppm Siloxanes ~ 1 ppm (TBC)

Emergency Flare

The biogas flare (Table 41) is adopted as a safe disposal of the biogas in case of equipment failure or maintenance.

Table 41. Emergency flare design conditions and basic specifications.

Tag	Design conditions	Basic Specifications
FL.001	Flow rate range: 253 to 1,011 Nm^3 of biogas per hour	Pressure: 60 to 120 mBar Gas pipe: 125 mm Flame Pipe: 800 mm

Energy Production

Four CHP units with the same capacity and a heat exchanger integrated are designed in parallel (Table 42). The total biogas flow rate is 948 Nm^3 per hour and per CHP unit it is 237 Nm^3 per hour. The total demand for the 4 CHP units is ~22,756 Nm^3 per day, which is equivalent to the expected daily biogas production. It is recommended that the engines operate continuously for 24 hours/day, with an approximately biogas consumption of ~5,689 Nm^3 per engine per day. Each unit can produce 592 kWe of electric power and 606 kWt of thermal power. Energy surplus to the needs of the Bio-Resource Recovery Facility can be used by the red meat processing operations, and the heat can be used for heating the anaerobic digesters and the biofertiliser plant.

Table 42. Energy Production equipment design conditions and basic specifications.

Tag	Design conditions	Basic Specifications
CHP.001 (A-D)	Overall biogas flow: 948 Nm^3 per hour Biogas flow per CHP unit: 237 Nm^3 of biogas per hour Biogas Methane content: 60%	Efficiency Electrical: 40.5% Efficiency Thermal: 41.5% kWe produced per hour: 592 kW (per CHP unit) kWt produced per hour: 606 kW (per CHP unit)
E.001 E.002 E.003 E.004	Heat exchanger integrated with CHP	Maintain reactor temperature at 37˚C

7.3.2 Biogas Plant Cost Estimate

Based on quotes from up to three suppliers for each equipment package (Table 43) and cost estimate methodologies, a cost estimate was accomplished for the implementation of the biogas plant (Table 44). Which is valuable for decision-making and financial planning, enabling stakeholders to assess feasibility and make informed choices regarding the anaerobic digestion plant implementation.

Table 43. Biogas plant equipment package and recommended supplier.

Biogas plant equipment package	Recommended supplier
Substrate receiving and pre-treatment	Boerger Finn Biogas
Anaerobic Digestion	Weltec Biogest Boerger Finn Biogas
Gas Treatment System and CHP units	Evo Energy Technologies Finn Biogas
Digestate Handling and Storage	Boerger Finn Biogas
Ancillary Equipment (pumps)	Boerger Finn Biogas

Table 44. Summary of the cost estimate for the biogas plant.

Description	Cost (Million AU$)
Contract preliminaries including supervision, safety, insurance etc (18% excluding equipment cost)	0.5
Contingency for installation and delivery (5%)	1.0
Design and Project Management (10%)	2.0
Biogas Plant Breakdown	
Civil Works	0.7
Amenities Lab/Control Room	0.8
Equipment Supply	14.0
Pipework	0.3
Electrical	0.8
Subtotal	**20.0**
Escalation (10%)	2.0
Total for full implementation of the biogas plant	**22.0**

7.4. CO_2 Recovery Plant

CO_2, primarily used in the red meat industry as dry ice for preserving and transporting products, has faced supply challenges in Australia in recent years, due to global supply chain disruptions, increased demand, and production facility closures. This has caused higher costs and product assurance issues, leading some red meat processors, such as the NSW case study facility, to look into alternative CO_2 supply chains. The CO_2 recovery plant concept design was conducted by using the estimated biogas production, where it is assumed that 40% of the biogas is comprised of CO_2. This section includes an analysis of CO_2 recovery technologies, and their industry readiness. It also presents the CO_2 recovery plant concept design, technical drawings, equipment list, recommended suppliers and a cost estimate.

7.4.1 Technology assessment

Various techniques for carbon dioxide (CO_2) recovery from biogas were analysed, including water and chemical absorption, physical scrubbing, membrane separation, and cryogenic separation. Table 45 summarises the advantages and disadvantages of techniques for CO_2 recovery from biogas.

Table 45. Advantages and disadvantages of CO_2 recovery techniques.

Techniques	Principles	Advantages	Disadvantages
Water scrubbing with Solvent Extraction	• Biogas treated with high-pressure water in a counterflow set up• CO_2 dissolves into water from biogas • Methane-rich biogas exits column	• Relatively simple process to recover CO_2 and remove H_2S from biogas • Yields high methane concentration at the output (over 99%) • Can recover 99.99% of CO_2 and H_2S • Solvent regenerated without degradation • Low energy required to regenerate the solvent	• High pressure needs higher energy • Slow process • Needs larger column volume than chemical absorption • Requires a lot of water even with regeneration • Corrosion problem due to H_2S • Clogging due to bacterial growth • High CAPEX
Chemical Scrubbing	• Employs amine or alkali solutions as absorbents • Chemicals react with CO_2 in the biogas, which is then recovered from the chemical stream after steam or heat is applied	• High CO_2 purities (>95 %). • The process is faster than water scrubbing • Smaller column volume than water scrubbing • Chemical solvent is easier to regenerate	• Energy-intensive due to the required steam for chemical regeneration • Solvent difficult to handle • Corrosion problems • Waste chemicals may require treatment • May require further separation process if H_2S concentration is high
Physical Scrubbing	• Utilises solvents in which CO_2 is highly soluble • Polyethylene glycol (PEG)	• Higher absorption rather than water • High CO_2 purities (90 -99%) can be achieved depending on the patented technology	• Need higher energy to regenerate the solvent • Solvent is expensive and difficult to handle • Limited capacity caused by low-efficiency CO_2 absorbents, making it non-viable for commercial-scale applications until R&D progress is made for more suitable absorbents • Patented technologies
Membrane-based Techniques	• Utilises differential permeability of CO_2 and methane • Highly permeable CO_2 passes through to the permeate • Low permeability methane remains in the retentate • Single-stage or multistage	• Fast installation and start-up • Production output is flexible • Purity and flow rate can vary • High CH_4 purities (>96 %)	• Consumes relatively more electricity per unit of gas produced • High-cost membrane •Most membranes have a short service life
Cryogenic Separation	• Relies on condensing gases into liquids at specific temperature-pressure conditions • Biomethane is produced by cooling and compression of biogas	• High CH_4 purities (90–98 %) • Produce CO_2 in marketable form (dry ice) • Liquid methane reduces the gas volume, thus can be packaged in the pipeline and easily distributed	• Uses lots of process equipment, mainly compressor, heat exchanger and cooler • High operating and maintenance costs. • Solidification of CO_2 at low temperatures leads to pipeline blockage • Not suitable for the capture of low CO_2 volume fraction

The major CO_2 recovery technologies were compared by Evo Energy Technologies (a biogas and CO_2 recovery expert supplier) and are summarised in Table 46.

Table 46. Multicriteria assessment of presented CO_2 recovery technologies.

Technology	Membrane Process	Amine Process	Cryogenic Process
Required Energy	Electricity	Electricity and steam	High electricity
Separation efficiency	Declines with age of membrane	Declines with higher oxygen in flue gas	No noticeable decline
Economic feasibility	Dependant on RNG sale price	Dependant on asset utilisation	Dependant on asset utilisation
Turndown operation	Up to 50%	Up to 30%	-
CAPEX	Highest $/MT of CO_2	Lowest $/MT of CO_2	-
OPEX	$170-$280/MT of CO_2	$150-$220/MT of CO_2	-
Maintenance	Certified skilled technicians required	Skilled technicians required	-
Ease of operation	Online monitoring, maintenance personnel required	Plant operators required	-
Technology Readiness Level - Ranking	9	10	3

7.4.2 Design

A comparison has been made between technologies recovering CO_2 from three different sources at the NSW case study facility, they are the boiler stack, and the pre and post-CHP biogas engine streams. The CO_2 recovery plant will focus on producing food-grade CO_2 for internal use. If there is a surplus of CO_2 production, the NSW case study facility may choose to use the CO_2 within their other facilities, a current preference over potentially commercialising CO_2 for sale to third-party off-takers. The CO_2 recovery plant will not only promote a circular economy by reusing the site's underutilised resources, but also offer the potential to reduce costs and bring additional revenue to the facility.

According to Evo Energy Technologies CO_2 Recovery Report, amine scrubbing is the recommended option, which will be used for post-CHP engine flue gas, due to its ability to capture the 40% CO_2 content in biogas in addition to the CO_2 produced during biogas combustion in the CHP engines. Amine scrubbing is proven and widely used in CO_2 production plants globally. On the other hand, Evo Energy Technologies identified that membrane technology is economically effective for biogas flow rates under 3,500 Nm^3/hr only and that the membrane processes pre-CHP yield less CO_2 than the amine scrubbing post-CHP option. Additionally, it was noted that the flue gas from the existing coal boiler offers lower CO_2 recovery compared to post-CHP gases, making it a less efficient choice for the same CAPEX. Post-biogas combustion provides higher CO_2 recovery than post-coal combustion for the same level of heating. Given the technology readiness level of the cryogenic process, it was disregarded for the CO_2 recovery plant. Therefore, the selected CO_2 recovery technology is the chemical absorption method using amine for biogas post-combustion (CHP engine exhaust), the design of which was undertaken by Evo Energy Technologies and is summarised in Table 47 below. It is recommended that the ultimate technology choice should be revised after a comprehensive re-assessment using the NSW beef processing plant business priorities and expansion strategies.

Table 47. CO_2 recovery design conditions and specifications.

Unit	Description	Design Conditions	Basic Specifications
Amine Scrubber Unit	1x Gas Scrubber (pretreatment cools and purifies the gas)	Operated with condensate Gas scrubber Lower section water quench Upper section chemical neutralisation (NaOH-lye) Water-recycle pump Recycle condensate cooler Flow meter Sensor for liquid level Required regulating valves and control modules	20kW
	1x Amine Scrubber	Operated with MEA-solution Consist of a gas scrubber Water-recycle pump Recycle condensate cooler 2x MEA transfer pumps Flow meter Sensor for the liquid level Required regulating valves and control modules	
	1x Amine Stripper	Operated with external heat source (MP-steam) for regeneration of the Rich-MEA solution Containing reboiler, including all required regulating valves, control modules and insulation	
Blower for flue gas			55kW
Compressor			110 kW
Drying Unit			15kW
Purification Unit			15 kW
Refrigeration Unit			90 kW
Blowers at Cooling tower			44 kW
Cooling water pump			75 kW
Switch board			5 kW

The amine for biogas post-CHP exhaust process efficiently removes CO_2 due to the high reactivity of amine solvents and directs exhaust gas through an absorption column where it contacts counter-current amine solvent. The captured CO_2 forms a chemically bound compound, which is then regenerated in a stripper unit to release pure liquid CO_2 for use by the NSW case study facility as dry ice for meat packing. This method offers low CAPEX, high liquid CO_2 quantity, reasonable production cost and operating expenses, and a short payback period. The process ideally requires 24/7 operation, due to long start-up and shut-down times, thus requiring a baseload of power at all times.

Appendix 5 shows the process flow diagram of the CO_2 recovery plant utilising the chemical absorption method with an amine solvent for biogas post-CHP engine exhaust proposed by Evo Energy Technologies. Considering the amine scrubbing for post-CHP technology and the design capacity of 135,200 t.HSCW/yr the recovered amount of liquid CO_2 is 9,200 tonnes/yr.

Note that the NSW case study facility currently has a snow horn system that produces dry ice snow from liquid CO_2 as a method to flash freeze their product. According to the amount of liquid CO_2 that will be recovered in the CO_2 plant (assuming a design stage of 135,200 t.HSCW/yr), the demand for liquid CO_2 is approximately 50% of the produced amount, resulting in a 50% surplus. It is known that a solid dry ice system can be implemented to enhance the surplus percentage. While the snow horn system requires 4.5 kg of liquid CO_2 to produce 1 kg of dry ice snow, the solid dry ice system requires 2.2 kg of liquid CO_2, if a recovery system is implemented, the intake of liquid CO_2 decreases to 1.3 kg. Thus, the surplus rates would be approximately 70% and 80%, respectively. Although the NSW case study facility is focused on producing food-grade CO_2 for internal use, it is important to note that offering the CO_2 surplus to their other facilities as well as commercialising it may provide additional income to the NSW case study facility. Table 48 shows the comparison between dry ice and CO_2 snow systems.

Table 48. Comparison between dry ice and CO_2 snow systems.

Dry Ice	**CO_2 Snow Production**
Low conversion ratio (2.2 kg of liquid CO_2 to 1 kg of solid CO_2, if a recovery system is implemented: 1.3 kg of liquid CO_2 to 1 kg of solid CO_2).	High conversion ratio (4.5 kg of liquid CO_2 to 1 kg of solid CO_2).
Minimum CO_2 Vapor.	Creates a large amount of CO_2 vapour.
High-density pellets are extruded.	Product lost due to high exhaust requirements.

7.4.3 Cost Estimate

Based on the quotation provided by Evo Energy Technologies, the cost estimate summary below (Table 49) shows the anticipated expenses for the NSW case study facility CO_2 recovery plant. It establishes the capacity for CO_2 recovery and production for processing up to 135,200 t.HSCW/yr of red meat. Given that the CO_2 recovery plant would be implemented along the biogas plant, costs regarding civil works, project management and installation were considered in the biogas plant cost estimate and excluded from the CAPEX presented below.

Table 49. CAPEX summary for the CO_2 recovery plant.

Description	**Cost (Million AU$)**
CO_2 recovery unit	7.2
CO_2 storage tanks	0.5
CO_2 analyser	0.4
Total for the CO_2 recovery Plant	**8.1**

7.5. Biofertiliser Plant

This section includes the concept design of a bio-based fertiliser plant for the NSW case study facility, detailing design specifications, operational requirements, equipment and suppliers, cost estimate, and design drawings, as well as characterising the fertiliser and analysing environmental regulations for bio-based products.

7.5.1 Digestate characterisation and quantification

The digestate's characteristics and quantifications at the NSW case study facility are shaped by the substrate type and biogas plant operation schedule, respectively. It is known that the biogas plant will process 279 kL of feedstock per day (under a 24/7 operation schedule). It was assumed that the digestate volume after the anaerobic digestion is equal to the substrate amount fed to the process. Given that the biofertiliser plant will operate 5 days a week, the inlet stream of the plant comprises 392 tonnes per day. Table 50 presents the quantities of the inputs, interim outputs, and final outputs of the bio-based fertiliser plant based on expected digestate characteristics and the capabilities of selected processing technologies.

Table 50. Inputs and outputs of the bio-based fertiliser plant.

Bio-based Fertiliser Plant Input/output	Item	Tonnes per Year	Tonnes per Operational Day	Total Solids (TS)
Input	Digestate from AD	101,807	392	5%
Interim output	Cake after dewatering	23,138	89	22%
Interim output	Thermally dried cake	5,989	23	85%
Final bio-based fertiliser output	Pellets Production	5,656	22	90%
Final bio-based fertiliser by-product output	Liquid filtrate sent to WWTP (kL)	96,151	370	<1%

7.5.2 Environmental regulation for bio-based solids and liquids

Before advancing with the biofertiliser plant design, it is crucial to understand relevant regulations and their impact on process design and final product application. A regulatory review found no existing regulations for biofertiliser from red meat digestate in NSW, suggesting the use of municipal biosolids guidelines as a framework. Analysis of the dewatered sludge from an anaerobic pond of a red meat facility located in the Australian southwest indicated that red meat digestate-derived biofertiliser could achieve a pathogen and contaminant level comparable to domestic biosolids Grade B, potentially reaching Grade A with pasteurisation.

The NSW municipal biosolids guideline is more progressive than some other areas of Australia, enabling a wider range of biosolids uses. Liquid anaerobic digestate (<7% TS) can be used for Grade A purposes if pasteurised at 70°C for 30 minutes, while Grade B (unpasteurised digestate) can still be used for a large variety of agricultural uses. Liquid digestate can be injected below the surface or applied on land, provided it is incorporated within six hours. Figure 6 shows the different biosolids uses permitted with liquid digestate in NSW.

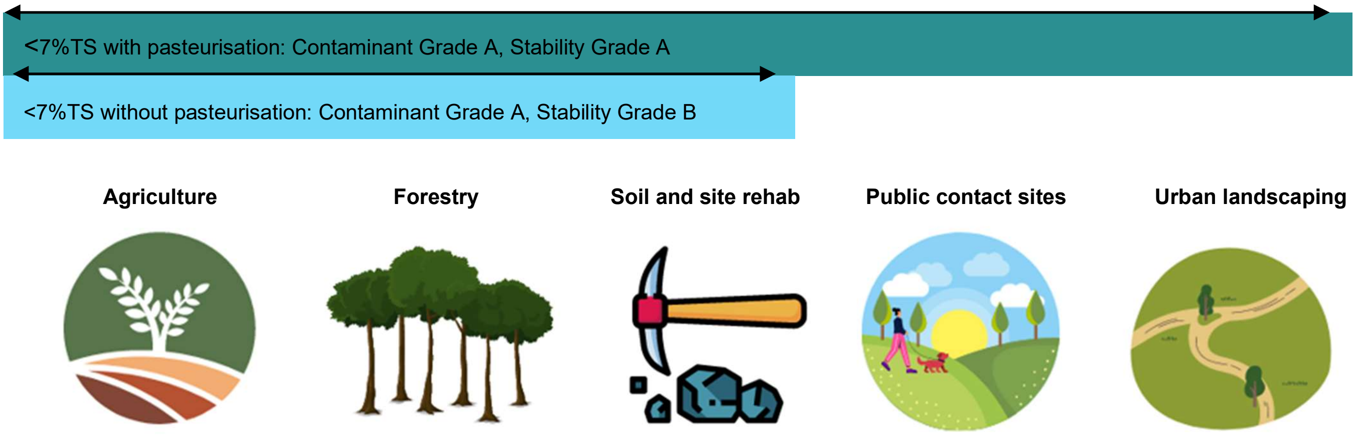


Figure 6. Applications of biosolids according to New South Wales (NSW) biosolids regulations.

7.5.3 Assessment of digestate and side-stream processing technologies

Various technologies have been evaluated for potential integration into the bio-based fertiliser plant, with each option requiring thorough analysis to align with the project's sustainability and environmental objectives. Selection criteria for the digestate and filtrate processing have been compared in Table 51 below.

Table 51. Selection criteria of digestate and side stream processing technologies applied to the NSW case study facility.

Processing Option	Details	Environmental	Social	Capex + Opex
Digestate processing	Liquid digestate (pasteurised or unpasteurised)	🟧	🟧	🟩
	Pelletised bio-based fertiliser	🟩	🟩	🟩
	Biochar from gasification	🟩	🟩	🟨
	Biochar from pyrolysis	🟨	🟩	🟨
Filtrate processing	Mainstream WWTP	🟩	🟩	🟩
	Struvite recovery	🟩	🟩	🟧
	Annamox	🟩	🟩	🟨

Out of all the processing technologies assessed, the most favourable alternative identified in the feasibility study involves dewatering, drying, and pelletising the bio-based fertiliser. This option boasts a small volume of product, simplifying transport and reuse besides keeping most of the nutrient content in the final product. Additionally, it is recommended that the filtrate side stream be directly returned to the initial stage of the WWTP due to ease of application and reduced cost, energy, and area requirements.

7.5.4 Selected biofertiliser product

Although liquid digestate is allowed for direct land use in NSW, the case study facility raised concerns about the nutrient balance of their land when used in conjunction with their recycled non-potable water. Using both liquid digestate and irrigation on their land could lead to liquid over-saturation and too much nutrient application to their land, resulting in non-compliance with environmental standards. Producing biofertiliser pellets from liquid digestate, for off-take to third parties, offers better storage and transportation due to the significantly reduced volume of a now dry

product, it also reduces odours. Given NSW case study facility's strategic goals and high regional demand for fertilisers due to nearby agricultural lands, pellets are preferred for their cost-effectiveness, ease of handling, and broad application uses. This approach aligns with the NSW case study facility's objectives and regional agricultural needs, making biofertiliser pellets the most suitable product.

7.5.5 Biomass as a Fuel

The Australian Beef Sustainability Framework points out that significant impact of high energy costs on the competitiveness of processors in the global market. This framework emphasizes profitability throughout the supply chain and pledges to reach carbon neutrality by 2030 (CN30), underscoring the importance of sustainable practices in the meat processing industry.

The Australian Meat Processor Corporation's (AMPC) experimental project at Riverina's Yanco facility in New South Wales, exploring the viability of biomass boilers for sustainable fuel in meat processing plants, has yielded promising results. This initiative, conducted at JBS, achieved a notable milestone by generating heat at a cost under $3 per gigajoule (GJ). The project showcased the feasibility of using various biomass materials, including partially digested grains and grass from animal stomachs, wood chips, nut shells, and sawdust. These materials were effectively mixed and utilised in a boiler to produce thermal energy.

In the context of energy sources for meat processing facilities, bioenergy currently ranks third, following grid electricity and natural gas, with coal being the fourth most used source. The cost-effectiveness of multi-fuel biomass is evident when compared to conventional thermal energy sources, such as onsite coal ($10/GJ) and grid gas ($25/GJ).

The NSW case study facility currently depends on coal boilers for its operations due to the absence of a natural gas network in its vicinity. This reliance is primarily attributed to the logistical challenges and increased costs associated with the procurement and transportation of bottled natural gas to their location. Given these constraints, the NSW case study facility has determined that coal is a more economically feasible energy source for them compared to the alternatives available. This situation underscores the need for infrastructure development in the region to provide more sustainable and cost-effective energy solutions.

Combustion

The process of digestate combustion emerges as an innovative and efficient method for managing by-products, transforming them into a source of renewable energy. This technique involves drying and pelletising digestate, which is then blended with wood in equal proportions. The resulting mixture serves as a fuel for conventional domestic air furnaces. This approach is not only effective in generating heat energy but also demonstrates the feasibility of this method in managing digestate sustainably. However, the calorific value from the resulting dried digestate is highly correlated to the feedstock used in the anaerobic digestors.

Hydrothermal Carbonisation (HTC)

Hydrochar production via hydrothermal carbonisation serves dual purposes as both fuel and soil amendment. However, its application is more suitable as a soil amendment due to limitations as a fuel.

The Hydrothermal Carbonisation (HTC) process, a notable advancement in material conversion, involves heating feedstock within a temperature range of 160–280 °C in an aqueous environment under autogenous pressure. The solid by-product, known as hydrochar, boasts multiple applications. It can be utilised as a biofuel, in the generation of syngas, and importantly, as a fertiliser and soil enhancer.

However, while the integration of HTC offers advantages in treating digestate and potentially enhancing biogas yields through the anaerobic digestion of process water, it's important to consider the suitability of the resulting hydrochar for specific applications. Notably, using hydrochar derived from digestate as a biofuel, presents challenges. The composition of its ash and the anticipated problems with slagging and fouling during combustion make it less than ideal for this purpose.

Given these limitations, it's advisable to explore alternative applications for the hydrochar produced. One promising avenue is its use in soil amendment. The nutrient-rich nature of hydrochar can contribute to soil health and fertility, making it a valuable resource in agricultural and environmental applications. Figure 7 shows the schematic representation of possible Hydrothermal carbonisation products and uses.

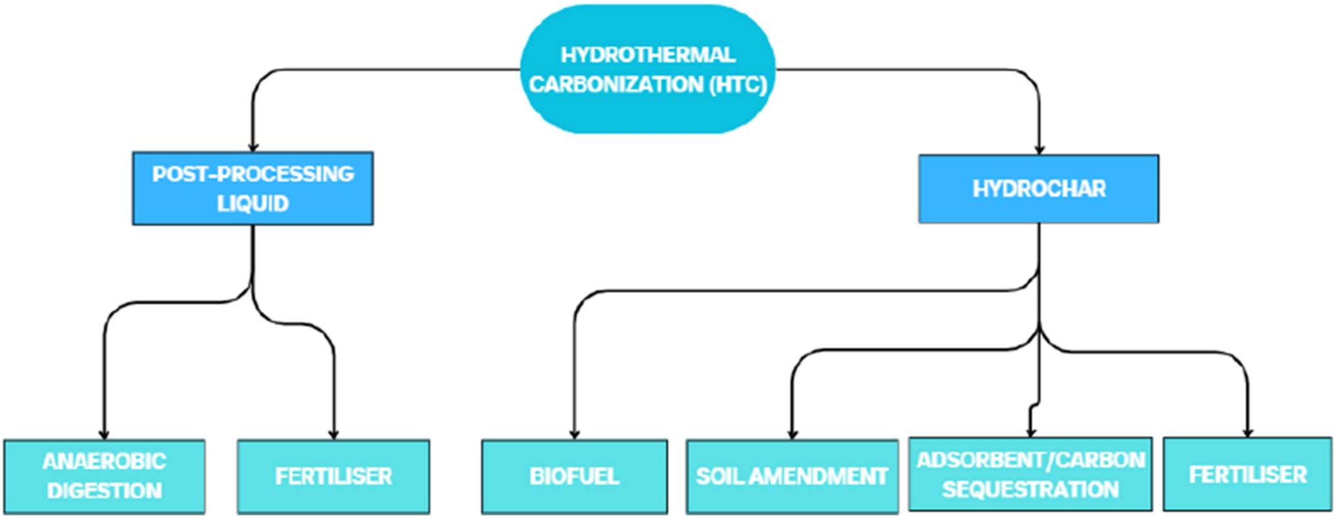


Figure 7. Hydrothermal carbonisation products and uses.

7.5.6 Design

The proposed digestate processing technology for implementation is mechanical dewatering, drying and pelletising the digestate into bio-based fertiliser pellets. Appendix 6 shows the general arrangement, process flow diagram, and elevations for the proposed design.

Dewatering

The dewatering process at the facility employs two screw presses to separate the liquid and solid content of the digestate, chosen for their availability, reliability, and proven performance in similar settings. The use of two presses, one as a standby, ensures uninterrupted operation during maintenance. The equipment design conditions and basic specifications are described in Table 52 below.

Table 52. Dewatering system design (screw press).

Tags	Design Conditions	Basic Specifications
LSS.001/002	Input: 5-14 m^3/hr at 5% TS 125 - 350 kg/hr DS per screw press (2 off)	2 x screw presses, including conditioning tank 1x control cabinet and instrumentation 1x electrical cabinet 1x screw conveyor for disposal 1x Solids meter 1x Macerator Polymer dosing system has been excluded following supplier's advice. However, this should be confirmed during further stages (R&D optimisation and detailed design) of the project.

Drying with pelleting

The drying and pelleting process for dewatered digestate involves conveying the material through a heated air system to produce pellets with ~90% TS, enhanced by a heat recovery system for efficiency. An advanced three-stage odour control system is also incorporated to manage emissions effectively. The design conditions and basic specifications of the dyer and pellet systems are described in Table 53 below.

Table 53. Drying and pelleting design specifications.

Tag	Operational Requirements	Basic Specifications
DS.001	Operational hours = 8,000 hrs/yr Input capacity = 23,137 t/yr of 22%TS dewatered digestate (cake) Output capacity = 5,990 t/yr of 85%TS product Heat consumption = 2,102 kWh Water temperature required = 90^{O} Celsius	Dosing mixer and frame (cake distribution onto dryer belt) Dryer (including floor cleaning system and drying belt) Agitators Back charge auger to dosing mixer (for mixing dry with wet product to get feed to >30%TS) Discharge augers Pressure fans, air ducts and recirculation Basic sprinkler system Control panel with remote access Three step chemical air scrubbers Biological scrubber: 50,000m^3 container
PL.001	Input dry matter content >85%TS Produced pellet size = 6mm Output dry matter content = 90%TS Running hours = 8,000 hrs/yr Input Capacity = 400 kg/hr per press (2 x off); 800 kg/hr in total	8m^3 intermediate bunker Output auger Crusher Screw conveyors Pellet press Sanitation unit Cooling unit with dust extraction cyclone Fine dust sieve removal Bag filling system, including bag frame and filling auger with manual valves

7.5.7 Equipment list, recommended suppliers and cost estimate

To streamline the engineering cost estimation process and facilitate future on-site equipment purchases, equipment manufacturers were requested to offer packages of equipment for different parts of the bio-based fertiliser plant. These packages include:

i. Dewatering.
ii. Drying, pelleting, and air treatment (odour control).

Refer to the Table 54 for the equipment list and recommended suppliers and Table 55 for the cost estimate for the biofertiliser plant.

Table 54. Bio-based fertiliser plant equipment packages and recommended suppliers.

Bio-based Fertiliser Plant Equipment Package	Recommended Supplier
Dewatering	Boerger Innovative Filtration Solutions Biogest Hydroflux Flottweg
Drying, pelleting, and air treatment (odour control)	Dorset Compost Matters

Table 55. CAPEX summary for the bio-based fertiliser plant considering a dewatering, drying and pelletising process.

Description	Cost (Million AU$)
Contract Preliminaries (18% excluding equipment cost)	0.2
Contingency for installation and delivery (5%)	0.3
Design and Project Management (10%)	0.7
Bio-based fertiliser Plant Breakdown	
Civil Works	0.2
Bio-based fertiliser shed	0.7
Equipment Supply	5.3
Pipework	N/A
Electrical	N/A*
Subtotal	
Escalation (10%)	0.7
Total for full implementation of the Bio-based Fertiliser Plant	**8.1**

* Electrical, instrumentation, and control were included as part of the equipment quotations.

7.6. Economic Analysis

7.5.8 Economic Analysis Scenarios

The economic analysis included different alternatives, encompassing full and partial BRRF implementation in single and double stages. The economic analysis scenarios are described and depicted in Table 56 and Figure 8, respectively. These scenarios were proposed by Tessele Consultants and validated by the NSW beef processing plant personnel.

Table 56. BRRF implementation scenarios considered in the economic analysis.

Scenario	Implementation	Proposed BRRF Implementation
1	Full BRRF	Long-term expansion design with CAPEX in one stage (WWTP, biogas, CO_2 and biofertiliser plants).
2	Partial BRRF	Long-term expansion design with CAPEX in one stage (WWTP, biogas and biofertiliser plants).
3	Partial BRRF	CAPEX in two stages (WWTP).
4	Partial BRRF	CAPEX in two stages (WWTP, biogas and CO_2 plants).
5	Partial BRRF	CAPEX in two stages (WWTP and biogas plants).
6	Full BRRF	CAPEX in two stages (WWTP, biogas, CO_2 and biofertiliser plants).
7	Partial BRRF	CAPEX in two stages (WWTP, biogas and biofertiliser plants).

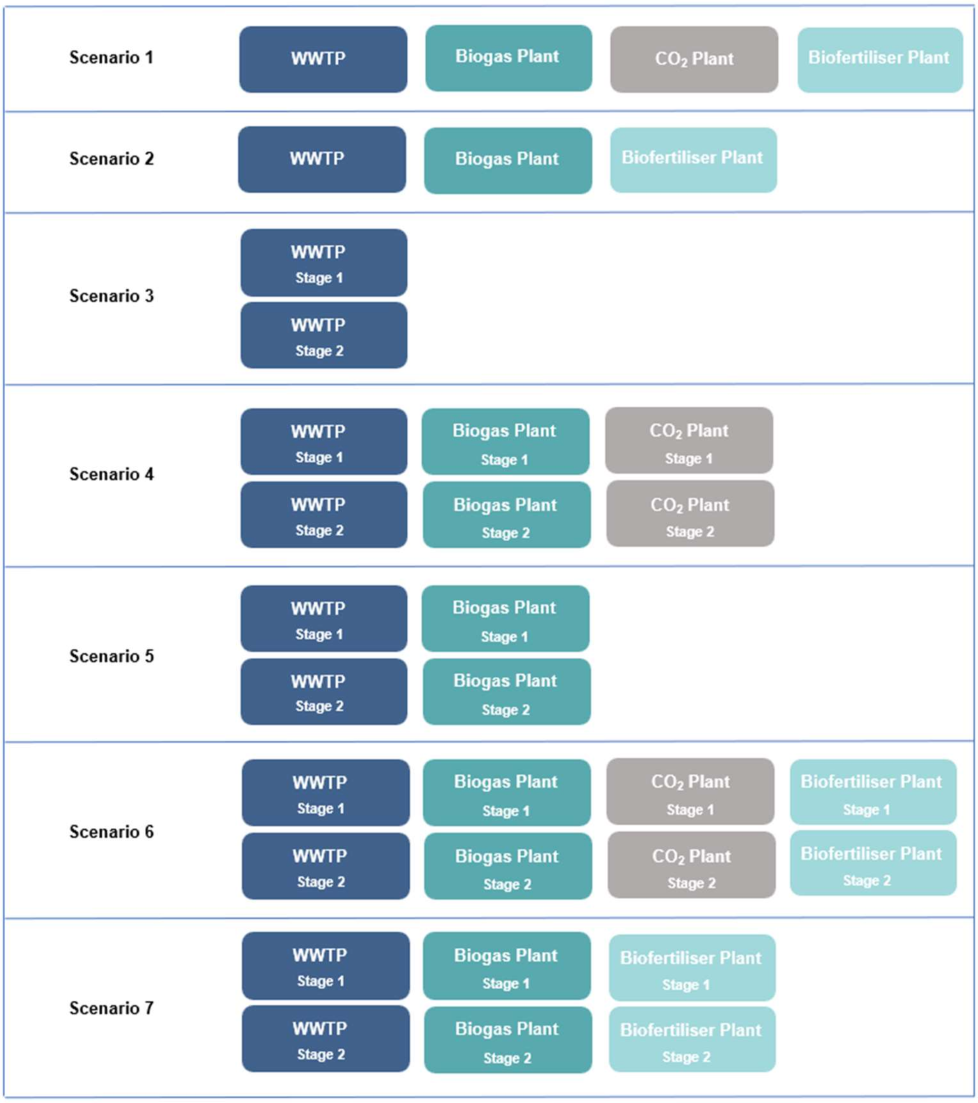


Figure 8. Economic analysis scenarios.

Table 57 outlines the planned expansion phases for the NSW case study facility, detailing their production capacities and resource demands, which were calculated using a conservative approach of linear proportion based on the facility's expansion capacity.

Table 57. Expansion phases and resources demand considered in the economic analysis.

Expansion Stages	t.HSCW /yr	Heads/yr	Water Intake (ML/yr)	Liquid CO_2 Demand (tonnes/yr)
Stage 1 (Execution* in 2026)	67,600	259,948	750	2,906
Stage 2 (Execution* in 2031)	135,200	519,948	1,500	5,811

*Where execution dates are the selected financial modelling dates however the NSW case study facility currently has no plans committed to delivering the project on these dates.

Utilising information on current production streams provided by the NSW beef processing plant personnel and the front-end engineering design completed by Tessele Consultants for the bioresource recovery plants, a summarised table (Table 58) was created to facilitate the economic analysis in the proposed scenarios. It's crucial to highlight that the interim stage values for the studied resources were determined using a linear relationship between current production and stage capacity. The resource value for the design stage was derived from the front-end engineering design.

Regarding the staged implementation scenarios, a 60% CAPEX investment was considered for building bioresource recovery plants that cope with the planned facility expansion for 67,600 t.HSCW/yr, assumed to occur within a two-year timeframe. The remaining amount of 40% CAPEX was regarded for the long-term facility expansion of 135,200 t.HSCW/yr projected to take place in 7 years. The higher percentage of CAPEX in Stage 1 is justified by site preparation for the full capacity implementation such as licensing, site civil works and preliminary actions (project management and equipment delivery), leaving the 40% CAPEX in Stage 2 only to accommodate the remaining equipment for the long-term facility expansion of 135,200 t.HSCW/yr.

The single-stage implementation accounts for the Stage 2 capacity (135,200 t.HSCW/yr) and assumes 100% of CAPEX will be incurred in 2026, coinciding with the anticipated start of the full plant construction. Note that the single and staged implementations considered escalation factors.

Table 58. Resource recovery plant capacity and CAPEX for different expansion stages.

	UOM	Current	Stage 1 (Execution* in 2026)	Stage 2 (Execution* in 2031)	Single stage (Execution* in 2026)
WWTP Capacity**	ML/yr	430	670	1,335	1,335
WWTP CAPEX	Million AU$	-	9.5	6.6	15.9
Biogas Production	Million Nm3/yr	-	4.2	8.3	8.3
Energy Production from Biogas***	GJ/yr	-	91,370	182,730	182,730
Liquid CO_2 Production	Tonnes/yr	-	4,600	9,200	9,200
Biogas and CO_2 plant CAPEX	Million AU$	-	20.0	14.0	33.3
Biogas Plant CAPEX	Million AU$	-	13.5	9.5	22.5
Biofertiliser production	Tonnes/yr	-	2,830	5,660	5,660
Biofertiliser plant CAPEX	Million AU$	-	5.0	3.5	8.3

* Where execution dates are the selected financial modelling dates however the NSW case study facility currently has no plans committed to delivering the project on these dates.
** Assuming 89% of the water used in the process becomes WW (According to AMPC ERP 2022).
*** Excluding efficiency rates of the CHP system.

In case site preparations in Stage 1 are disregarded, the project's capital investment can be considered as 50% in Stage 1 and 50% in Stage 2. Table 59 presents the required CAPEX for this approach. Note that the project's cost analysis (NPV evaluation) considered 60% CAPEX in Stage 1 and 40% in Stage 2.

Table 59. CAPEX values for Stage 1 and Stage 2 disregarding site preparations in Stage 1.

CAPEX	UOM	Stage 1 (Execution* in 2026)	Stage 2 (Execution* in 2031)
WWTP	Million AU$	7.9	8.3
Biogas and CO_2 Plant	Million AU$	16.6	17.4
Biogas Plant (alternative, without CO_2)	Million AU$	11.2	11.8
Biofertiliser Plant	Million AU$	4.1	4.3

* Where execution dates are the selected financial modelling dates however the NSW case study facility currently has no plans committed to delivering the project on these dates.

To assess in detail the CAPEX necessary for full implementation of the Bioresource Recovery Facility, Table 60 and Table 61 present the percentage of total CAPEX for each resource recovery plant in single and double-stage scenarios, respectively.

Table 60. CAPEX of BRRF components delivered in one stage.

Components of BRRF	CAPEX	Percentage of Total CAPEX
WWTP	$15.9M	28%
Biogas Plant	$22.5M	39%
CO_2 Recovery	$10.7M	19%
Biofertiliser Plant	$8.3M	14%
Sum	**$57.4M**	

The double-stage scenario below utilises 60% CAPEX in Stage 1 followed by 40% CAPEX in Stage 2.

Table 61. CAPEX of BRRF components delivered in two stages

Components of BRRF	CAPEX	Percentage of Total CAPEX
WWTP Stage 1	$9.5M	16%
WWTP Stage 2	$6.6M	11%
Biogas Plant Stage 1	$13.5M	23%
Biogas Plant Stage 2	$9.5M	16%
CO_2 Recovery Stage 1	$6.4M	11%
CO_2 Recovery Stage 2	$4.5M	8%
Biofertiliser Plant Stage 1	$5.0M	8%
Biofertiliser Plant Stage 2	$3.5M	6%
Sum	**$59.5**	

7.5.9 Income Assumptions

The income assumptions were executed identifying the amount of recovered bioresource from the BRRF that could bring value to the red meat processing site, multiplying them by the respective market prices. Most of the resource prices considered are based on what the NSW case study facility currently pays on-site, except for biofertiliser, by-products disposal and carbon credits costs.

A broad market research for pelletised biofertiliser was undertaken and adopted a conservative estimate of AU$600/tonne for the biofertiliser to be produced at NSW case study facility. It's important to highlight that the cost of biofertiliser plays a significant role in the BRRF cost analysis, directly affecting its feasibility. Therefore, adding value to the biofertiliser is crucial. It is recommended to conduct more in-depth market research to determine the potential market value of the biofertiliser produced at the NSW case study facility, identifying the NPK rates present in the organic material, marketing strategy and package as well as the target customer group.

By-products disposal costs arise from the on-site handling of organic by-products, which are processed in the facility's boiler before being disposed of in site ponds. The disposal cost was assumed as the cost of the thermal energy (coal) used for the cooking process. It was assumed an energy demand of 50kWh per tonne of organic by product cooked in the facility's boiler. Such an assumption was based on ≈10% of the energy consumption of a rendering process (Ramírez, C.A., et al).

The carbon credit cost was assumed as 32 AU$/tonne according to the latest price for an Australian Carbon Credit Unit (ACCU) reported by the Australian Government Clean Energy Regulator in mid-August 2023.

The expected amount and revenue from the different resources recovered in the plants (treated water, energy, liquid CO_2 and biofertiliser) for the staged implementation are presented in Table 62. It is important to note that for a single implementation, the expected amounts and revenue for each resource are equal to the combined values of Stage 1 and Stage 2. Given that the carbon credits vary for each scenario studied in the economic analysis, a detailed examination of the carbon credit values and revenues is described in the following section.

Table 62. Potential revenue from bioresource recovery.

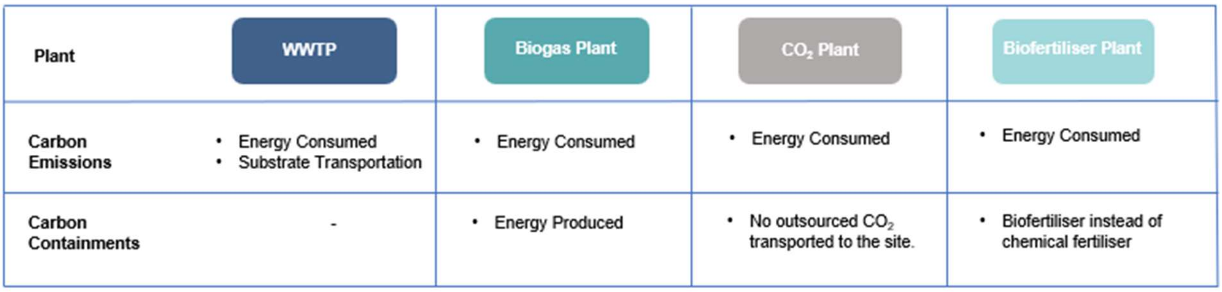
		Units	Stage 1 (Execution* in 2026)	Stage 2 (Execution* in 2031)
Recycled Water	Expected recycled water**	kL/yr	39,826	39,826
	Potential Revenue	AU$/yr	43,012	43,012
Energy	Electrical Energy from Biogas Plant	Mwhe	1.2	1.2
	Thermal Energy from Biogas Plant	MWht	1.2	1.2
	Electrical Energy Revenue	Million AU$/ yr	1.2	1.2
	Thermal Energy Revenue	Million AU$/ yr	0.4	0.4
Liquid CO_2	Recovered CO_2	tonnes/yr	2,906	2,906
	Expected Revenue	Million AU$/yr	3.2	3.2
Biofertiliser	Biofertiliser Produced	tonnes/yr	2,828	2,828
	Expected Revenue	Million AU$/yr	1.7	1.7
Saved Disposal Costs	Organic by-products	tonnes/yr	12,538	12,538
	Expected Savings	AU$/yr	25,423	25,423

* Where execution dates are the selected financial modelling dates however the NSW case study facility currently has no plans committed to delivering the project on these dates.

**The recycled water amount was calculated assuming that 6% of the treated wastewater will be allocated for non-potable uses at the facility. It is known that the remaining amount of treated water will be used for irrigation which does not bring additional income to the NSW case study facility.

Carbon credits

The approach used to calculate carbon credits in each scenario of the BRRF implementation started by identifying the boundaries of carbon emissions and containments of each plant as shown in Figure 9.



Plant	WWTP	Biogas Plant	CO_2 Plant	Biofertiliser Plant
Carbon Emissions	• Energy Consumed • Substrate Transportation	• Energy Consumed	• Energy Consumed	• Energy Consumed
Carbon Containments	-	• Energy Produced	• No outsourced CO_2 transported to the site.	• Biofertiliser instead of chemical fertiliser

Figure 9. Boundaries considered for the carbon credits estimate.

The energy demand for the wastewater treatment, biogas, and biofertiliser plants assumed a 100% running load, while the CO_2 plant used a 107% running load based on supplier recommendations. The substrate transportation emissions were allocated under the wastewater treatment plant since all studied scenarios for the economic analysis encompass this plant. The substrate transportation regards the organic by-products produced at the red meat facility which will be taken to the biogas plant.

The resource quantities identified in each plant within the boundaries considered for the carbon credits estimate were multiplied by the respective Australian National Greenhouse Accounts Factors (ANGAF) to determine the carbon emissions and containment for each plant in the different cost analysis scenarios. The carbon emissions and avoidances for scenarios 1 and 2 of the economic analysis are presented in Table 63, where negative values are the carbon emissions and positive values are carbon credits.

Table 63. Carbon emissions and avoidances for scenarios 1 and 2 of the economic analysis.

	Scenario 1 (tonnes CO_2-e/yr)	**Scenario 2 (tonnes CO_2-e/yr)**
WWTP		
Total CO_2-e Emission	-4,361	-4,361
Total CO_2-e Avoidance	0	0
Balance CO_2-e	-4,361	-4,361
Biogas Plant		
Total CO_2-e Emission	-2,587	-2,587
Total CO_2-e Avoidance	28,326	28,326
Balance CO_2-e	25,739	25,739

	Scenario 1 (tonnes CO_2-e/yr)	**Scenario 2 (tonnes CO_2-e/yr)**
CO_2 Plant		
Total CO_2-e Emission	-2,734	-23
Total CO_2-e Avoidance	23	0
Balance CO_2-e	-2,712	-23
Biofertiliser Plant		
Total CO_2-e Emission	-12,059	-12,059
Total CO_2-e Avoidance	4,357	4,357
Balance CO_2-e	-7,703	-7,703
Total Carbon Credits	***10,964***	***13,653***

The carbon emissions and avoidances for staged scenarios 3 to 7 are summarised in Table 64.

Table 64. Carbon emissions and avoidance for scenarios 3 to 7 of the economic analysis.

Scenario	**Stage 1 (tonnes CO_2-e/yr)**	**Stage 2 (tonnes CO_2-e/yr)**
3	-2,835	-1,526
4	12,133	6,533
5	13,881	7,474
6	7,126	3,837
7	8,874	4,778

Assuming the previously mentioned ACCU price of 32 AU$/tonne, the expected annual revenue from carbon credits for each studied scenario was calculated and is presented in Table 65.

Table 65. Expected yearly revenue from carbon credits for scenarios 1 to 7 of the economic analysis.

Scenario	**Total Carbon Credits (tonnes CO_2-e/yr)**	**Expected Revenue (AU$/yr)**
1	10,964	$350,833
2	13,653	$436,889
3	-4,383	-$140,271
4	18,666	$597,313
5	21,355	$683,369
6	10,964	$350,833
7	13,653	$436,889

7.5.10 Profitability measurements and best scenario

The economic analysis encompassed the capital expenditure costs combined with operational costs of 6% of CAPEX and revenue from recovered resources. Profitability measurements were calculated and are shown in Table 66 below.

Table 66. Profitability measurements for scenarios 1 to 7 of the economic analysis.

Scenario	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Plants*	**W** **B** **C** **BF**	**W** **B** **BF**	**2W**	**2W** **2B** **2C**	**2W** **2B**	**2W** **2B** **2C** **2BF**	**2W** **2B** **2BF**
NPV (Million AU$)	225.3	76.8	-41.5	138.2	5.5	195.8	63.1
Water CAPEX AU$/ ML	8,156	8,156	9,015	9,015	9,015	9,015	9,015
Energy CAPEX AU$/GJ	5	5	-	6	6	6	6
CO_2 CAPEX AU$/tonne	76	-	-	83	-	83	-
Biofertiliser CAPEX AU$/tonne	60	60	-	-	-	66	66
ROI (%)	492	264	-156	376	114	434	233
Annualised ROI (%)	7.4	5.3	-197.7	6.4	3.1	6.9	4.9
Payback Period	7	11	-	10	23	9	14

The resource unit per plant CAPEX was calculated assuming a 25-year effective life. For the staged scenarios (3 to 7) these profitability measurements were assumed as the average value obtained from Stages 1 and 2.

* Where W= Wastewater, B=Biogas, C= CO_2 Recovery, BF=Biofertiliser and 2=Staged implementation.

Scenario 3 shows negative NPV, indicating unprofitability over the facility's effective life. Scenario 5 (only WWTP) presents the lowest NPV and longest payback period among the staged scenarios, AU$ 5.5 Million and 23 years, respectively. Scenario 4, including wastewater, biogas, and CO_2 plants, has a positive NPV of AU$138.2 million with a 10-year payback. While scenario 7, including wastewater, biogas, and biofertiliser plants, has an NPV of AU$63.1 million with a 14-year payback. Thus, it can be concluded that the CO_2 recovery plant offers a higher investment return than the biofertiliser plant. Out of the staged scenarios, scenario 6, incorporating all components, has the highest NPV of AU$195.8 million and a 9-year payback. In terms of the one-stage scenarios, scenario 1, mirroring scenario 6, has the highest NPV at AU$225.3 million and the shortest payback of 7 years. Scenario 2, without the CO_2 plant, reduced the NPV to AU$76.8 million with an 11-year payback. Thus, Scenario 1 presents the best outcomes and is the recommended scenario to be implemented at NSW case study facility. Figure 10 presents a comparison of the return on investment (ROI) amongst the modelled scenarios.

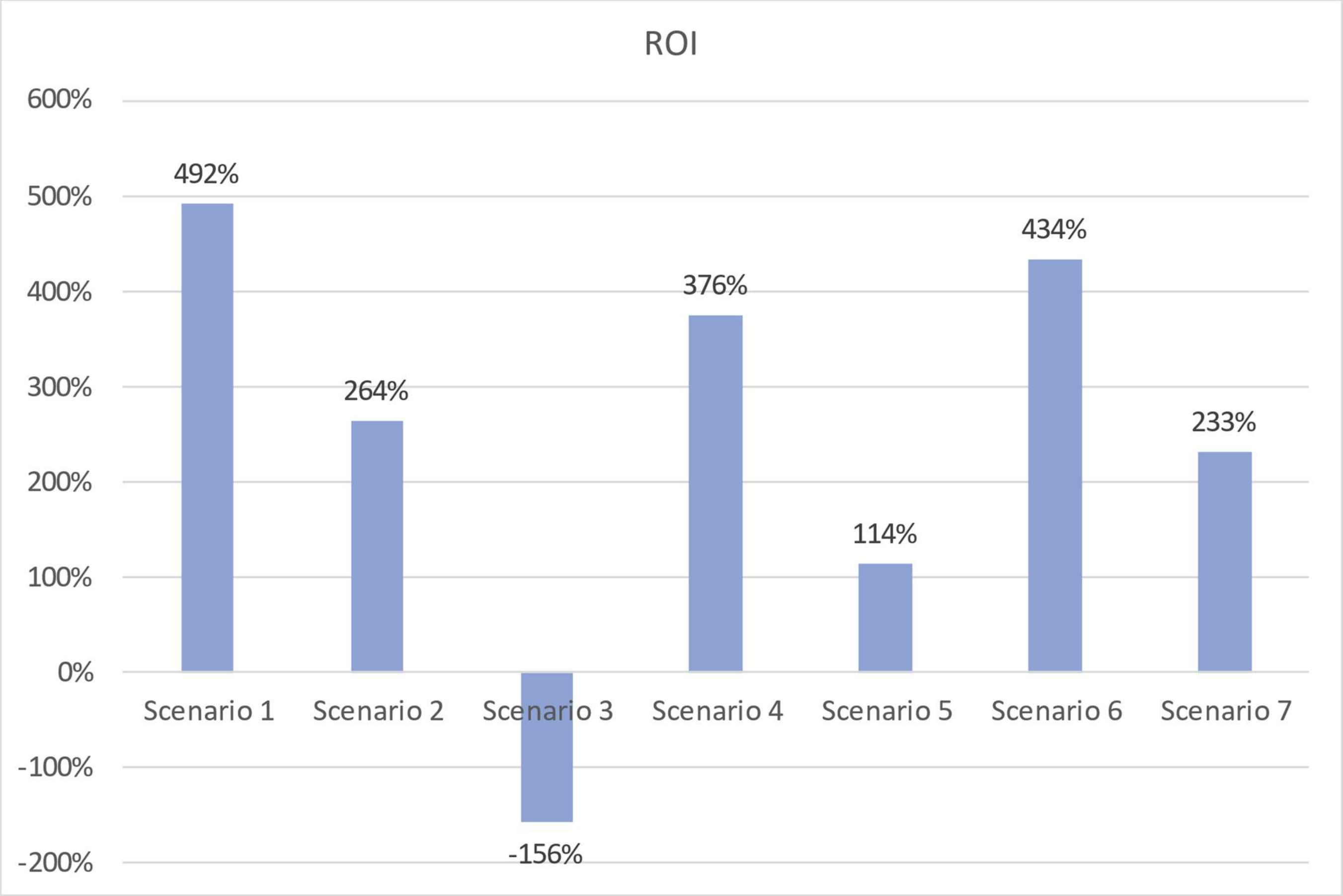


Figure 10. Comparison of the return on investment (ROI) amongst the scenarios modelled.

8.0 Discussion

The NSW beef processing plant aims to innovate its wastewater treatment and solid waste management. In the proposed WWTP, efficient nitrogen and phosphorus removal from the wastewater will allow water recycling for irrigation and non-potable uses at the facility. The organic red meat processing by-products will be recovered as thermal and electric energy, liquid CO_2 and biofertiliser, reducing the facility's carbon footprint and expanding the NSW case study facility's revenue streams. The information presented in this report will support licensing applications, decision-making, procurement, and funding for further implementation stages.

8.1. Wastewater Treatment Plant

The Stage 1 project for the Front-End Engineering Design of the Integrated Bio-resource Recovery Facility at the NSW case study facility included designing a new wastewater treatment plant (WWTP). Key steps involved a site assessment, design flowrate estimates, wastewater characterisation using the NSW beef processing plant data, determination of treated effluent quality targets and potential uses, reuse assessment review, and development of a concept design. This concept design included equipment selection, engineering drawings, an equipment list with renowned suppliers, a cost estimate, and validation of the WWTP design via BioWin modeling.

WWTP equipment selection and concept design involved calculating wastewater flowrates, component balance, and process requirements. An equipment list was prepared, suggesting one to three reliable suppliers. A detailed cost estimate, including civil, pipe, and electrical works, was developed to provide a financial overview of the project.

8.2. Solid Streams Audit and BMP Analysis

This work involved laboratory tests on organic by-product samples from the NSW beef processing plant.

Sample Analysis: Nine organic by-products were analysed for TS/VS, TSS/VSS, pH, EC, and BMP using the Automatic Methane Potential Test System (AMPTS). Additional tests for Total Ca, K, Mg, Na, P, and Total Carbon/Nitrogen were conducted by a partner laboratory. An additional co-digestion sample, utilising estimated ratios of available by-products, was also analysed because co-digestion often produces more biogas than the summation of individual bio-methane potential of separate samples.

Results and Validation: The solid streams audit and BMP testing validated the biogas plant design, resulting in a calculated biogas production of 8,305,940 Nm^3/year. This was based on current by-product volumes (excluding tallow) extrapolated to a future design throughput of 135,200 t.HSCW per year. The total by-product volume was multiplied by the Co-Digest BMP result.

8.3. Biogas Plant

The methodology for this milestone involved a desktop review of available information, collaboration with equipment vendors, and process calculations conducted using Microsoft Excel. This approach, combined with design assumptions and data provided by the NSW beef processing plant through a Request for Information process, resulted in the development of the Front-End Engineering Design (FEED) for the anaerobic digestion plant at the NSW beef processing plant.

Digester Feedstock Assumptions: The feedstock analysis aimed to determine its Bio-Methane Potential (BMP), serving as the basis for estimating biogas generation. The design was originally based on BMP results from literature and tests conducted at another red meat processing facility, with future quantities estimated by scaling up current red meat byproduct production rates to a future design throughput of 135,200 t.HSCW per year. The design was validated at a later date, using real BMP analysis obtained from the NSW case study facility's by-product samples provided to the laboratory.

Design Process: Utilising feedstock characteristics and data from the NSW case study facility, process calculations were performed to develop the FEED. Key factors influencing the design included total solids, volatile solids content, and forecast feedstock quantities.

Design Drawings: FEED drawings were produced, plus an equipment list, quotations from suppliers, and a cost estimate.

8.4. CO_2 Recovery

This section focused on assessing technologies for liquid CO_2 recovery from biogas, with the aim of producing dry ice for meat storage and transportation.

CO_2 Recovery Technologies: An analysis of CO_2 recovery systems was conducted, leading to the identification of a process for capturing and purifying CO_2 to food-grade quality. The concept design of the CO_2 recovery plant, along with a feasibility study and technical drawings, was created in collaboration with Evo Energy Technologies.

CO_2 Production Estimates: Estimates were based on biogas yield from the anaerobic digestion plant design. Various scenarios were analysed, including CO_2 production from raw biogas (pre-combustion), exhaust gas post-CHP unit combustion, and CO_2 recovery from the existing coal boiler stack.

Market and Application Analysis: Current demand, application, and pricing for commodity gases and electricity were provided by the NSW beef processing plant personnel. A study on potential uses for bio-CO_2 in various sectors was conducted, presenting opportunities for external commercialisation.

Cost Estimate: Developed with biogas equipment vendors and Tessele Consultants' cost database, the estimate included civil and electrical works, installation, commissioning, project management, and contingencies.

8.5. Biofertiliser

The methodology for this milestone focused on the development of a bio-based fertiliser concept design.

Literature Review: A review was conducted on biomass uses and conversion technologies, benchmarking against best practices and identifying innovation opportunities.

Technical Evaluation: Various commercial biomass recovery systems were evaluated based on technical performance, environmental impact, energy consumption, and economic viability. A specific process for dewatering and drying digestate was selected for its efficiency and suitability.

Design Phase: Detailed technical drawings, an equipment list, preferred suppliers, and a cost estimate were prepared. Supplier selection focused on sustainability, reliability, and cost-effectiveness.

Market, Compliance and Logistical Management: Strategies to ensure compliance with evolving environmental regulations were explored, including exploration of the potential to directly use the liquid digestate as fertiliser. Methods to convert liquid digestate into stable forms like pellets or biochar were assessed.

Thermal Optimisation: Integration of cutting-edge technologies and thermal optimisation strategies aimed at reducing operational costs and improving thermal efficiency.

8.6. Economic Analysis

This report focused on refining the capital expenditure (CAPEX) and providing an economic analysis of the bioresource recovery facility (BRRF) to be implemented at the NSW case study facility.

CAPEX Review: The CAPEX for the wastewater treatment, biogas, and biofertiliser plants was reviewed with a professional cost estimator. Assumptions included paving with crushed limestone, direct engagement with equipment suppliers, and a contingency allowed for installation and delivery.

Implementation Scenarios: Different scenarios encompassing full and partial BRRF implementation in single and double stages were considered. The staged implementation scenarios regarded 60% CAPEX for short-term expansion and 40% for long-term expansion. Flow rates, volumes, and potential revenues from recovered bioresources were analysed.

Economic Analysis: Conducted using a Microsoft Excel spreadsheet, the analysis included CAPEX, operational costs, and revenue from recovered resources. Net Present Value (NPV), Return on Investment (ROI) and Payback Period for each scenario were analysed to identify the best investment option.

These methodologies underpin the comprehensive analysis and design processes detailed in the milestone reports, providing a robust foundation for the development and implementation of bioresource recovery initiatives at the NSW case study facility.

9.0 Conclusions / Recommendations

In conclusion, this comprehensive final report compiles the findings from each milestone report, outlining the design and feasibility of an Integrated Bio-resource Recovery Facility to be implemented at the NSW case study facility, incorporating wastewater treatment, biogas, CO_2 recovery and biofertiliser plants.

The wastewater treatment plant is designed for an estimated future flow rate of 2,520 kL/d but has the flexibility to handle lower flow rates and higher concentrations, within reason, in case different estimates are provided by the NSW case study facility at a later stage. The design enables the treated effluent to be recycled for uses as agreed upon with the NSW case study facility, reducing the NSW case study facility's reliance on potable water and addressing supply concerns. The higher-quality treated effluent will also improve the NSW case study facility’s ability to meet environmental license requirements for irrigation. Figure 11 summarises the proposed WWTP design.

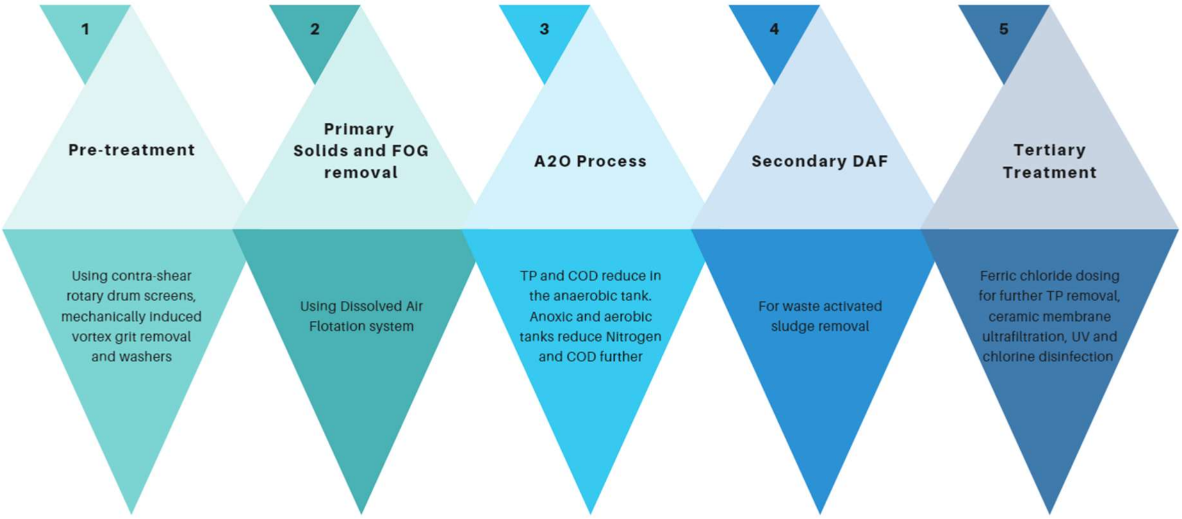


Figure 11. Wastewater treatment plant design summary.

The biogas plant design, validated by information obtained in the solids streams audit and BMP testing, incorporates modular units to enhance redundancy and supports future expansion, with an energy production capacity of 1.4 GJ per t.HSCW. The generated energy reduces onsite gas and electricity consumption, contributing to environmental stewardship and financial efficiency. The solid streams audit and BMP used to validate the biogas plant design resulted are shown in Figure 12 below.

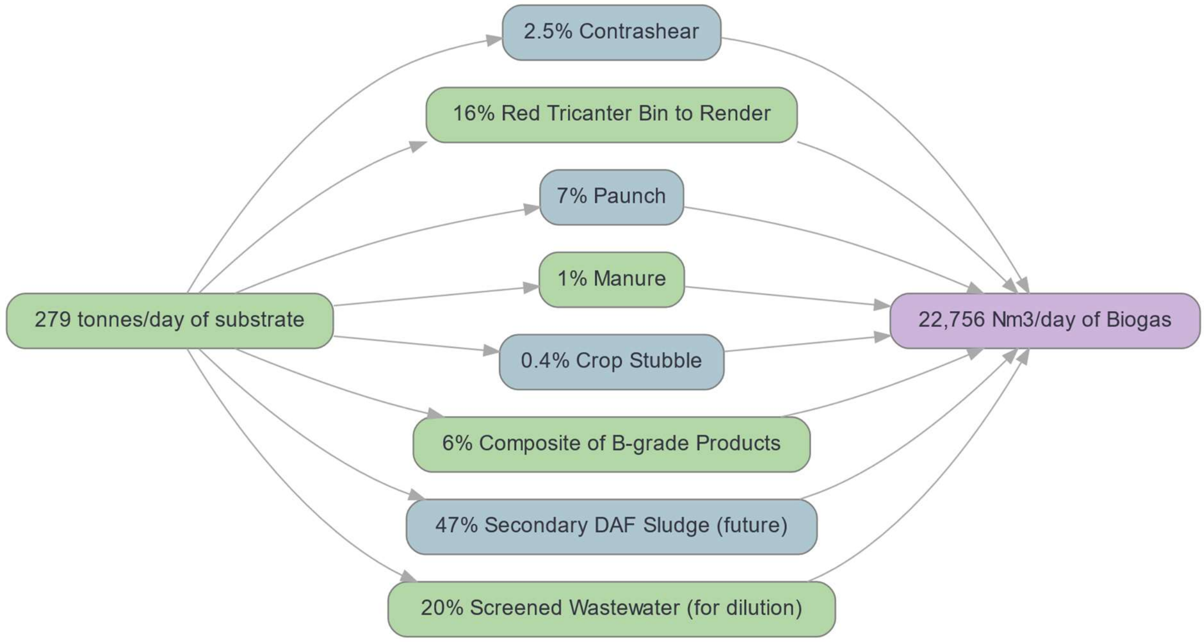
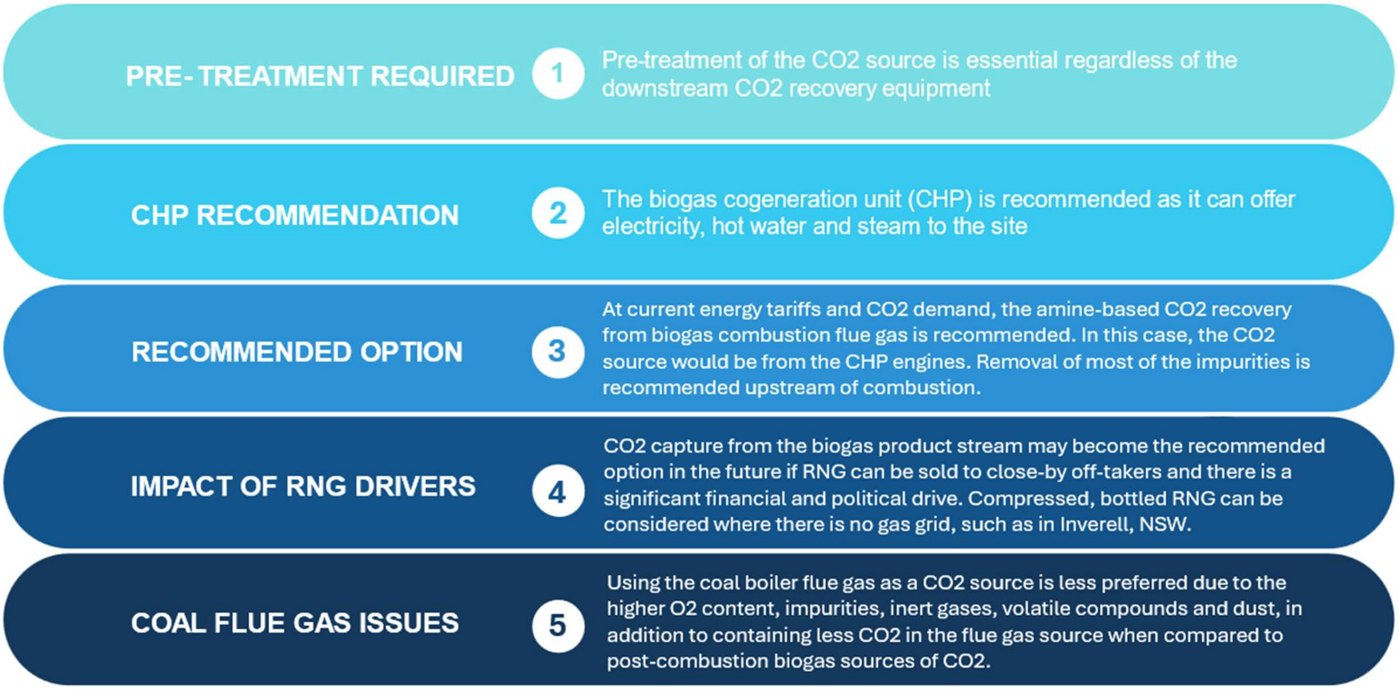


Figure 12. Solids stream audit and BMP test results output.

The CO_2 recovery plant design includes evaluations of recovery methods and their feasibility, tailored to the NSW case study facility's needs. This design aims to enable the production of the NSW case study facility's liquid CO_2, enhancing supply reliability and significantly reducing the high costs associated with externally supplied CO_2. The recommended cost-effective CO_2 recovery option will extract CO_2 post-CHP combustion using the chemical absorption method with amine. The CO_2 recovery plant design outcomes are summarised in Figure 13 below.



PRE- TREATMENT REQUIRED 1 Pre-treatment of the CO2 source is essential regardless of the downstream CO2 recovery equipment

CHP RECOMMENDATION 2 The biogas cogeneration unit (CHP) is recommended as it can offer electricity, hot water and steam to the site

RECOMMENDED OPTION 3 At current energy tariffs and CO2 demand, the amine-based CO2 recovery from biogas combustion flue gas is recommended. In this case, the CO2 source would be from the CHP engines. Removal of most of the impurities is recommended upstream of combustion.

IMPACT OF RNG DRIVERS 4 CO2 capture from the biogas product stream may become the recommended option in the future if RNG can be sold to close-by off-takers and there is a significant financial and political drive. Compressed, bottled RNG can be considered where there is no gas grid, such as in Inverell, NSW.

COAL FLUE GAS ISSUES 5 Using the coal boiler flue gas as a CO2 source is less preferred due to the higher O2 content, impurities, inert gases, volatile compounds and dust, in addition to containing less CO2 in the flue gas source when compared to post-combustion biogas sources of CO2.

Figure 13. CO_2 recovery plant design outcomes.

The bio-based fertiliser plant design characterises and quantifies processed biomass, proposing technologies for digestate processing with an overall energy demand lower than the biogas plant's output. This facility not only reduces landfill disposal costs but also generates additional revenue and completes a circular economy loop.

Recommended Technology

The recommended biofertiliser recovery technology for implementation is mechanical dewatering to ~22% TS, thermally drying and pelletising the digestate into bio-based fertiliser pellets ready for third-party off-take. The plant will produce approximately 5,656 t/year of biofertiliser pellets.

Out of all economic scenarios analysed, implementing a full Bio-resource Recovery Facility (BRRF), including wastewater, biogas, CO_2 recovery, and biofertiliser plants in one stage, offers the highest return on investment, helping offset energy consumption and support carbon neutrality. The economic outcomes for a full BRRF implementation in one stage are shown in Figure 14 below.

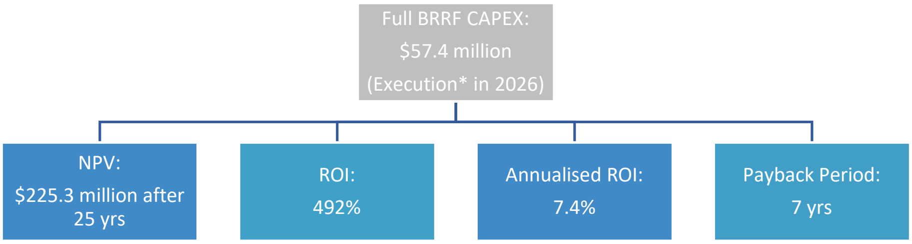


Figure 14. Economic outcomes for implementing a full Bio-resource Recovery Facility (BRRF) in one stage.

* Where execution date is the selected financial modelling date however the NSW case study facility currently has no plans committed to delivering the project on this date.

It is recommended to include sensitivity analyses in further project stages to optimise recovered resources quantities and prices, enhancing financial viability. Ongoing BMP tests and participation in RACE to 2030 anaerobic digestion trials are recommended to refine biogas, CO_2 recovery and biofertiliser component process designs and improve outcomes. Implementing flowmeters and a comprehensive sampling campaign, in addition to reassessing the assumptions provided for the wastewater treatment plant, are recommended to refine the wastewater treatment plant component for further project design stages. Refer to Figure 15 below for a summary of the outputs for each stage of the process.

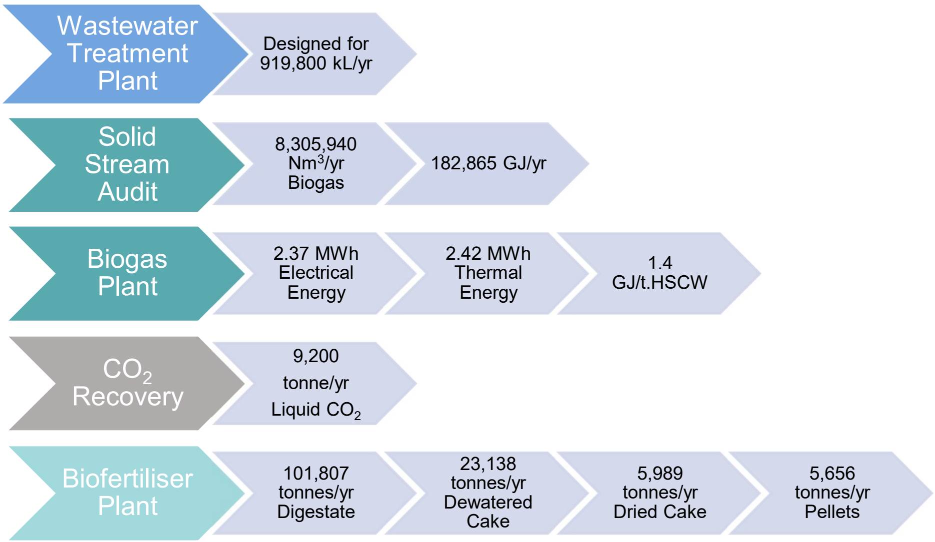


Figure 15. Bio-resource Recovery Facility summary and key values.

Overall, implementing a Bio-resource Recovery Facility at the NSW case study facility transforms the necessary wastewater treatment plant upgrades, that would otherwise be a financial burden, into a profitable venture. It offers a positive return on investment by adding bio-resource recovery components that recycle high-quality non-potable water, produce thermal and electrical energy from biogas, recover food-grade liquid CO_2, and produce value-adding biofertiliser. This initiative produces carbon offsets, fosters environmental stewardship, improves regulatory compliance, and promotes a circular economy. The design offers social, economic, and environmental benefits, reinforcing the rationale for advancing to the next phases of the project.

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11.0 Appendices

11.1 Appendix 1: Wastewater Characterisation

Table 67. Full wastewater analysis of combined red and green streams.

		Samples														
Parameter	**UOM**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Ave**	**Min**	**Max**
pH	pH Units	5.7	5.9	6.6	5.6	5.6	7.0	6.2	6.7	7.5	6.8	6.4	6.5	6.4	5.6	7.5
Conductivity (EC)	dS/m	1	1	2	1	1	2	1	2	2	1	1	1	1	1	2
TDSalts	mg/L	787	684	1,223	894	907	1,373	802	1,015	1,533	762	635	878	958	635	1,533
TD Solids	mg/L	850	715	2,480	3,150	2,650	1,590	757	1,110	955	1,550	733	1,230	1,481	715	3,150
TSS	mg/L	5,880	2,510	5,120	7,740	9,050	2,214	2,171	3,050	1,505	4,667	3,880	2,190	4,165	1,505	9,050
BOD	mg/L	6,610	4,320	975	12,815	14,833	5,010	7,475	3,820	2,230	7,300	6,960	4,020	6,364	975	14,833
O&G	mg/L	3,597	2,627	4,626	5,172	5,358	10,148	4,757	2,098	1,505	2,291	2,476	1,546	3,850	1,505	10,148
TP	mg/L	21	27	52	51	54	66	40	44	72	44	34	60	48	21	72
TN	mg/L	485	218	417	588	535	253	259	424	254	319	283	182	351	182	588
Ammonia	mg/L	53	36	82	6	6	126	38	96	181	26	46	36	61	6	181
Sodium	mg/L	126	120	190	132	145	182	104	140	188	112	114	180	144	104	190
Potassium	mg/L	45	39	96	43	48	87	52	54	104	60	41	63	61	39	104

		Samples														
Parameter	**UOM**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Ave**	**Min**	**Max**
Calcium	mg/L	20	30	24	50	60	50	50	28	76	34	29	41	41	20	76
Magnesium	mg/L	8	9	11	8	9	14	8	10	20	11	8	10	11	8	20
Sodium Absorption Ratio (SAR)	mg/L	6	5	8	5	5	6	4	6	5	4	5	7	5	4	8
Chloride	mg/L	142	135	253	88	121	124	61.9	78	216	31	178	82	126	31	253

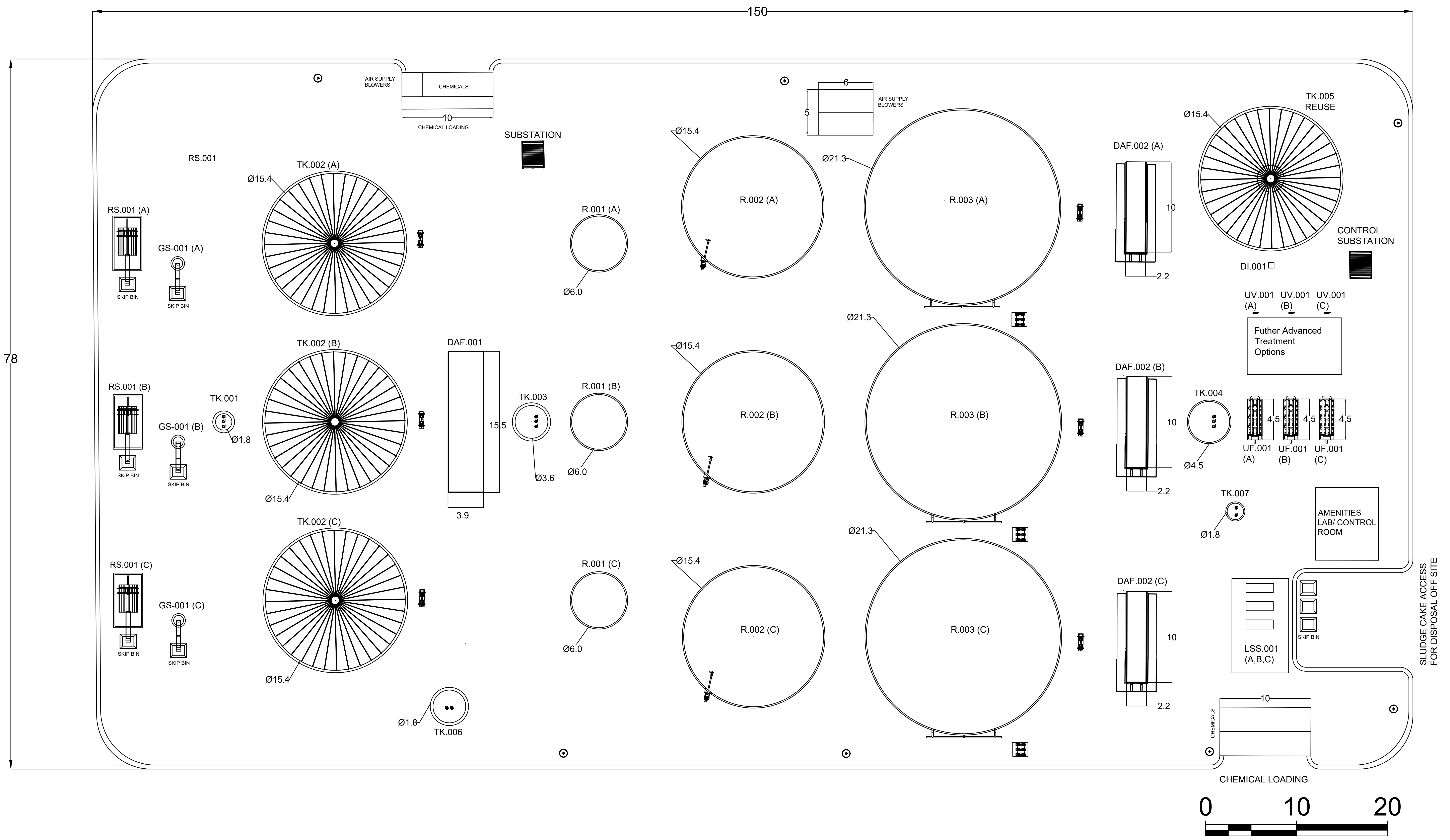
11.2 Appendix 2: WWTP Technical Drawings

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS NOTED OTHERWISE.
2. SITE AREA ~12,000 M^2

WWTP COMPONENTS:

RS.001	Rotary Screen
GS.001	Grit Separation
TK.001	Pumping Station
TK.002	Equalisation Tank
TK.003	Pumping Station
TK.004	Pumping Station
TK.005	Treated Water Storage Tank
TK.006	Thickened Primary Sludge Tank
TK.007	Thickened Excess Activated Sludge Tank
R.001	Reactor - Anaerobic Stage
R.002	Reactor - Anoxic Stage
R.003	Reactor - Aerobic Stage
DAF.001	Dissolved Air Flotation
DAF.002	Dissolved Air Flotation
UF.001	Ultrafiltration System
UV.001	Ultraviolet Disinfection
DI.001	Hypochlorite Disinfection
LSS.001	Liquid Solid Separator



LEGEND:

⊙ Hydrants

DATE	DESCRIPTION	REV
18.04.23	ISSUED FOR MS3 REPORT	B
04.04.23	ISSUED FOR MS3 REPORT	A

NOTE: CHECK ALL DIMENSIONS ON SITE PRIOR TO COMMENCING WORK. WRITTEN DIMENSIONS SHALL TAKE PRECEDENCE. ALL DRAWINGS TO BE READ IN CONJUNCTION WITH MANUFACTURERS AND CONSULTANTS DOCUMENTATION AND SPECIFICATION. REPORT ANY DISCREPANCIES TO DESIGNER BEFORE PROCEEDING WITH WORK.

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NORTH:

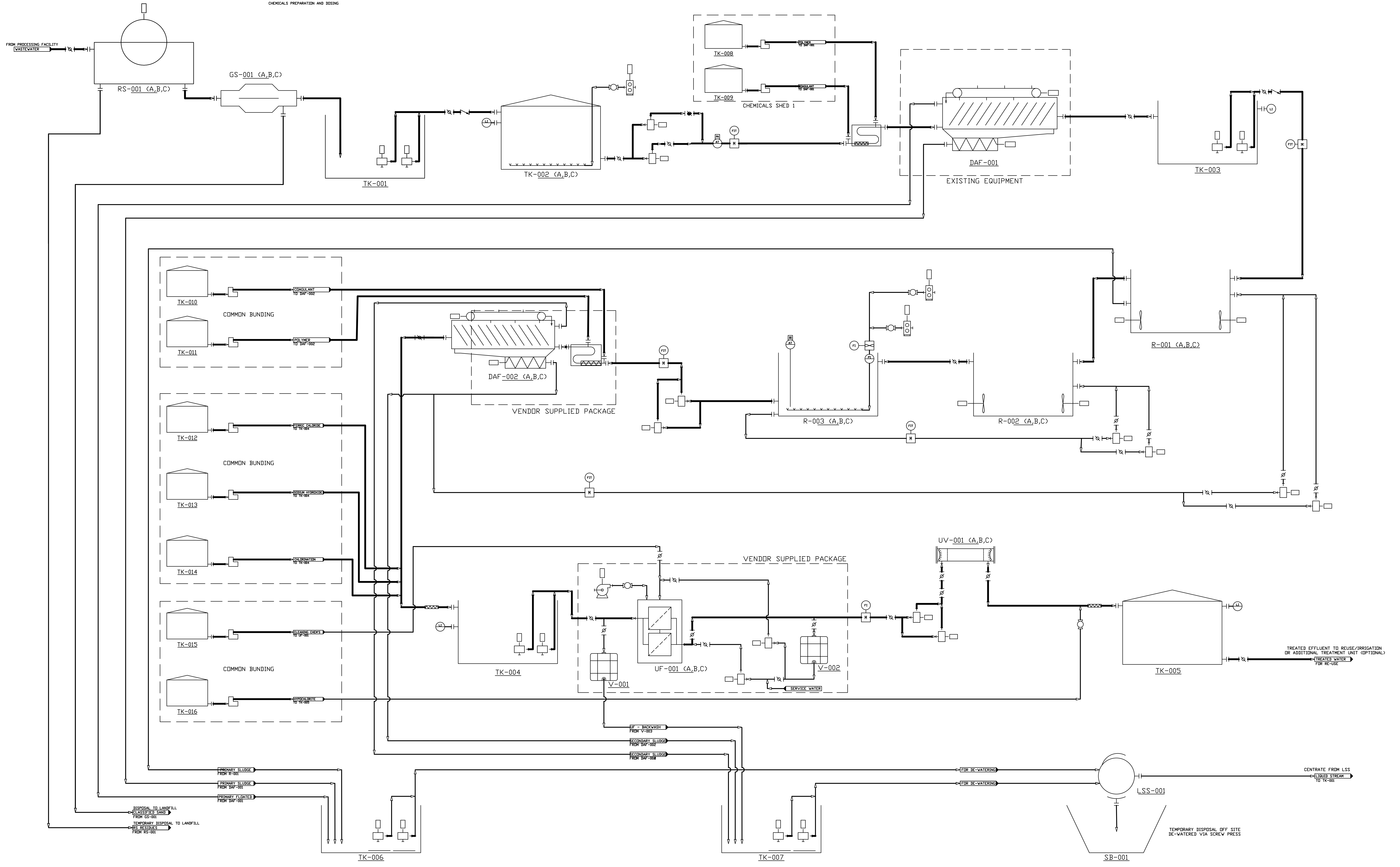
PROJECT TITLE:
FRONT END ENGINEERING DESIGN
INTEGRATED BIO-RESOURCE RECOVERY FACILITY
STAGE - 1

SCALE@A1:
PLOT DATE:
PROJECT NO: 2023-1028
DRAWN: L.M
CHECKED: K.F
APPROVED: F.T
SHEET: 2 OF 4

DRAWING TITLE:
WASTEWATER TREATMENT SYSTEM
GENERAL ARRANGEMENT

DRAWING NUMBER: 2023-1028-AMPC-CP-DW-002
REVISION: B

RS-001	ROTARY DRUM - SCREEN
GS-001	GRIT SEPARATOR
TK-001	PUMPING STATION
TK-002	EQUALISATION TANK
DAF-001	DISSOLVED AIR FLOTATION
TK-003	PUMPING STATION
TK-008 TO TK-016	CHEMICALS PREPARATION AND DOSING
R-001	ANAEROBIC REACTOR
R-002	ANOXIC REACTOR
R-003	AEROBIC REACTOR
DAF-002	DISSOLVED AIR FLOTATION
TK-004	PUMPING STATION/CONTACT TANK
UF-001	CERAMIC ULTRAFILTRATION PACAKGE
UV-001	ULTRAVIOLET DISINFECTION SYSTEM
TK-005	TREATED WATER STORAGE TANK
TK-006	THICKNED PRIMARY SLUDGE PUMPING STATION
TK-007	THICKNED EXCESS ACTIVATED SLUDGE PUMPING STATION
LSS 001	LIQUID SOLID SEPARATOR
SB-001	SKIP BIN



DATE	DESCRIPTION	REV
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04.04.23	ISSUED FOR MS3 REPORT	A

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INTEGRATED BIO-RESOURCE RECOVERY FACILITY
STAGE - 1
AMPC

SCALE@A1:	PLOT DATE:	PROJECT NO:
NTS		2023-1028

DRAWN:	CHECKED:	APPROVED:	SHEET:
L.M	K.F	F.T	3 OF 4

DRAWING TITLE:
WASTEWATER TREATMENT SYSTEM
PROCESS FLOW DIAGRAM - PFD

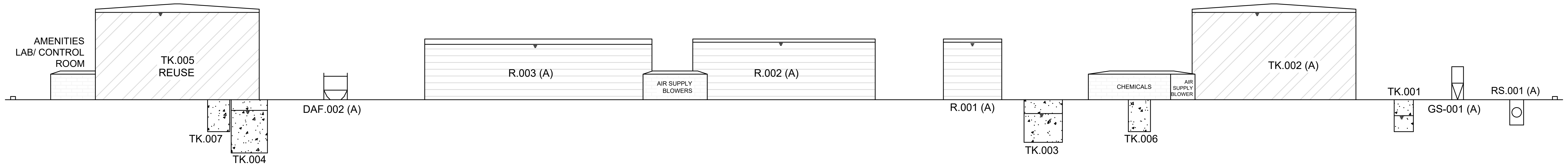
DRAWING NUMBER:	REVISION:
2023-1028-AMPC-CP-DW-003	B

NOTES:

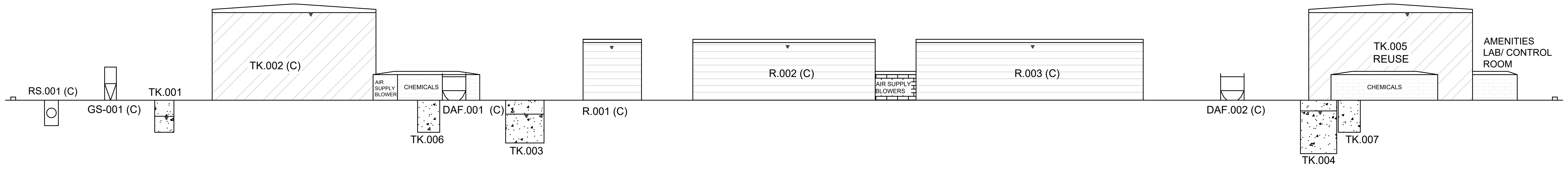
1. ALL DIMENSIONS ARE IN METERS UNLESS NOTED OTHERWISE.
2. SITE AREA ~12,000 M^2

WWTP COMPONENTS:

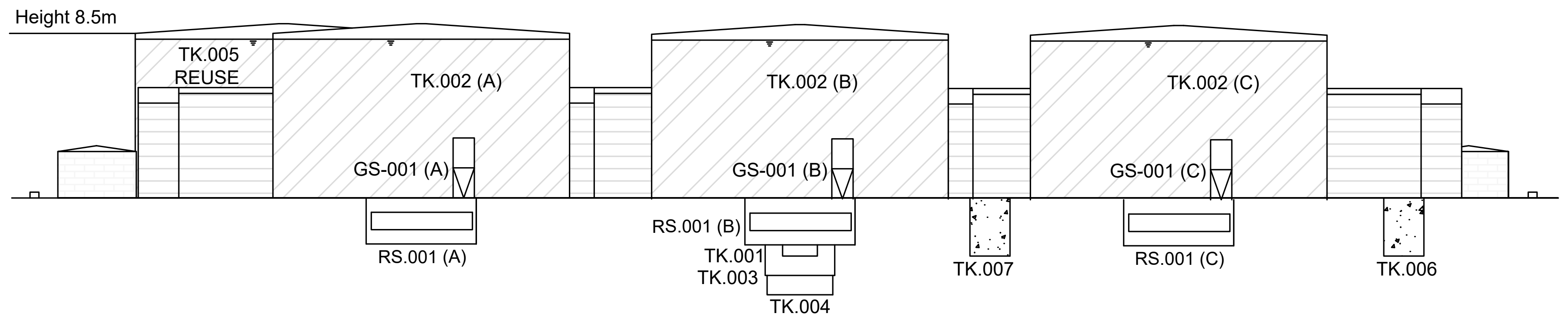
RS.001	Rotary Screen
GS.001	Grit Separation
TK.001	Pumping Station
TK.002	Equalisation Tank
TK.003	Pumping Station
TK.004	Pumping Station
TK.005	Treated Water Storage Tank
TK.006	Thickened Primary Sludge Tank
TK.007	Thickened Excess Activated Sludge Tank
R.001	Reactor - Anaerobic Stage
R.002	Reactor - Anoxic Stage
R.003	Reactor - Aerobic Stage
DAF.001	Dissolved Air Flotation
DAF.002	Dissolved Air Flotation
UF.001	Ultrafiltration System
UV.001	Ultraviolet Disinfection
DI.001	Hypochlorite Disinfection
LSS.001	Liquid Solid Separator



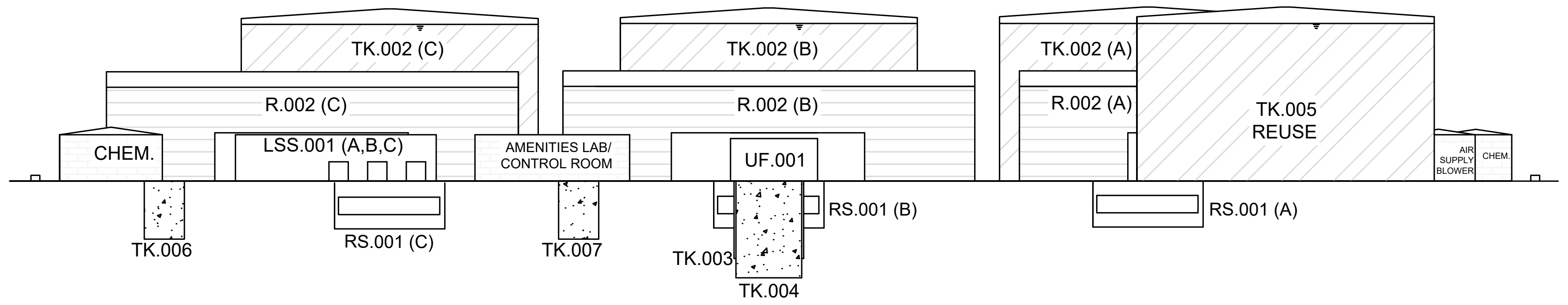
EAST VIEW



WEST VIEW



SOUTH VIEW



NORTH VIEW

DATE	DESCRIPTION	REV
18.04.23	ISSUED FOR MS3 REPORT	B
04.04.23	ISSUED FOR MS3 REPORT	A

NOTE: CHECK ALL DIMENSIONS ON SITE PRIOR TO COMMENCING WORK. WRITTEN DIMENSIONS SHALL TAKE PRECEDENCE. ALL DRAWINGS TO BE READ IN CONJUNCTION WITH MANUFACTURERS AND CONSULTANTS DOCUMENTATION AND SPECIFICATION. REPORT ANY DISCREPANCIES TO DESIGNER BEFORE PROCEEDING WITH WORK.

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PLOT DATE:
PROJECT NO: 2023-1028
DRAWN: L.M
CHECKED: K.F
APPROVED: F.T
SHEET: 4 OF 4

DRAWING TITLE:
WASTEWATER TREATMENT SYSTEM
ELEVATIONS

DRAWING NUMBER: 2023-1028-AMPC-CP-DW-004
REVISION: B

11.3 Appendix 3: WWTP Equipment List and Recommended Suppliers

Table 68. WWTP Equipment List and Recommended Suppliers.

Item	Drawing Label	Equipment List	Qty	Supplier
Pre-treatment				
1.01	RS.001A RS.001B RS.001C	Rotary Screen Package	3	Aqseptence Group/ Hydroflux
1.02	GS.001A GS.001B GS.001C	Grit Removal Package	3	Aqseptence Group/ Hydroflux
1.03	GW.001A GW.001B	Grit Removal Package	2	Aqseptence Group/ Hydroflux
1.04	TK.001	Pumping Station	1	Xylem/ Allied Pumps/ All purposes Pumps
1.05	P.001A P.001B P.001C P.001D P.001E P.001F	Pumping Station (Transfer Pumps - Pre-treatment to Equalisation Tank)	6	Xylem/ Allied Pumps/ All purposes Pumps
1.06	TK.002A TK.002B TK.002C	Equalisation Tanks	3	CST
1.07	TK2A TK2B TK2C	Coarse bubble diffusor	3	Xylem
1.08	TK2A TK2B TK2C	Blower Supply Aerator	3	Robuschi
Primary Treatment				
2.01	DAF.001	Transfer Pumps to Primary DAF	2	Dynapumps/ Allied Pumps/ Capari
2.02	DAF.001	Static Mixer Before Primary DAF	1	
2.03	DAF.001	Chemical Dosing	8	Dynapumps/ Allied Pumps/ Capari
2.04	TK.006	Sludge Transfer Pumping Station (Pit)	1	Xylem/ Allied Pumps/ Allpurposes Pumps
2.05	TK.006	Sludge Pumps	2	Xylem/ Allied Pumps/ Allpurposes Pumps
2.06	TK.003	Pumping Station	1	Xylem/ Allied Pumps/ Allpurposes Pumps
2.07	P.002A P.002B P.002C P.002D P.002E P.002F	Pumping Station (Transfer Pumps - Primary treatment to Anaerobic Reactors)	6	Xylem/ Allied Pumps/ Allpurposes Pumps
Secondary Treatment				
3.01	R.001A R.001B R.001C	Anaerobic Reactors	3	CST/ Boerger
3.02	R.001A R.001B R.001C	Submerged mixers	3	Xylem
3.03	R.002A R.002B R.002C	Anoxic Reactors	3	CST/ Boerger
3.04	R.002A	Submerged mixers	3	Xylem

Item	Drawing Label	Equipment List	Qty	Supplier
	R.002B R.002C			
3.05	R.003A R.003B R.003C	Aerobic Reactors	3	CST/ Boerger
3.06	R.003A R.003B R.003C	Air Diffusers	3	Xylem/ Hydroflux
3.07	R.003A R.003B R.003C	Blowers	4	Robuschi
3.08	R.003A R.003B R.003C	Internal Recirculation Pumps	6	Xylem/ Allied Pumps/ Dynapumps/ Capari
3.09	DAF.002A DAF.002B DAF.002C	RAS Pumps	6	Xylem/ Allied Pumps/ Dynapumps/ Capari
3.10	DAF.002A DAF.002B DAF.002C	Transfer Pumps to Secondary DAF	6	Xylem/ Allied Pumps/ Dynapumps/ Capari
3.11	DAF.002A DAF.002B	Static Mixer Before Secondary DAF	3	
3.12	DAF.002A DAF.002B DAF.002C	Secondary DAF	3	FRC/ Xylem/ Hydroflux
3.13	DAF.002A DAF.002B DAF.002C	Polymer preparation system	1	IFS
3.14	DAF.002A DAF.002B DAF.002C	Polymer dosing pumps	4	Dynapumps/ IFS/ Allied Pumps/ Capari
3.15	TK.007	Sludge Transfer Pumping Station (Pit)	1	Xylem/ Allied Pumps/ All purposes Pumps
3.16	TK.007	Sludge Pumps	2	Xylem/ Allied Pumps/ Allpurposes Pumps
Tertiary Treatment				
4.01	TK.004	Buffer Tank (Pumping Station)	1	Xylem/ Allied Pumps/ Allpurposes Pumps
4.02	TK.004	Transfer Pumps	6	Xylem
4.03	TK.004	Static Mixers TK.004	3	
4.04	TK.004	Chemical Dosing Pumps	12	Dynapumps/ Allied Pumps/ Capari
4.05	UF.001A UF.001B UF.001C	Ultrafiltration	1	Aquavoda
4.06	UV.0001A UV.0001B UV.0001C	UV Disinfection	3	Xylem/ Evoqua/ Aquavoda
4.07	DI.001	Transfer Pump Set to DI.001	3	Xylem/ Allied Pumps/ Allpurposes Pumps
4.08	DI.001	Static Mixer before Chlorination Disinfection DI.001	1	
4.09	DI.001	Chlorination Disinfection	1	Ixom/ Aquavoda
4.10	TK.005	Treated Water Storage Tank	1	CST
Sludge Handling				
5.01	TK.008	Sludge Blending Tank	1	CST

Item	Drawing Label	Equipment List	Qty	Supplier
5.02	LSS.001A LSS.001B LSS.001C	Centrifuge Feed Pumps	4	IFS/ Hydroflux
5.03	LSS.001A LSS.001B LSS.001C	Centrifuge	3	IFS/ Hydroflux
5.04	LSS.001A LSS.001B LSS.001C	Polymer preparation system	1	IFS/ Hydroflux
5.05	LSS.001A LSS.001B LSS.001C	Polymer dosing pumps	4	IFS/ Hydroflux

11.4 Appendix 4: Biogas Plant Technical Drawings

NOTES:

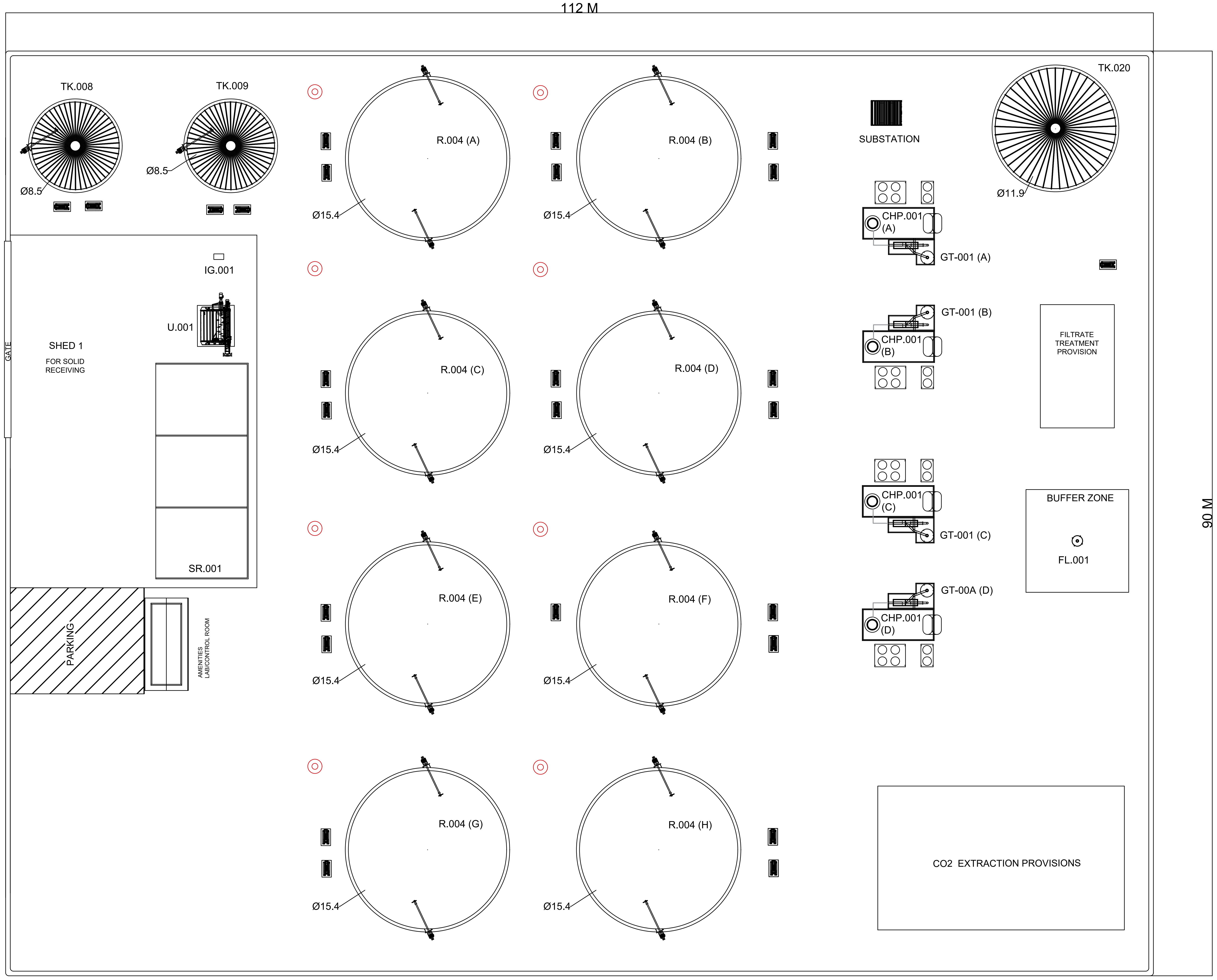
1. ALL DIMENSIONS ARE IN METRES UNLESS NOTED OTHERWISE.
2. SITE AREA ~10,000 M^2

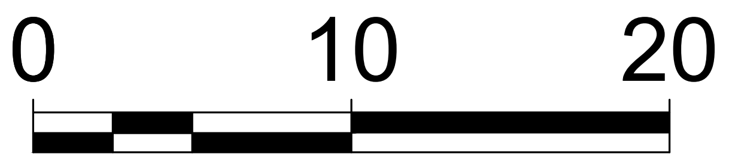
BIOGAS COMPONENTS:

TK.008	Liquid Receiving Tank
TK.009	Blending Tank
R.004(A)	Anaerobic Digester & Biogas Storage
R.004(B)	Anaerobic Digester & Biogas Storage
R.004(C)	Anaerobic Digester & Biogas Storage
R.004(D)	Anaerobic Digester & Biogas Storage
R.004(E)	Anaerobic Digester & Biogas Storage
R.004(F)	Anaerobic Digester & Biogas Storage
R.004(G)	Anaerobic Digester & Biogas Storage
R.004(H)	Anaerobic Digester & Biogas Storage
TK.010	Post Digester Storage
SR.001	Solids Receiving Station
U.001	Receiving Hopper
A.003	Solids/Liquid Mixer
CHP.001(A)	Combined Heat & Power Package
CHP.001(B)	Combined Heat & Power Package
CHP.001(C)	Combined Heat & Power Package
CHP.001(D)	Combined Heat & Power Package
FL.001	Emergency Flare
IG.001	In-Line Shaft Grinder
GT.001(A)	Gas Treatment
GT.001(B)	Gas Treatment
GT.001(C)	Gas Treatment
GT.001(D)	Gas Treatment

LEGEND:

◎ Hydrants





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18.12.2023	ISSUED FOR MS2 REPORT	A

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NORTH:

PROJECT TITLE:
INTEGRATED BIORESOURCE
RECOVERY FACILITY
NOVEL FEED STUDY - STAGE 2
NSW CASE STUDY FACILITY

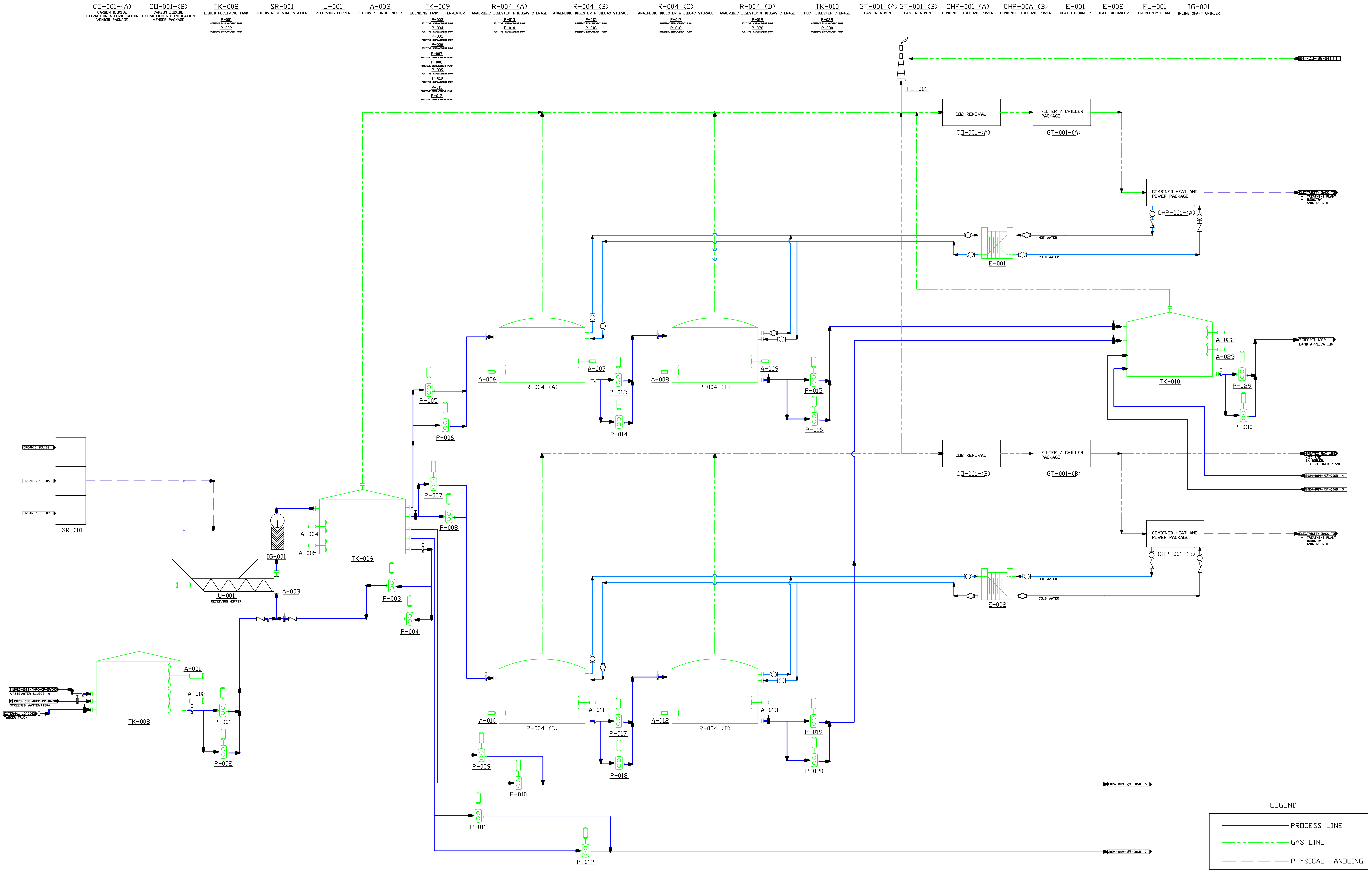
SCALE@A1:	PLOT DATE:	PROJECT NO:
1:250		2024-1019

DRAWN:	CHECKED:	APPROVED:	SHEET:
L.L	K.F	F.T	1 OF 1

DRAWING TITLE:
BIOGAS PLANT
GENERAL ARRANGEMENT

DRAWING NUMBER:
2024-1019-NSW-005

REVISION:
A



18.12.2023	ISSUED FOR MS2 REPORT	A
DATE	DESCRIPTION	REV

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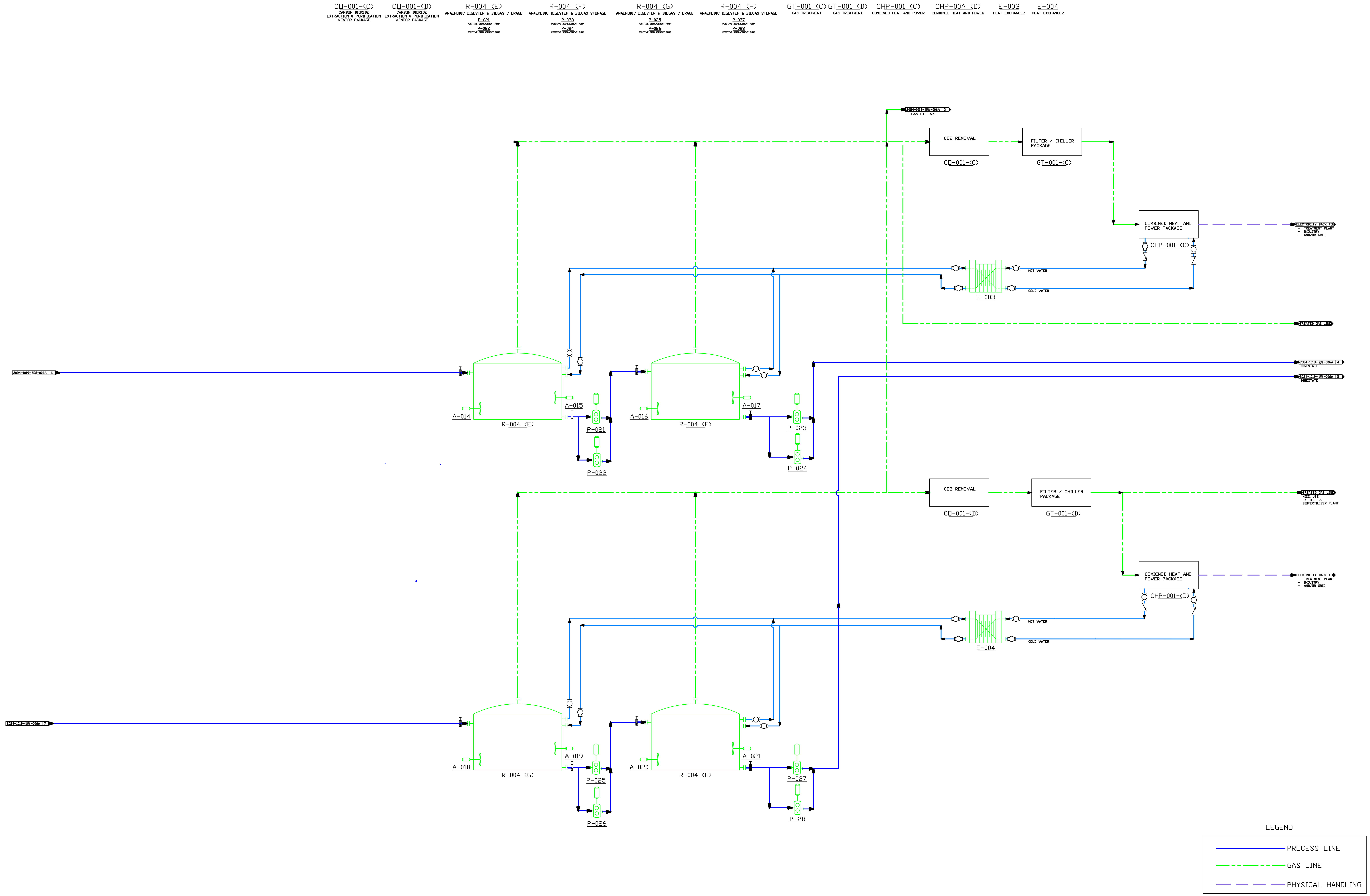
NSW CASE STUDY FACILITY

SCALE@A1: NTS
PLOT DATE:
PROJECT NO: 2024-1019
DRAWN: L.L
CHECKED: K.F
APPROVED: F.T
SHEET: 1 OF 2

DRAWING TITLE:
BIOGAS PLANT
PROCESS FLOW DIAGRAM - PFD

DRAWING NUMBER: 2024-1019-NSW-006A
REVISION: A



18.12.2023	ISSUED FOR MS2 REPORT	A
DATE	DESCRIPTION	REV

NOTE: CHECK ALL DIMENSIONS ON SITE PRIOR TO COMMENCING WORK. WRITTEN DIMENSIONS SHALL TAKE PRECEDENCE. ALL DRAWINGS TO BE READ IN CONJUNCTION WITH MANUFACTURERS AND CONSULTANTS DOCUMENTATION AND SPECIFICATION. REPORT ANY DISCREPANCIES TO DESIGNER BEFORE PROCEEDING WITH WORK.

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NOVEL FEED STUDY - STAGE 2
NSW CASE STUDY FACILITY

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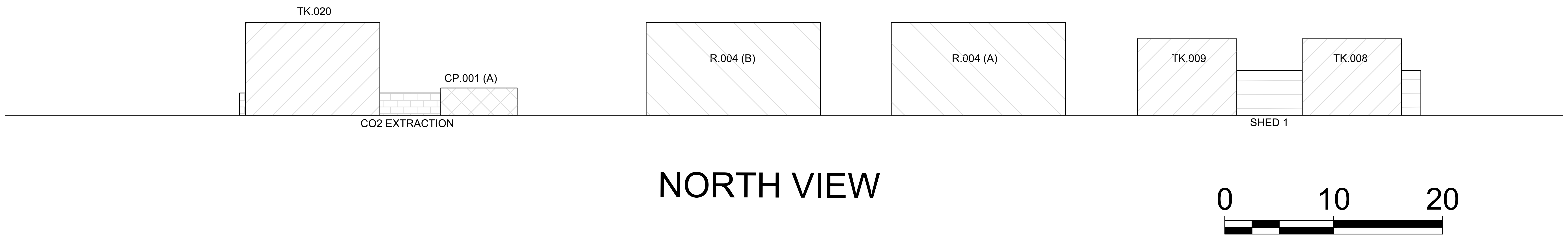
DRAWING TITLE:
BIOGAS PLANT
PROCESS FLOW DIAGRAM - PFD

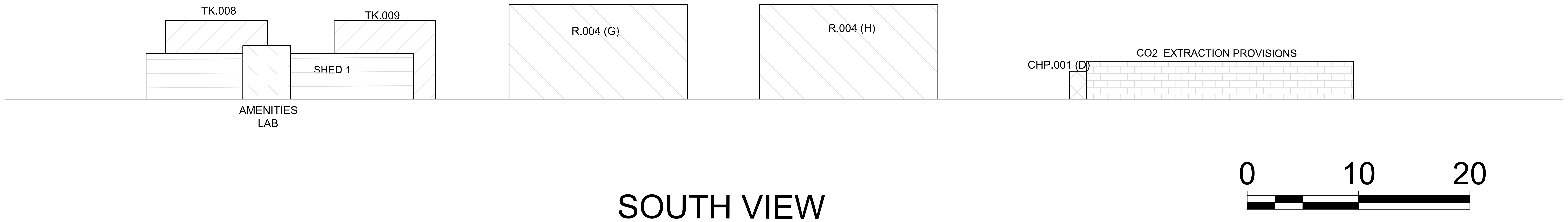
DRAWING NUMBER:	REVISION:
2024-1019-NSW-006B	A

BIOGAS COMPONENTS:

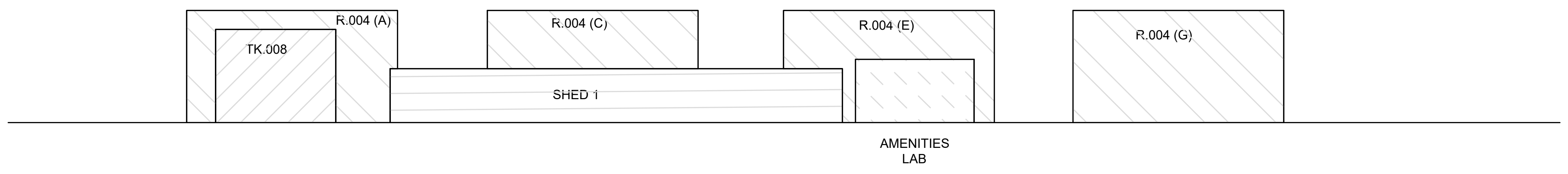
TK.008	Liquid Receiving Tank
TK.009	Blending Tank
R.004(A)	Anaerobic Digester & Biogas Storage
R.004(B)	Anaerobic Digester & Biogas Storage
R.004(C)	Anaerobic Digester & Biogas Storage
R.004(D)	Anaerobic Digester & Biogas Storage
R.004(E)	Anaerobic Digester & Biogas Storage
R.004(F)	Anaerobic Digester & Biogas Storage
R.004(G)	Anaerobic Digester & Biogas Storage
R.004(H)	Anaerobic Digester & Biogas Storage
TK.020	Post Digester Storage
SR.001	Solids Receiving Station
U.001	Receiving Hopper
A.003	Solids/Liquid Mixer
CHP.001(A)	Combined Heat & Power Package
CHP.001(B)	Combined Heat & Power Package
CHP.001(C)	Combined Heat & Power Package
CHP.001(D)	Combined Heat & Power Package
FL.001	Emergency Flare
IG.001	In-Line Shaft Grinder
GT.001(A)	Gas Treatment
GT.001(B)	Gas Treatment
GT.001(C)	Gas Treatment
GT.001(D)	Gas Treatment



NORTH VIEW



SOUTH VIEW



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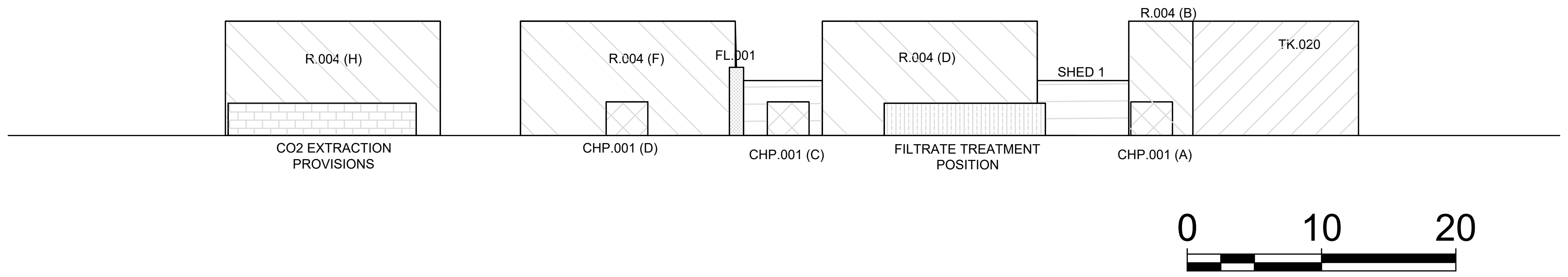

EAST VIEW

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NOVEL FEED STUDY - STAGE 2
NSW CASE STUDY FACILITY

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PLOT DATE:
PROJECT NO: 2024-1019
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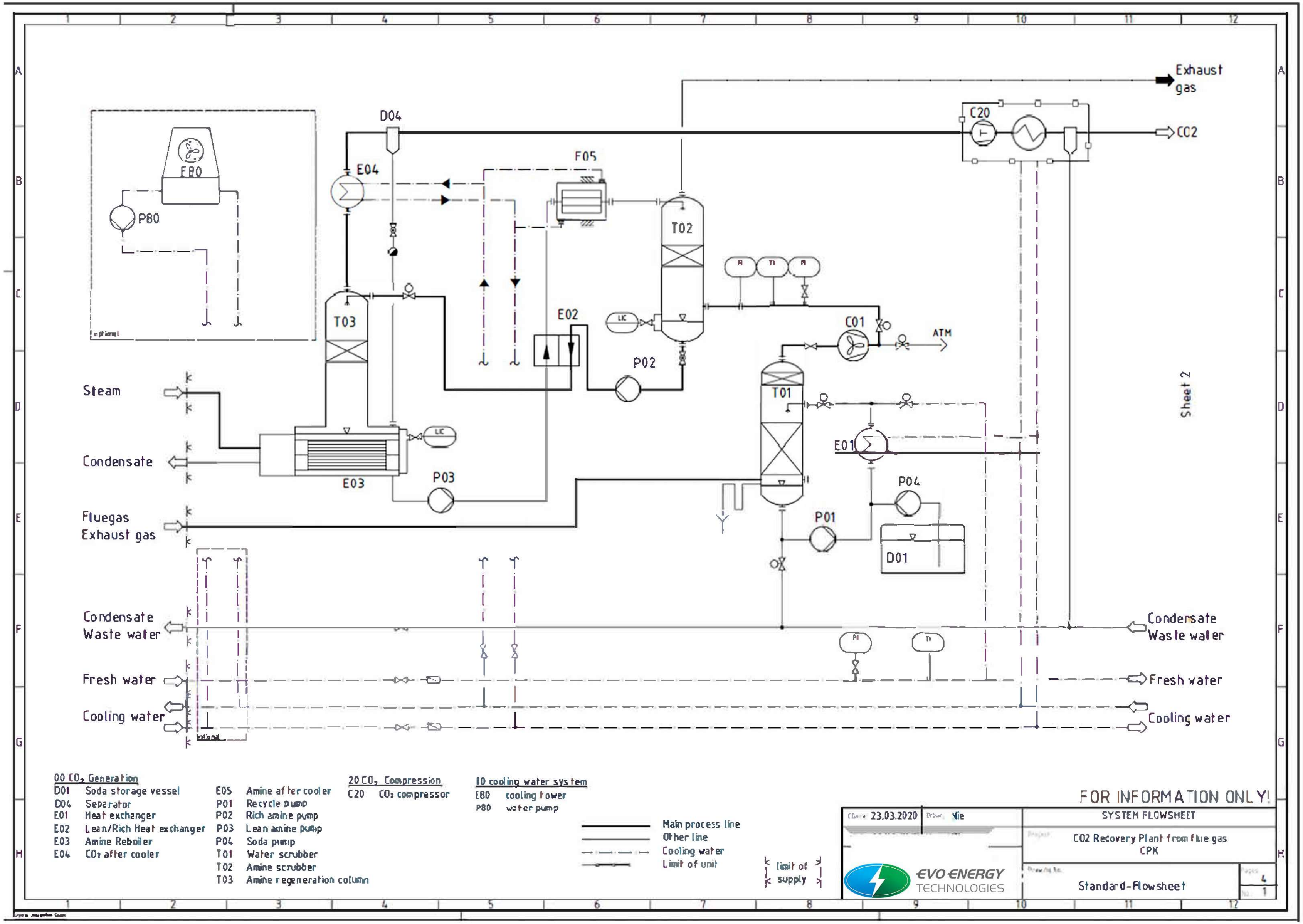
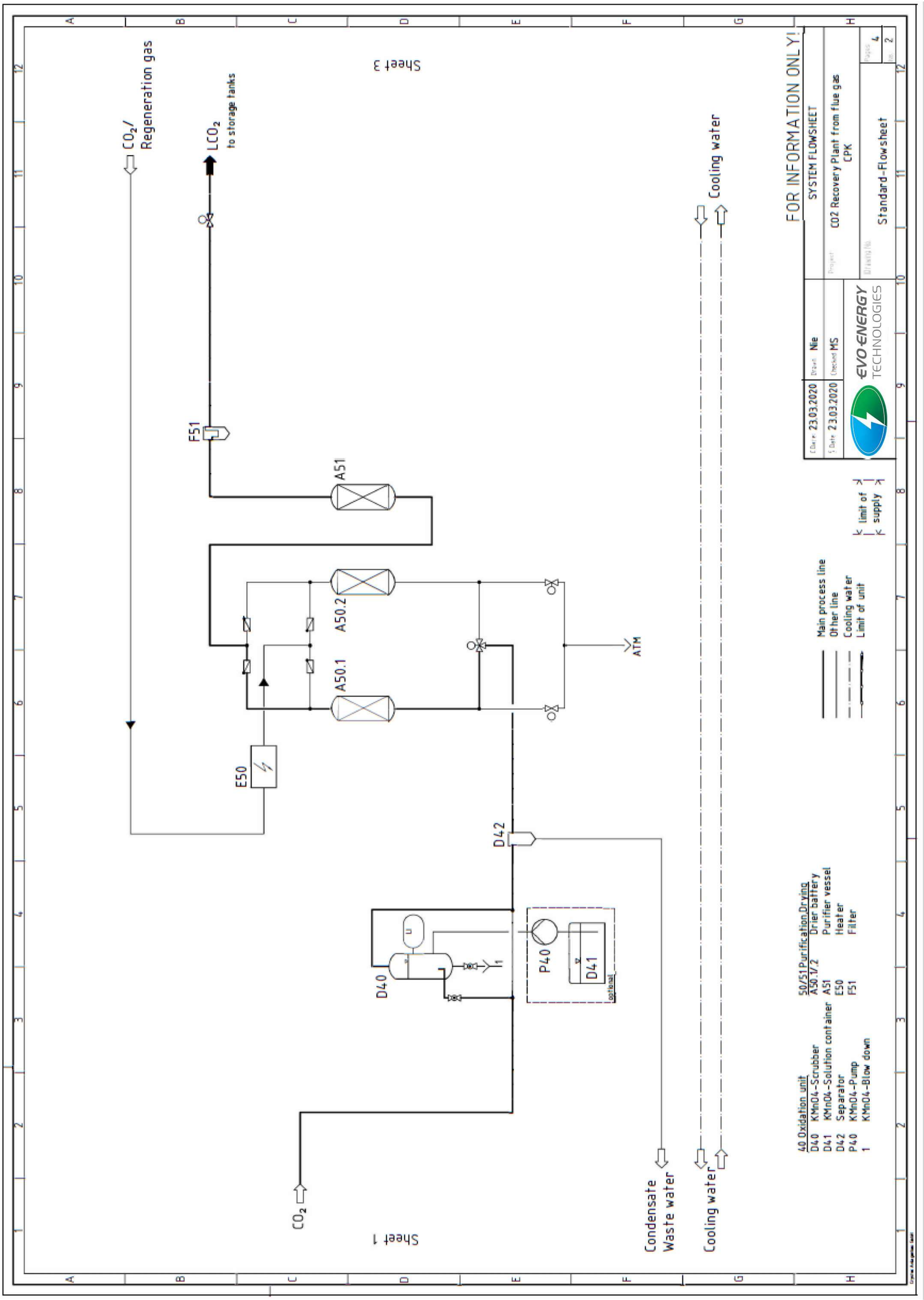
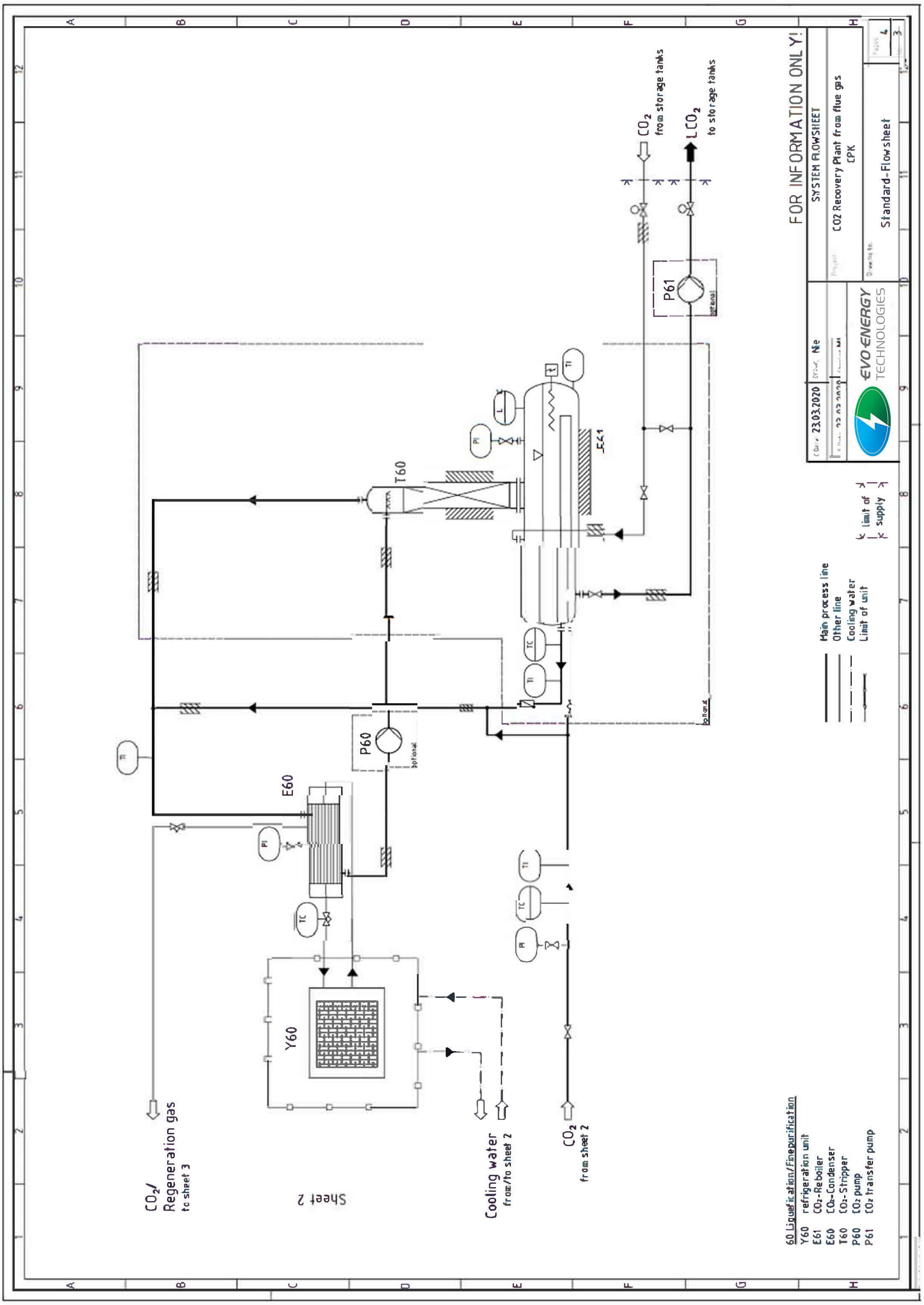
CHECKED: K.F
APPROVED: F.T
SHEET: 1 OF 1

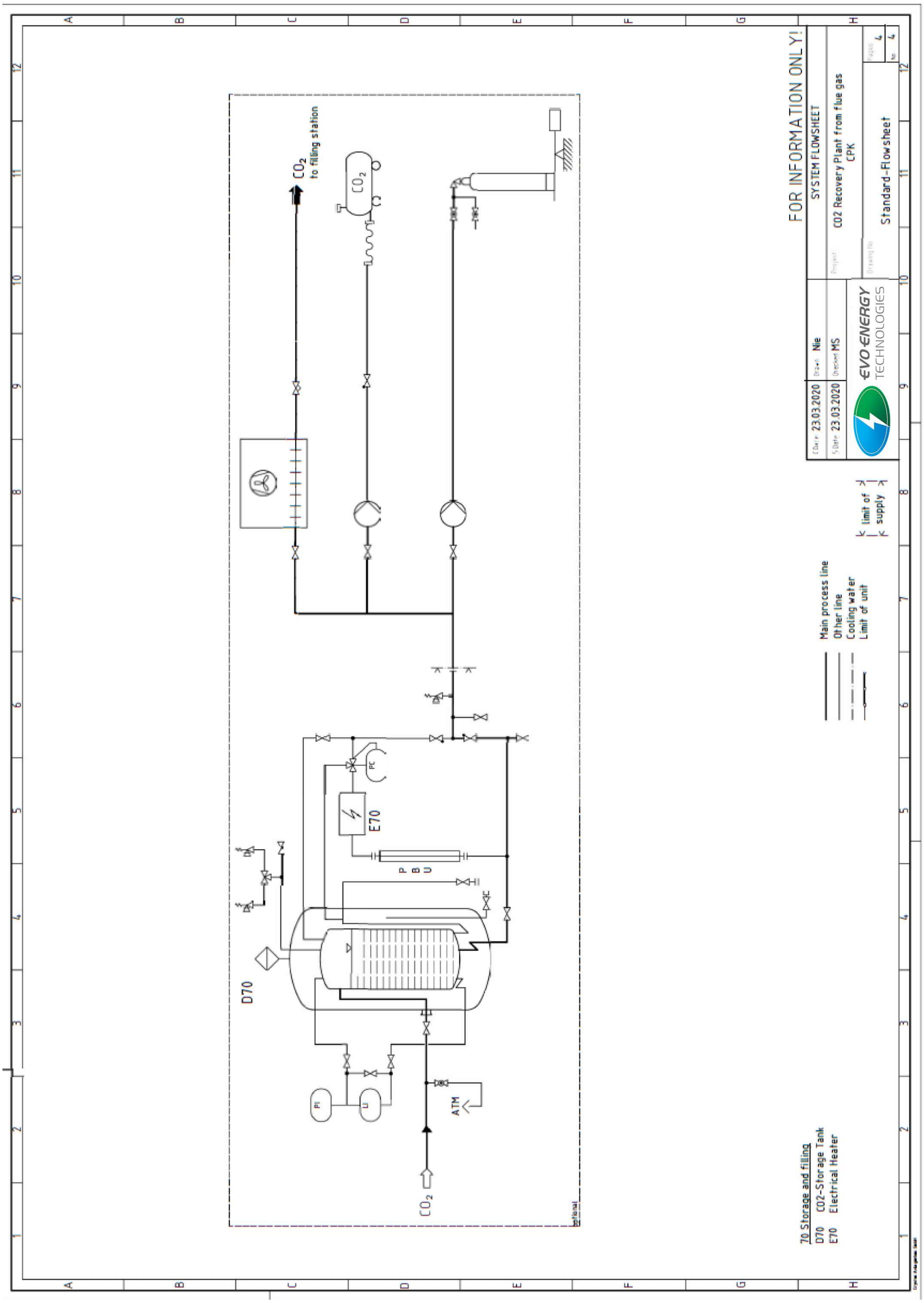
DRAWING TITLE:
BIOGAS PLANT
ELEVATIONS
DRAWING NUMBER: 2024-1019-NSW-007
REVISION: A

11.5 Appendix 5: Process Flow Diagram of the CO_2 Recovery Plant (Evo Energy Technology)


Exhaust gas
C20
CO2
D04
E04
F05
T02
P80
E80
optional
T03
E02
LIC
FI
TI
FI
C01
ATM
P02
T01
Steam
Condensate
E03
LIC
P03
E01
P04
P01
D01
Fluegas Exhaust gas
Sheet 2
Condensate Waste water
Fresh water
Cooling water
optional
PI
TI
Condensate Waste water
Fresh water
Cooling water
00 CO₂ Generation
D01 Soda storage vessel
D04 Separator
E01 Heat exchanger
E02 Lean/Rich Heat exchanger
E03 Amine Reboiler
E04 CO₂ after cooler
E05 Amine after cooler
P01 Recycle pump
P02 Rich amine pump
P03 Lean amine pump
P04 Soda pump
T01 Water scrubber
T02 Amine scrubber
T03 Amine regeneration column
20 CO₂ Compression
C20 CO₂ compressor
80 cooling water system
E80 cooling tower
P80 water pump
Main process line
Other line
Cooling water
Limit of unit
limit of supply
FOR INFORMATION ONLY!
Date 23.03.2020
Drawn Vie
SYSTEM FLOWSHEET
Project CO2 Recovery Plant from flue gas CPK
EVO ENERGY TECHNOLOGIES
Drawing No. Standard-Flowsheet
Pages 4
No. 1


Sheet 3
CO_2/ Regeneration gas
LCO_2 to storage tanks
Cooling water
F51
A51
A50.2
A50.1
E50
ATM
D42
D40
P40
D41
optional
CO_2
Sheet 1
Condensate Waste water
Cooling water
FOR INFORMATION ONLY!
SYSTEM FLOWSHEET
Project CO2 Recovery Plant from flue gas CPK
Drawing No. Standard-Flowsheet
Pages 4
No. 2
C.Date 23.03.2020 Drawn Nie
S.Date 23.03.2020 Checked MS
EVO ENERGY TECHNOLOGIES
Main process line
Other line
Cooling water
Limit of unit
limit of supply
40 Oxidation unit
D40 KMnO4-Scrubber
D41 KMnO4-Solution container
D42 Separator
P40 KMnO4-Pump
1 KMnO4-Blow down
50/51 Purification Drying
A50.1/2 Drier battery
A51 Purifier vessel
E50 Heater
F51 Filter


FOR INFORMATION ONLY!
SYSTEM FLOWSHEET
Project: CO2 Recovery Plant from flue gas CPK
Drawing to: Standard-Flowsheet
Date: 23.03.2020
Drawn: Nie
EVO ENERGY TECHNOLOGIES
Pages 4
3
CO_2 from storage tanks
LCO_2 to storage tanks
P61
optional
T60
E61
TI
PI
L
TC
TI
optional
P60
optional
E60
TI
PI
TC
Y60
CO_2/ Regeneration gas to sheet 3
Cooling water from/to sheet 2
CO_2 from sheet 2
Sheet 2
Main process line
Other line
Cooling water
Limit of unit
limit of supply
60 Liquefication/Finepurification
Y60 refrigeration unit
E61 CO_2-Reboiler
E60 CO_2-Condenser
T60 CO_2-Stripper
P60 CO_2 pump
P61 CO_2 transfer pump
A
B
C
D
E
F
G
H
1
2
3
4
5
6
7
8
9
10
11
12


FOR INFORMATION ONLY!
SYSTEM FLOWSHEET
Project
CO2 Recovery Plant from flue gas
CPK
Drawing No
Standard-Flowsheet
Pages 4
No 4
C.Date 23.03.2020
Drawn Nie
S.Date 23.03.2020
Checked MS
EVO ENERGY TECHNOLOGIES
limit of supply
Main process line
Other line
Cooling water
Limit of unit
70 Storage and filling
D70 CO2-Storage Tank
E70 Electrical Heater
CO2 to filling station
CO2
E70
P
B
U
PC
D70
PI
LI
ATM
CO2
optional
A
B
C
D
E
F
G
H
1
2
3
4
5
6
7
8
9
10
11
12

11.6 Appendix 6: Biofertiliser Plant Technical Drawings

NOTES:

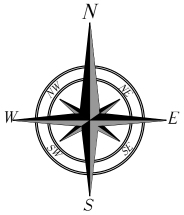
1. ALL DIMENSIONS ARE IN METRES UNLESS NOTED OTHERWISE.
2. BIOFERTILISER PROCESSING AREA
3. ~810 M^2
4. BIOFERTILISER LOADING AREA
5. ~170 M^2

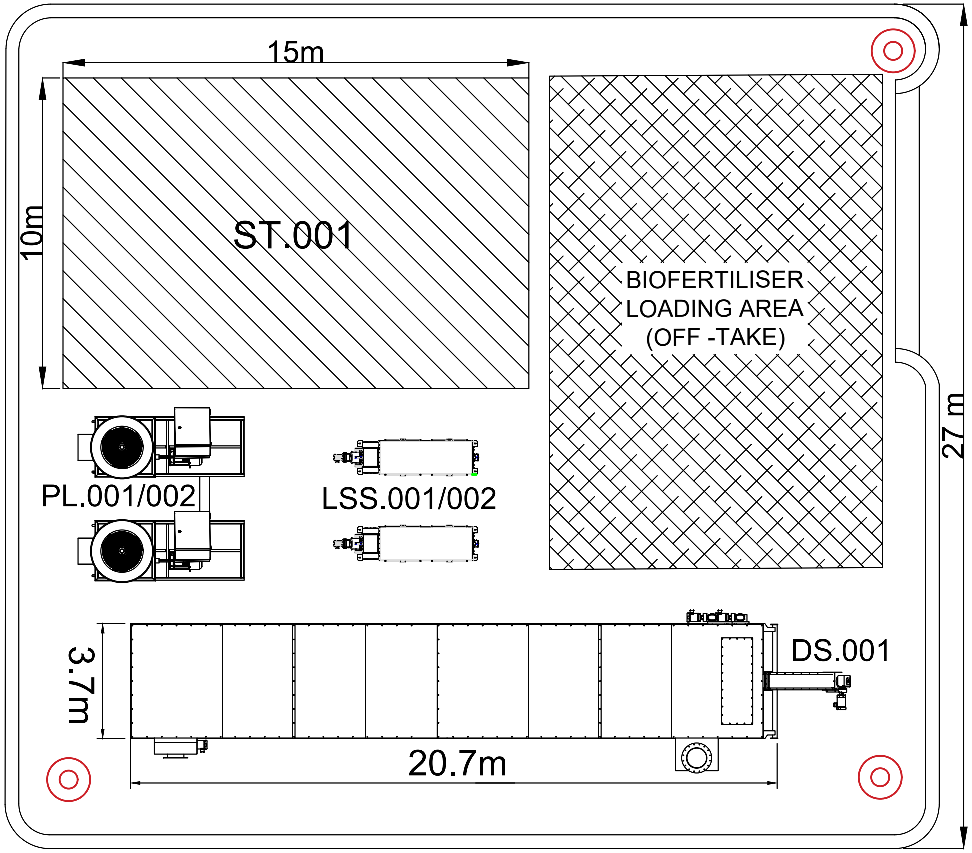
BIOFERTILISER COMPONENTS:

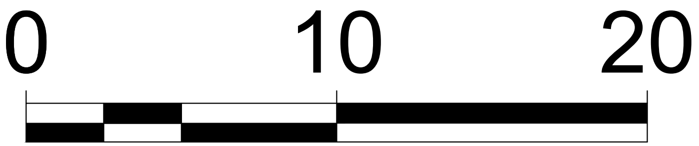
LSS.001/002	Liquid Solids Separation
DS.001	Drying System
PL.001/002	Pelleting System
ST.001	Storage Area

LEGEND:

◎ Hydrants







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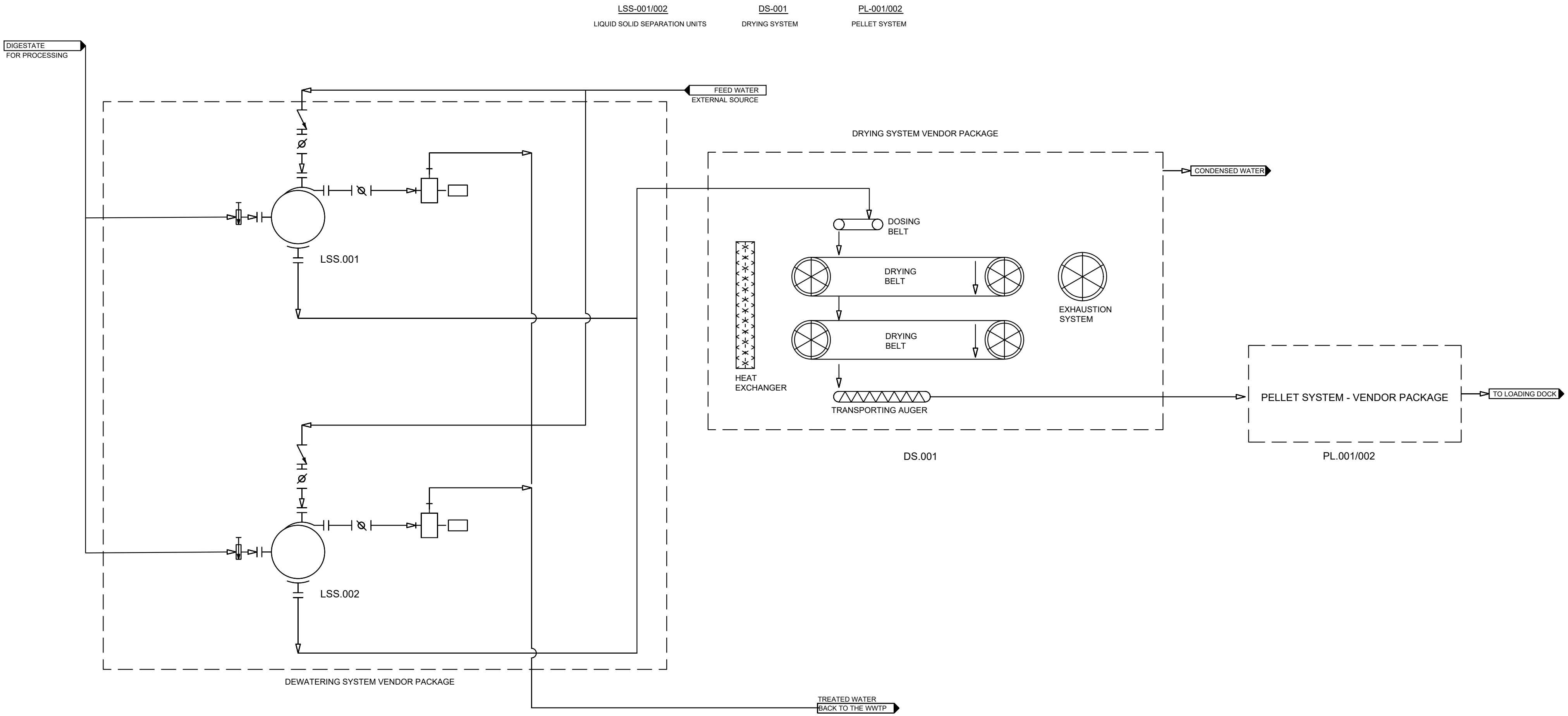
NSW CASE STUDY FACILITY

SCALE@A1: 1:1000	PLOT DATE:	PROJECT NO: 2024-1019	
DRAWN: L.M	CHECKED: K.F	APPROVED: F.T	SHEET: 1 OF 1

DRAWING TITLE:
BIOFERTILISER PLANT
ELEVATIONS

DRAWING NUMBER: 2024-1019-NSW-BF-008

REVISION: A



20-2-24	ISSUED FOR MS4 REPORT	A
DATE	DESCRIPTION	REV

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NOVEL FEED STUDY - STAGE 2
NSW CASE STUDY FACILITY

SCALE@A1:	PLOT DATE:	PROJECT NO:	
1:1000		2024-1019	
DRAWN:	CHECKED:	APPROVED:	SHEET:
L.M	K.F	F.T	1 OF 1

DRAWING TITLE:
BIOFERTILISER PLANT
ELEVATIONS

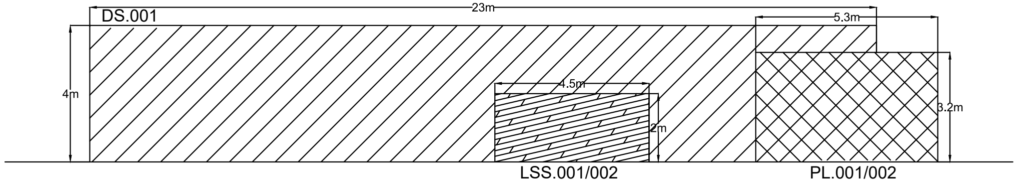
DRAWING NUMBER:
2024-1019-NSW-010

REVISION:
A

BIOFERTILISER COMPONENTS:

LSS.001/002	Liquid Solids Separation
DS.001	Drying System
PL.001/002	Pelleting System
ST.001	Storage Area

NORTH



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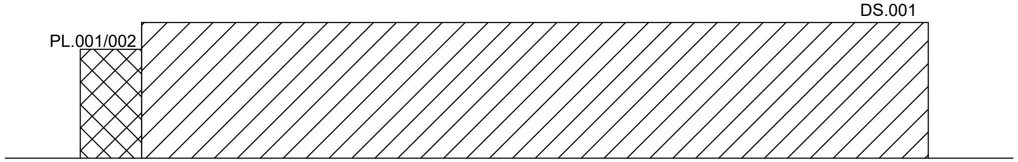

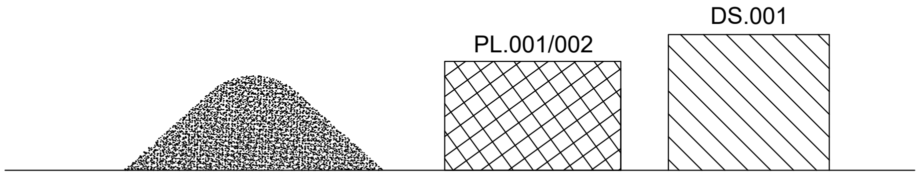

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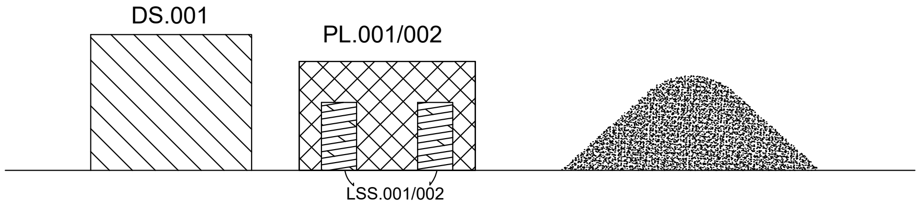

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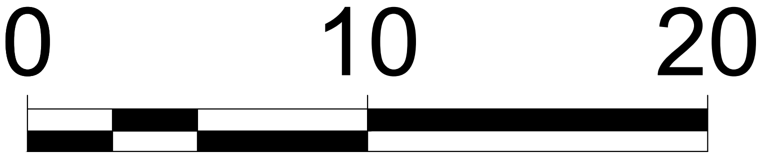

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RECOVERY FACILITY
NOVEL FEED STUDY - STAGE 2
NSW CASE STUDY FACILITY

SCALE@A1: 1:1000
PLOT DATE:
PROJECT NO: 2024-1019
DRAWN: L.M
CHECKED: K.F
APPROVED: F.T
SHEET: 1 OF 1

DRAWING TITLE:
BIOFERTILISER PLANT
ELEVATIONS
DRAWING NUMBER: 2024-1019-NSW-011
REVISION: A