Final Report

V&V Integrated Waste Management

Integrated Wastewater Treatment, Biogas and Biofertiliser FEED

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1 Executive Summary

V&V Walsh is the largest meat processor in Western Australia, employing more than 1000 staff and producing more than 40 million kg of meat products annually. The Bunbury facility can process 5,000 sheep per day, approximately half of this is boned and packed on-site. In addition, it can process a further 400 cattle per day, with the ability to bone and process 300 beef carcasses per day.

The processing plant, operating since 1993, is located adjacent to the Preston River, and close to environmental conservation areas. In recent years, the environmental regulation has become increasingly stricter, both regarding the amount of water that can be disposed via irrigation, and the nutrients loading (nitrogen and phosphorous). In the past five years several attempts to improve the existing system weren't entirely successful, mainly due to the current wastewater treatment plant (WWTP) configuration, designed for the removal of organic matter, but not nutrients.

Following a series of technical assessments, including sampling campaigns and Biowin modelling, the conclusion was that to achieve compliance with the regulation, a new WWTP is required, focussing on the removal of nitrogen. This is a challenge facing the red meat industry across the board, and several processing plants are going through a similar process. The new treatment process needs to achieve efficient nitrogen removal, combined with an improved water quality, so it becomes suitable for uses in other applications other than irrigation.

In the other hand, abattoir wastewater is a rich source of valuable nutrients, energy, and water[1]. When appropriately managed, and integrated with selected streams of organic wastes, optimised anaerobic digestion and resource recovery can be achieved, along with robust long-term environmental compliance, along with side-streams revenue.

Implementing the concept of integrated management of wastewater and organic wastes will future-proof the company's operation in terms of environmental compliance, potentially generating income from side-streams, such as energy, water, and fertiliser.

Towards Net Zero – C30

In the integrated concept, carbon-rich streams are concentrated and combined aiming to maximise the production of biogas, in parallel to the WWTP. This results in a reduction in the overall carbon footprint both by reducing aeration needs and by the production of biogas as a source of renewable energy. Landfill emissions are also eliminated in this process.

This Final Report presents the outcomes of the Front-End Engineering Design (FEED), V&V Walsh's *Integrated Wastewater Treatment,* Biogas *and Biofertiliser plant*. The integrated design was conceived based on the concepts of approaching Net Zero Carbon, via resource recovery and a circular economy.

In this concept, the liquid streams were processed in the modular wastewater treatment plant (WWTP), aiming for recovery of oil & grease, solids and organic matter, nitrogen, phosphorous and pathogens. The technology selection was based on maximising the recovery of recycled water, combined with optimised biogas production. This is possible using a sequence of secondary/tertiary and advanced water treatment technologies, allowing for unrestricted irrigation and other non-potable uses.

In parallel, carbon-rich solid waste streams, including paunch, save all screened solids, manure, sludge, and fat from WWTP, are diverted to an anaerobic digester (AD), aiming to produce biogas and bio-fertiliser. This prevents the WWTP from being overloaded by BOD/COD, which could increase the aeration requirements, whilst still preserving sufficient carbon for the denitrification process to take place efficiently. This brings along opportunities to reduce costs by reducing aeration and external carbon requirements, and where possible, redirect carbon to energy-generating processes. The concept plant will allow for flexibility for solid and liquid waste received and pre-treatment

[1] Sustainable Management of Waste and Wastewater Streams at V&V Walsh (AMPC, July 2020)

to achieve an adequate mixing ratio, consequently higher methane yield offsetting energy consumption by the WWTP.

Figure 1 shows the 3D rendering of the proposed Integrated Wastewater Treatment, Biogas and Biofertiliser plant at V&V Walsh processing plant in Bunbury, WA

Figure 1. Proposed Integrated Wastewater Treatment, Biogas and Biofertiliser plant at V&V Walsh processing plant in Bunbury, WA.

This project is aligned with the Australian red meat and livestock industry target to achieve Carbon Neutrality by 2030 (CN30) [2] and will bring V&V Walsh to the forefront of the industry, as a model to be implemented by other red meat processing plants (RMPs).

Cost Estimate and Economic Analysis

The total capital expenditure (CAPEX) based on a +/-30% cost estimate is of $16.5M. The investment is planned to occur in stages, over 5- 6 years, as per suggested on Table 1:

Table 1. Summary of estimated capital investment over the next six years.

		2022	2023	2024	2025	2026	2027	2028
Stage 1 – Wastewater treatment plant	$7.31M							
Stage 2 – Biogas Plant	$5.95M							
Stage 3 – Biofertiliser plant	$3.37M							
Total	$16.63M							

[2] www.mla.com.au/research-and-development/Environment-sustainability/carbon-neutral-2030-rd/cn30

The streams generating revenue, based on conservative assumptions, are presented on Table 2:

Table 2. Summary of revenue streams.

Income	Start	$/annum
Recycled water	2024	393,600
Energy From Biogas (Combined)	2025	989,250
Biochar	2027	523,200
Savings from disposal	2027	875,000
Carbon credits	2028	177,600
Total revenue per annum		**$2.96 M**

The economic analysis (using the Net Present Value method) considered the capital expenditure, Operating costs based on a percentage of CAPEX, and the estimated incomes. The outcome is net positive, over a 25 year's total project life, with a Net Present Value of $28.9M. The payback time is estimated to be 10 years, with an annual ROI of 2.7%. Table 3 presents the summary of the Economic Analysis of the implementation of the Integrated Waste Management system.

Table 3. Summary of Economic Analysis of the implementation of the Integrated Waste and Wastewater Management system.

Item	Value
Net Present Value	$ 28,9 M
PV of Costs (CAPEX & OPEX))	$ 30,3 M
ROI 25 years	95.4%
Annualised ROI	2.72%
Payback time	~10 years

Based on the technical and economical outcomes presented in this report, the implementation of the Integrated Waste and Wastewater Management system will result on:

- The integrated system is self-sufficient in terms of power, the entire system can be powered by biogas, with a surplus of energy in the form of heat
- The income generated by side-streams will offset costs (CAPEX and OPEX). The estimated return on investment is 2.7% per annum, when traditionally waste/wastewater management is a cost (negative ROI).
- The biogas system is designed to receive additional feedstock, with a potential to double the energy output by adding high carbon wastes (such as food waste, breweries waste, etc.).
- The methane produced in the biogas system can be used for producing Hydrogen if that is desirable. It can be on sold to power new green energy industry initiates e.g. green hydrogen.
- The facility will offset carbon, contributing for V&V Walsh's net zero carbon programme.

2 Introduction

Abattoir wastewater is a rich source of valuable nutrients, energy, and water. When appropriately managed, and combined with selected streams of organic wastes, optimised anaerobic digestion and resource recovery can be achieved, along with robust environmental compliance. Implementing the concept of integrated concept to V&V Walsh wastewater and waste management will future-proof the company's operation in terms of environmental compliance, aligned with the concepts of circular economy and resource recovery.

The schematic flow diagram in Figure 2 provides a high-level description of the integrated processes. The concept proposed includes pre-conditioning and treatment for liquid and solid waste streams.

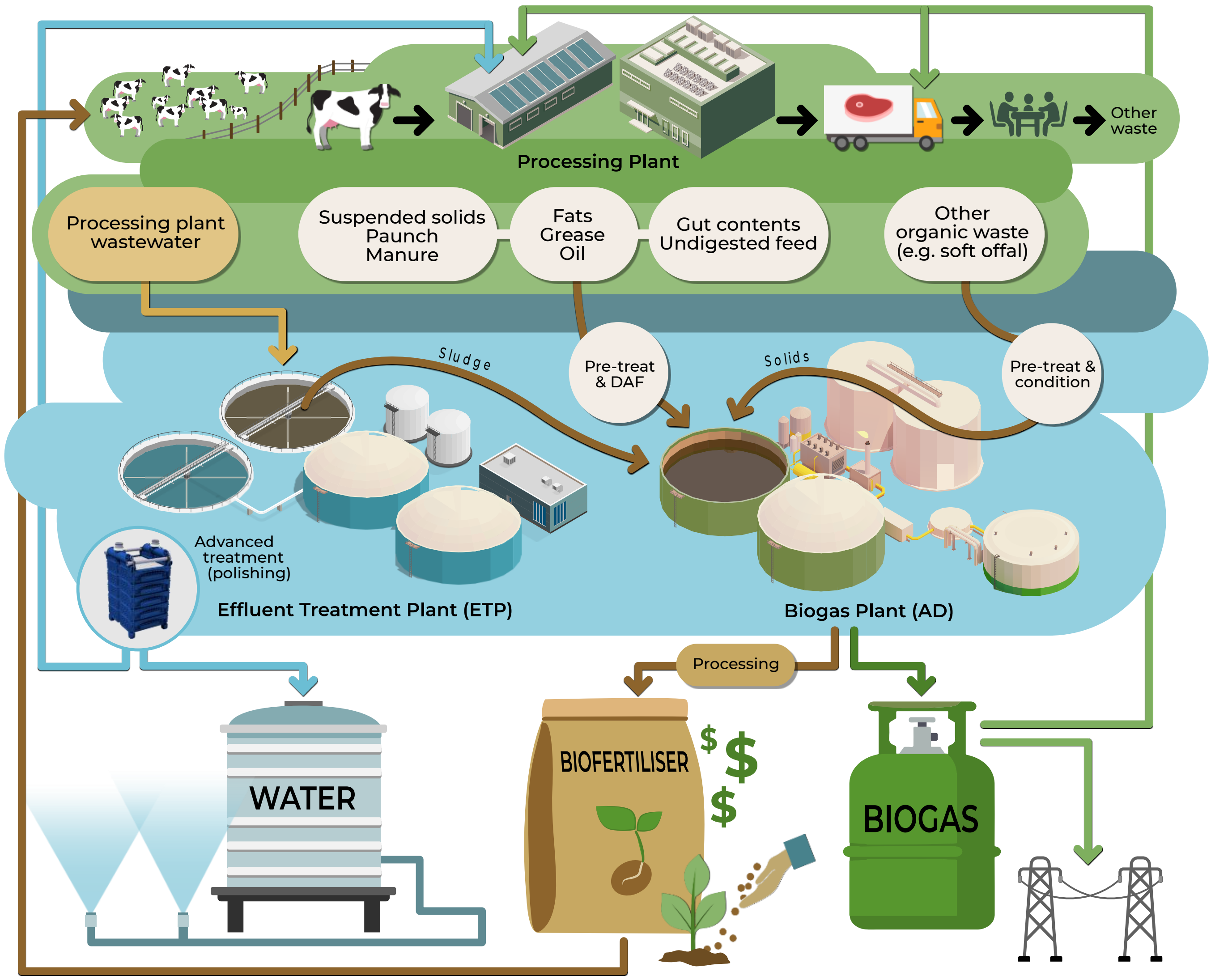

Figure 2. Schematic model of the V&V Walsh Integrated Waste Management system. ©Tessele Consultants.

This is also contributing to the Australian red meat and livestock industry ambitious target to be Carbon Neutral by 2030 (CN30) and will bring V&V Walsh to the forefront of the industry, as a model to be implemented by other red meat processing plants (RMPs).

In this context, the Concept Design proposed for this project has taken into consideration the production of recycled water compliant with medium and high exposure quality, and production of biogas and fertiliser from mixed solid waste streams from V&V Walsh Abattoir. The process integration, along with resource recovery and combining the treatment of both solid and liquid streams is an innovative concept in the Australian red meat industry resulting in positive environmental, economic, and social outcomes.

In this concept, the liquid streams will be processed in the modular wastewater treatment plant, aiming for removal of oil & grease, solids and organic matter, nitrogen, phosphorous and pathogens. For the technology selection it was considered the recovery of recycled water. This is possible using a combination of secondary/tertiary and advanced water treatment technologies allowing V&V Walsh to irrigate and find alternative end-users for the treated water.

Selected solid waste streams, including paunch, save all screened solids, manure, sludge, and fat from WWTP, will processed in an anaerobic digester (AD), aiming to produce biogas and bio-fertiliser. The plant will allow for flexibility for solid and liquid waste receival and pre-treatment to achieve adequate mixing ratio, consequently higher methane yield offsetting energy/gas consumption from the WWTP.

This Final Report presents the outcomes of the Front-End Engineering Design (FEED), V&V Walsh's Integrated Wastewater Treatment, Biogas and Biofertiliser plant. The integrated design was conceived based on the concepts of approaching Net Zero Carbon, via resource recovery and a circular economy

3 Project Objectives

This project aims to develop a front-end engineering design of integrated wastewater treatment, biogas and biofertiliser plant. The concept to be used in the design considers engineered biological reactors for adequate management of wastewater and organic solid waste originated from the abattoir processing plant.

This design is for a new optimized and modular wastewater treatment plant with high flexibility of process control, focusing on attending current wastewater disposal issues faced by the abattoir. Design upgrades of the existing infrastructure will not be considered and the decommissioning of such infrastructure, existing ponds, was purposed after the implementation of new designed WWTP.

The new plant design is considering aspects such as nutrients (N, P) and other compounds removal from wastewater, with the possibility of irrigation and other water recycling uses (either Class C or Class A), within compliance. Additionally, the design of an integrated biogas plant will allow organic solid waste (currently disposed of off-site) and sludge from the WWTP, to be processed on-site for biogas production with potential for thermal and electrical energy applications. The incorporation of a biofertiliser plant design will consider upgrades of the digestate (resulting from the biogas plant) for conversion into an added value fertiliser product.

The result of this project, including the cost estimates for the plants, will then be used by V&V Walsh for the decision-making process for further stages of the plant implementation. These results will also support the Environmental Licensing application process. The proposed system has never been trailed in the Australian Red Meat Processing Industry and represents a quantum leap in terms of innovation and resource recovery.

The overarching objective of this project is to prepare a front-end engineering design for an integrated wastewater, biogas and fertiliser plant for management of the abattoir wastewater and organic solid waste. The final report was used for the licensing application, decision making process, procurement related to this and further stages of the system implementation. The objectives to be achieved include:

- Introduce to the Red Meat Processing Industry a new concept of recovering value from wastewater and organic solid wastes
- Development of a design of an Integrated Wastewater, Biogas and Biofertiliser plant
- Preparation of an equipment list to be used in the procurement stages
- Development of a cost estimate for the wastewater, biogas and biofertiliser plants
- Development of an economic analysis including CAPEX and OPEX, which will support the decision-making process for the plant implementation

4 Methodology

To undertake the design of the integrated facility and cover all aspects required for a successful and concise outcome, the project was be comprised of 3 main phases with detailed sub-tasks:

- Phase 1 – Wastewater Characterisation and Wastewater Plant Design
- Phase 2 – Organic Waste Characterisation and Biogas Plant Design
- Phase 3 – Biofertiliser assessment and Biofertiliser Plant Design

Following the design stages and cost estimates, and economic analysis was performed, considering revenue from side-streams such as water, biogas and biofertiliser. The methodology followed for the project delivery is described below:

4.1 Wastewater characterisation and wastewater plant design

- Site Assessment: the site assessment will include a desktop review of existing documentation, gap-analysis, site visit for assessing the site constraints/conditions, identification of available areas for system implementation, new processes requirements (why current infrastructure cannot perform proposed work), evaluate existing infrastructure and equipment to be maintained.
- Wastewater Characterisation (liquid Stream): A composite sampling campaign of the wastewater before and after the Dissolved Air Flotation (DAF) was conducted prior to for detailed Characterisation of the wastewater. This was carried-out via sampling collection (three times daily for five consecutive days) and samples was sent for accredited laboratory analysis (with selected parameters). The resulting data will then be processed to evaluate trends and variability. The Environmental License was assessed for wastewater irrigation limitations. Nutrients and mass balance was calculated, and these was used to the assess the need for outsourcing carbon from external source.
- Wastewater uses, demand & off-take potential: the water source/quality, costs and demand were confirmed via client consultation. The Guidelines for recycling water in WA was assessed and opportunities for water reuse on/off site was evaluated. Potential areas for receiving wastewater for irrigation purposes was considered. Rainfall data (BOM) was collected for the region, and this was followed by calculation of water balance (dry/wet) season. The treated effluent quality was established based on requirements of the environmental regulator and

water reuse possibility, ensuring full compliance of the design. Design parameters was than consolidate and the Basis of Design was established.

- Wastewater treatment Plant Equipment Selection and Concept Design: following the basis of design, the wastewater flow rates, and balancing requirements was calculated. The inlet wastewater quality suitability, including the equipment selection and process requirements was detailed. The system hydraulics/pumping requirements was defined, including hydraulic calculations for equipment, piping and interconnection (using excel spreadsheet). The process design of the treatment plant was developed, based on selected process, and a BIOWIN model was used to validate the process design assumptions. The resulting effluent quality was estimated during the process calculations. Treated wastewater storage and improvements required for irrigation and reuse was defined. Process and hydraulic calculation will allow the definitions of electrical requirements of the plant. Based on the selected system, the level of instrumentation and automation was defined, and the development of a preliminary control philosophy was established. The minimal civil infrastructure was defined. The Drafting of the WWTP was undertaken (1 x General Arrangement, Process Flow Diagram, 1 x Plant Layout, 1 x Piping and Interconnections - up to 3 sections, 1 x Hydraulic Profile – based on a flat slab).
- Preparation of an equipment list for the Wastewater treatment plant: A list of equipment was prepared and quotations with up to three suppliers was requested for specific equipment of the Wastewater treatment Plant.
- Cost estimate of the Wastewater Treatment Plant: The cost estimate was undertaking considering all the mechanical, electrical and instrumentation, installation, commissioning, operation and maintenance costs of the Wastewater treatment Plant.

4.2 Organic waste characterisation and biogas plant design

- Wastewater Characterisation & Optimization (solid Stream): Previous project undertaken by AMPC, V&V Walsh and Tessele Consultants “Sustainable management of waste and wastewater streams at V&V Walsh”, have identified and characterized potential organic waste to be processed at a Biogas Plant; these are: Combined Save-all, Beef Paunch Sheep Paunch, DAF belt press and Sheep manure. Their respective quantity was confirmed during site assessment. The organic waste data was processed, considering inputs from sludge from the plant. The adequate substrate mixing ratios was calculated, followed by a nutrients and mass balance and these was used to the assess the need for outsourcing carbon from external source.
- Energy uses, demand & offtake potential: the current energy sources (electrical, gas, thermal), costs, uses and demand was confirmed via client consultation. The opportunities of using energy (gas, electrical and/or thermal) in the plants was assessed.
- Biogas Plant Equipment Selection and Concept Design: the design of the biogas plant will take into consideration adopted substrate mixing ratios. The substrate pre-treatment, condition sanitization and feeding system was dimensioned. The biodigester process design was undertaken including estimative of biogas production. The definition of ancillary parts was undertaken. The system hydraulics and pumping requirements was defined, including hydraulic calculation for equipment, piping, and interconnections (using excel spreadsheet). Requirements for biogas storage, management and treatment was defined as per previously identified uses. The energy balance was undertaken, and the selection of an appropriate CHP engine was made based on biogas availability, electrical and thermal energy demands. Based on selected equipment the electrical

requirements of the plant was calculated. Based on the selected system, the level of instrumentation and automation was defined, and the development of a preliminary control philosophy was established. The minimal civil infrastructure was defined. The Drafting of the Biogas Plant was undertaken (1 x General Arrangement, Process Flow Diagram, 1 x Plant Layout, 1 x Piping and Interconnections - up to 3 sections, 1 x Hydraulic Profile – based on a flat slab).

- Preparation of an equipment list for the Biogas Plant: A list of equipment was prepared and quotations with up to three suppliers was requested for specific equipment of the Biogas Plant.
- Cost estimate of the Biogas Plant: The cost estimate was undertaking considering all the mechanical, electrical and instrumentation, installation, commissioning, operation and maintenance costs of the Biogas Plant.

4.3 Biofertiliser assessment and biofertiliser plant design

- Biofertiliser potential: Characterisation and quantification of the biofertiliser to be produced was undertaken based on combined wastewater sludge and organic waste (co-digestion) in the biofertiliser. The environmental regulation regarding biosolids (biofertiliser) application and transporting was undertaken, ensuring full compliance of the design.
- Biofertiliser Plant Equipment selection and Concept Design: the selection of a suitable biofertiliser processing plant was undertaken based on feasibility (due to scale). Storage requirements was defined, as well as required treatment and improvements in the biofertiliser quality prior to land application. The main equipment and ancillary parts was defined followed by the process and hydraulics calculations. The energy balance was undertaken assessing process/ equipment energy requirements. Based on selected equipment the electrical requirements of the plant was calculated. Based on the selected system, the level of instrumentation and automation was defined, and the development of a preliminary control philosophy was established. The minimal civil infrastructure was defined. The Drafting of the Biofertiliser Plant and Components was undertaken, including 1 x General Arrangement, Process Flow Diagram, 1 x Plant Layout, 1 x Piping and Interconnections - up to 3 sections, 1 x Hydraulic Profile – based on a flat slab.
- Preparation of an equipment list for the Biofertiliser Plant: A list of equipment was prepared and quotations with up to three suppliers was requested for specific equipment of the Biofertiliser Plant
- Cost estimate of the Biofertiliser Plant: The cost estimate was undertaking considering all the mechanical, electrical and instrumentation, installation, commissioning, operation and maintenance costs of the Biofertiliser Plant.

4.4 Economic Analysis

The total Capital Investment of the three plants (CAPEX of Wastewater, Biogas and Biofertiliser plant) was grouped into a total; the operational costs (OPEX of Wastewater, Biogas and Biofertiliser plant) of these plants was calculated, including potential offsets from energetic uses benefits resulting from the plant's integration. Inputs and outputs of the system such as water in and recycled water out, solid organic waste in biogas and biofertiliser out, and their respective economic values was summarized.

5 Project Outcomes

Below the project outcomes are presented in detail for the three Phases of the project: wastewater treatment, biogas and biofertiliser.

5.1 Wastewater characterisation

Red meat processing facilities use water in several steps of their process and generate relatively high volumes of wastewater, containing high concentrations of organic matter and nutrients. V&V Walsh processing facility operates 5 days a week, approximately 8 – 10 hours per day, resulting in a variable effluent, both in terms of quality and quantity.

5.1.1 Design flow rate definition

The wastewater production is summarized as per Table 4. The wastewater of production days is generated in a period of 8 to 10 hours. Over the weekends the wastewater volume is around four times lower (~302 kL/day) if compared to production days (average 1,200 kL/day).

Table 4. Wastewater production from the processing facility on weekdays and weekends.

	Value	Unit
Days of operation per year	251	days
Operation hours per weekday	8 -10	h/d
Operation hours per weekend day	0	h/d
Weekdays Flow	1100 -1300	kL/day
Weekend Flow	604	kL/day

Based on the current processing number: a total of 40,708 tHSCW/yr; the wastewater production per tHSCW is 8.2 kL (including water during weekends). It is aligned with numbers obtained in the *AMPC 2020 Environmental Performance Review (EPR) for the Red Meat Processing (RMP) Industry*, with average values ranging from 6.5 to 8.5 kL/tHSCW.

Although V&V Walsh is planning to increase production from 40,708 tHSCW/yr to 73,921 tHSCW/yr the wastewater flow rate is not expected to double. The facility is planning to expand sheep and lamb production (3,400 to 5,500 lamb/sheep per day) by using the same kill floor and a similar amount of water. On the other hand, to increase beef production (300 to 600 cattle per day) additional site upgrades will be required. As per discussion with client the kill floor will incorporate water savings technologies, therefore the average wastewater generation per t.HSCW is considered to be lower than current numbers.

Other few considerations such as a new spray chiller (~30,000 kL/yr) implementation and external effluent from onsite contractors (~30,000 kL/yr) are also incorporated into the total wastewater effluent to be processed in the future. A summary of the considerations including historic analysis of monthly, weekly, daily and hourly flow rate data is presented in the sequence.

Monthly flow rate variation

- The wastewater volumes data over the last three years was analysed (Figure 3). The highest monthly wastewater volume has been reached 36,167 kL, resulting in an average flow rate of 1,206 kL per day.
- Similar results were obtained for the last week of July 2021, summing 8,660 kL and an average daily flow rate of 1,237 kL.
- The average flow of the 31 months (Jan 19 to July 21) is 29,384 kL with a daily average flow rate of 979 kL

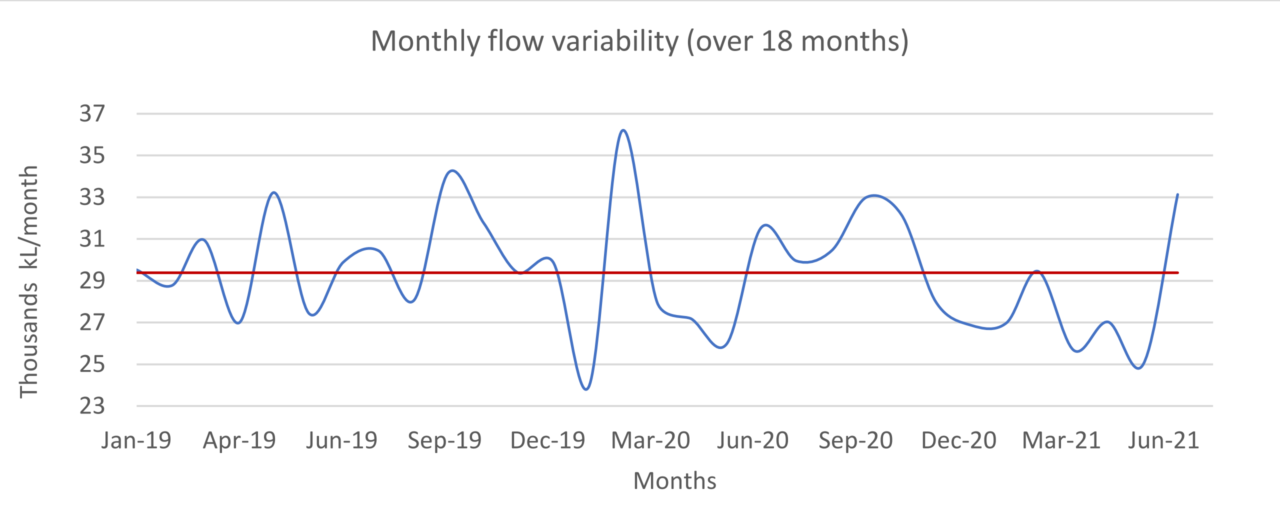

Figure 3. Monthly wastewater volumes variation (measured at DAF flowmeter).

Daily flow rate variation

- Analysing the daily data from 151 days from March to July 21 the average daily flow rate is 906 kL; including Hilton external effluent (Figure 4).
- The maximum observed flow rate was 1,449 kL on the 15th of June 2021.

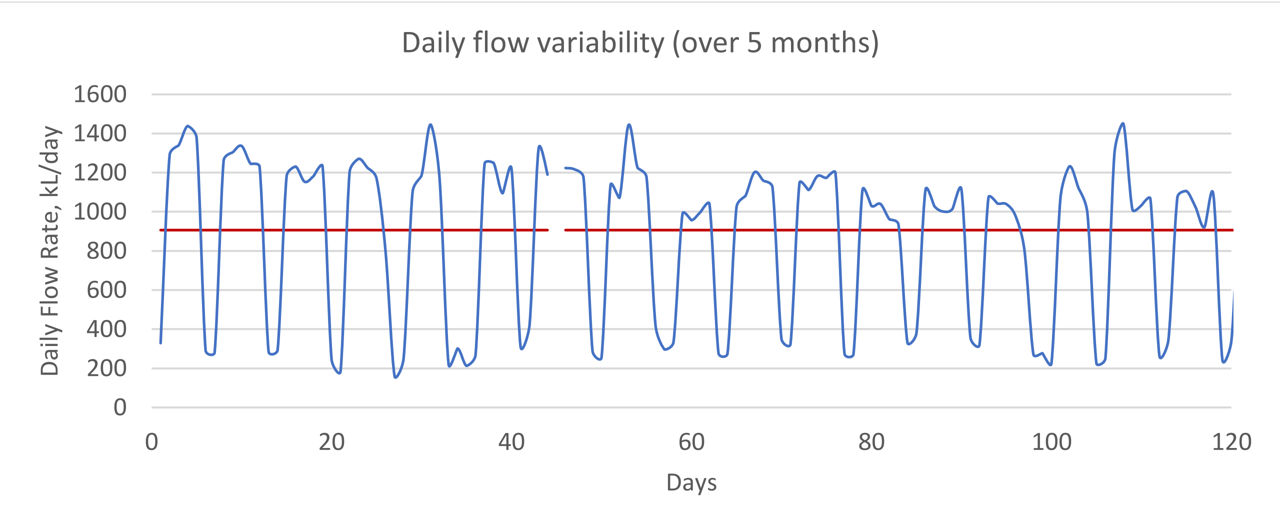

Figure 4. Daily total flow over 151 days. Data provided by V&V Walsh.

Hourly flow rate variation

- The average hourly flow rate for 18 days considering low, average and high wastewater volume (264, 1,100 and 1,439 kL per day) is 50 kL per hour (Figure 5).
- The highest hourly flow rate was equal to 134 kL/hour reached at 9.00 am on 04/03/21
- The flow has a similar pattern and runs for 24 hours with minima during the night period usually ranging from 10 to 35 kL per hour.

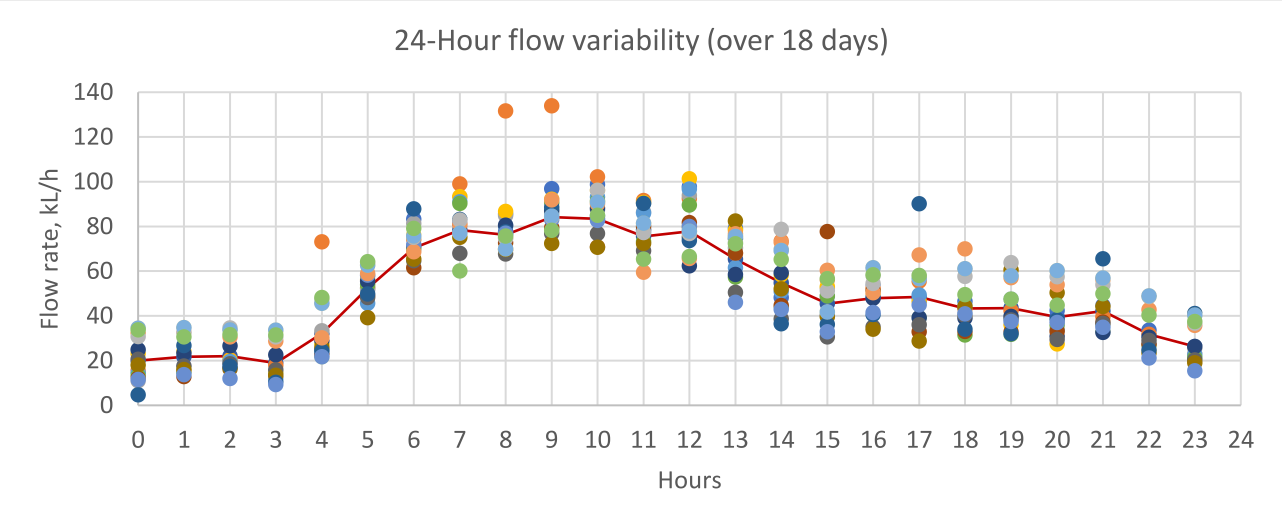

Figure 5. Wastewater hourly flow rate - eighteen isolated days

Flow Balancing and Impact on Design Considerations

Although water savings technologies are expected to be implemented for future expansions, at this stage the impact on wastewater production cannot be evaluated and therefore the design has made the assumptions presented in the sequence and summarised in Table 5. Assumptions for design flow rate:

Assumptions

- The most recent daily average data was used as input (water savings technologies have been implemented over the last years reducing the average consumption from 979 down to 907 kL per day). Design safety of 10% was added to the total.
- Maximum effluent daily peak flows (1,449 kL/ day) was equalized at the balancing tank (1.5 day holding capacity adopted)
- Additional effluent from onsite contractors 30,000 kL per year is added to current wastewater volumes.
- Additional plant upgrades have the potential to add 30,000 kL per year.
- The facility is constantly implementing water savings technologies and expansions was undertaken with lower water consumption. The assumed target of 6.5 kL of wastewater per t.HSCW processed.
- The wastewater treatment plant is assumed to have the capacity to treat effluent in 5 days, considered 2 days buffer capacity.

- WWTP will run 24/7 at an average flow rate of 48 kL / hour (1,161 kL per day)
- WWTP could run 24/7 with an average up to 68 kL / hour (1,640 kL per day)
- This represents a capacity increase of 41% based on current averaged values +10%
- Two modules of 820 kL / day implemented at first with the capacity to increase the flow rate by including the third module.
- Sensitive analysis (flow rates and loads was undertaken in the next stage of design)
- The designed WWTP can treat total effluent generated for maximum production (if targeted consumption is achieved). Possibility to implement the third module of same/or reduced capacity over the expansion's horizon of ten years.

Table 5. Assumptions for design flow rate and future flow rate.

Description	Value	Unit	Total kL/yr
Average flow rate from March to July (+10%)	997	kL/d - 7 days	363,863
Contractor external effluent	82	kL/d - 7 days	30,000
Wastewater flow Over 7 days	1,079	kL/d - 7 days	393,863
Spray Chilling implemented in 2022	82	kL/d - 7 days	30,000
Wastewater flow Over 7 days including spray chilling form next year	1,161	kL/d - 7 days	423,863
WWTP flow operating 5 days/week	1,626	kL/d - 5 days	408,126
WWTP flow operating 7 days/week	1,626	kL/d - 7 days	593,409
Two Modules are to be implemented now	820	kL/ day each	598,600
Future Flow Estimate			
30% increase on effluent production over years	1,403	kL/d - 7 days	512,022
Target 6.5 kL of wastewater per t.HSCW	73,921	tHSCW/yr	480,487

Temporary peak flows of 1,968 kL/day (+ 20% of the maximum) were also considered during the design development. Table 6 summarises the average, maximum and peak WWTP flows considered for the design.

Table 6. Average, maximum and peak WWTP flows considered for the design.

		Average	Maximum	Peak
Flow	kL/day	1,171	1,640	1,968

5.1.2 Wastewater Characteristics

Abattoir effluent composition can vary significantly during the day, depending on the processing floor operations. Therefore, the water quality considered for the design was based on a composite set of sampling and analysis undertaken to investigate the effluent variations in different days and time periods (Milestone Report 2). The resulting input parameters used for the design to the WWTP presented in Table 7.

Table 7. Summary of wastewater quality to be used in the design.

Parameter	Unit	Average	Maximum
BOD	mg/L	1,733	2,200
COD	mg/L	4,300	5,100
TN	mg/L	313	390
TP	mg/L	48	65

When compared to the wastewater quality from other processing facilities, V&V Walsh's wastewater can be considered as moderate strength (Table 8).

Table 8. Summary of wastewater quality encountered in the Australian red meat industry.

Parameter	Unit	Low Strength	Moderate Strength	High Strength
TSS	mg/L	< 2500	2,500 – 5,000	>5,000
BOD	mg/L	<1500	1,500 – 3,000	>3,000
COD	mg/L	<5000	5,000 – 10,000	>10,000
TN	mg/L	<180	180 – 360	>360
TP	mg/L	<35	35-55	>55

NOTE ON C:N:P RATIO

*For the adequate performance of a nutrient removal system based on the nitrification/denitrification process, there is an ideal carbon, nitrogen and phosphorous ratio (C:N:P) of **100:10:1.***

*In the case of V&V Walsh's effluent, the average ratio is **100:7.3:1.1**, which is reasonably favourable for the performance of the denitrification process.*

This indicates that the use of an anaerobic pond (CAL) upfront the process is <u>not</u> recommended, aiming to maintain the carbon required in the system, and eliminating the requirement for an external carbon source to be added. This is a very common process mistake found in several WWTP's, which impairs the performance of nitrogen removal.

5.1.3 Treated effluent quality target

The physico-chemical parameters targets for the treated effluent quality considered for the design is presented in Table 9.

Table 9. Treated water quality targets for recycling: physico-chemical parameters.

Parameters	Unit	High Risk	Medium Risk
Soluble BOD	mg/L	10	20
TSS	mg/L	10	30
pH	N/A	6.5 - 8.5	6.5
Turbidity	in 95% of sampling	2	5
Turbidity	maximum	5	N/A
TN	mg/L	20	20
TP	mg/L	1.5	1.5

The pathogens disinfection targets for the treated effluent quality considered for the design is presented in Table 10.

Table 10. Treated water quality targets for recycling: pathogens.

Parameters	Unit	High Risk	Medium Risk
UV dose	mJ per cm^2	40 – 70	40 – 70
UV transmittance	%	75	75
Residual chlorine	mg/L	0.2 - 2	0.2 - 2
E.coli	CFU per 100 ml	1	1
Virus	log reduction	6.5	5
Protozoa	log reduction	5	3.5
Bacteria	log reduction	5	4

5.2 Solid streams characterisation

The current processing capacity and future processing capacity estimates have been defined in Milestone Report 2 (item 5.4.1). As guidance, Table 11 summarises the current processing numbers and capacity per animal category per tonne of hot carcass weight per year.

Table 11. Current processing capacity (average and maximum) and the 10 years production estimate.

	Cattle			Lamb		
	Average	Max	10 years	Average	Max	10 years
t.HSCW/yr	21,080	23,192	42,170	19,628	25,978	31,751
heads/day	300	330	600	3,400	4,500	5,500

The organic solid waste currently produced at V&V Walsh facility, has been previously characterized. The organic solid waste with potential for recovery includes beef and sheep paunch, solids from the rotary screen (save-all), solids originated from the DAF, sheep manure, and solids to be produced from the wastewater treatment plant. Desktop and site assessment were undertaken to quantify the solid organic and outcome of solid stream quantities is described in the sequence.

5.2.1 Solid waste quantities, characteristics, and biogas plant inputs

The organic solid waste was quantified in three different production days and the amount of waste generated was correlated to the number of animals processed during.

Since the Biogas plant was implemented in a horizon of 2-3 years the solid waste number generation was monitored closely and BMP analyses was repeated in the Detailed Design stage. Also, estimated organic sludge streams from the new WWTP was adopted according to design/modelling outcomes and was monitored after implementation. This will allow numbers to be updated prior to the construction of the Biogas and Biofertiliser Plants.

Currently, cattle waste manure is not collected. Changes in the regulation might impose the cattle manure to be collected and therefore this organic solid waste should be accounted for in future quantifications/Characterisations.

Table 12. Estimated future meat production (lamb and cattle).

Description	Number of animals processed	
	Lamb/Sheep	Cattle
Averaged three days	3,085	249
HSCW (kg) per animal	23	280
t.HSCW per day	71	70
Total t.HSCW per day	141	
Max current t.HSCW per year	49,170	
Max future t.HSCW per year	73,921	

Table 13. Organic solid materials production (current and future).

Description	Current (tonne/yr)	Future (tonne/yr)	kg/tonne of HSCW
Sheep Manure	437	657	9
Save-all	609	915	12
Sheep Paunch	1,107	1,664	23
Beef Paunch	1,573	2,365	32
DAF	1,049	1,576	21
Total solids	**4,774**	**7,177**	**97**

The organic waste characteristics were previously analysed *"Sustainable management of waste and wastewater streams at V&V Walsh- AMPC Final Report 17/08/2020".* Daily production was update in accordance with results reported in Table 14.

Table 14. Current Organic solid waste quantity and characteristics and Bio Methane Potential (BMP).

Biosolids Production	Production (tone/day)	TS (kg/ton)	VS (kg/ton)	BMP (L.kgVS^{-1})
Sheep Manure	1.25	749	595	211
Save-all	1.72	287	275	568
Sheep Paunch	3.17	184	159	307
Beef Paunch	4.50	189	181	285
DAF Belt Press	3.00	379	341	658
*DAF Sludge (Purged bottom)	14.8	81	80.9	0.8

*Values of BMP estimated based on VS and TS content analysis.

Substrate mixing and preparation

The nature of the organic solid streams and its availability has showed potential for adoption of an anaerobic digester, having biogas and biofertiliser as by-products. However, the solids stream must be optimized up front of the process to achieve adequate Total Solids (TS) content for the AD plant. This project is proposing an integrated plant to managed both liquid and solid streams from the abattoir facility, and therefore, sludge from the treatment plant can be incorporated into the digestor optimizing the substrate that will feed the Biogas plant. Potential sources identified includes mainly the sludge originated from the secondary DAF (from the new WWTP). The

Table 15 show the summary all solids to serving as inputs for the biogas plant based on maximum future project capacity of 73,921 t.HSCW/year.

Table 15. Future organic solid waste quantity and characteristics (based on previous study).

Biosolids Production	Production (ton/day)	TS (kg/ton)	VS (kg/ton)	BMP (L.kgVS^{-1})
Combined Save-all	3.65	287	275	568
DAF Belt Press	6.28	379	341	658
Sheep Paunch	6.63	184	159	307
Beef Paunch	9.42	189	181	285
Sheep Manure	2.62	749	595	211
DAF Sludge Purged (bottom)	14.8	81	80.9	65
WAS EX	36.6	56	46.1	37
Wastewater for dilution	16.4	0.1	0.11	0.1
Total (5 days)	**96.4**			
Total (7 days)	**69**			

Based on the waste optimization conditions to feed the digester (

Table 15), the total solids stream production was 96 tonnes per operational day and 69 tonnes over 7 days period with a solid content of ~12%; suitable for CSTR system.

5.3 Digestate characteristics

Digestate is the by-product from the Biogas production via anaerobic digestion process. It is a slurry containing the stabilised bio-degradable materials and minerals, at around 2-3% solids. The digestate is an excellent crops and plants fertiliser because it is rich in micro, macro nutrients and organic matter, which are not lost during anaerobic digestion process. The stabilised digestate is a form of biofertiliser, enabling nutrient recycling, forming an essential part for closing the loop in resource recovery facilities.

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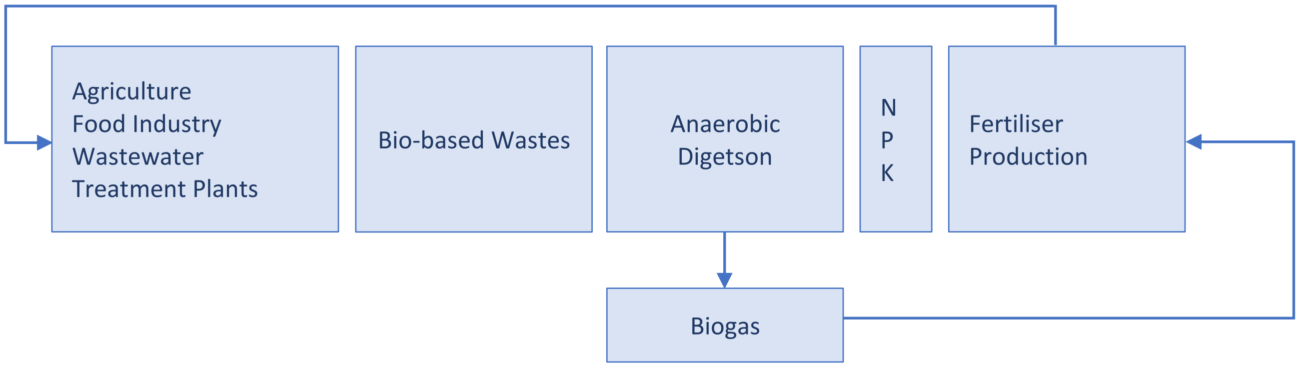

Figure 6. Schematic representation and example of the “closed loop” biofertiliser production.

The characteristics of the digestate are dependent on the type of substrate feeding the biogas plant, as well as operational parameters of the Biogas plant process. The characteristics of digestates originated from AD process operated under mesophilic and thermophilic conditions are presented in Table 16 (Risberg et al., 2017). These ranges are based on various substrates from the red meat processing industry in combination with other substrates such as waste from food processing industries, organic waste, silage, manure, and others,

Table 16. Average characteristics of digestate produced in the meat processing industry.

Parameter	Unit	Range Values
Dry matter (Total solids)	%	1.4 to 6.1
Total-Carbon	kg ton^{-1} of fw	6.3 to 21
NH4-N	kg ton^{-1} of fw	1.9 to 5.3
Organic-N	kg ton^{-1} of fw	0.5 to 2.6
Total-N	kg ton^{-1} of fw	2.4 to 7.6
VFA	g L^{-1}	0.1 to 3.6
Utilization rate of Carbon	%	11.4 to 40.2

fw – fresh weight

5.4 Concept design: integrated liquid and solid streams management

Abattoir wastewater is a rich source of valuable nutrients, energy and water[3]. When appropriately managed, and combined with selected streams of organic wastes, optimised anaerobic digestion and resource recovery can be achieved, along with robust environmental compliance. Implementing the concept of integrated concept to V&V Walsh wastewater and waste management will future-proof company’s operation in terms of environmental compliance, aligned with the concepts of circular economy and resource recovery.

[3] Sustainable Management of Waste and Wastewater Streams at V&V Walsh (AMPC, July 2020)

This is also contributing to the Australian red meat and livestock industry ambitious target to be Carbon Neutral by 2030 (CN30) [4], and will bring V&V Walsh to the forefront of the industry, as a model to be implemented by other red meat processing plants (RMPs).

In this context, the Concept Design proposed for this project has taken into consideration the production of recycled water compliant with medium and high exposure quality[5], and production of biogas and fertiliser from mixed solid waste streams from V&V Walsh Abattoir. The process integration, along with resource recovery and combining the treatment of both solid and liquid streams is an innovative concept in the Australian red meat industry resulting in positive environmental, economic and social outcomes.

In this concept, the liquid streams will be processed in the modular wastewater treatment plant, aiming for the removal of oil & grease, solids and organic matter, nitrogen, phosphorous and pathogens. For the technology selection, it was considered the recovery of recycled water. This is possible using a combination of secondary/tertiary and advanced water treatment technologies allowing V&V Walsh to irrigate and find alternative end-users for the treated water.

Selected solid waste streams, including paunch, save all screened solids, manure, sludge, and fat from WWTP, was processed in an anaerobic digester (AD), aiming to produce biogas and bio-fertiliser. The plant will allow for flexibility for solid and liquid waste receival and pre-treatment to achieve an adequate mixing ratio, consequently higher methane yield offsetting energy/gas consumption from the WWTP.

5.4.1 WWTP process design description

The treatment process sequence was designed based on a combination of unit operations, aiming to achieve the staged removal / recovery of contaminants, as described in Figure 7.

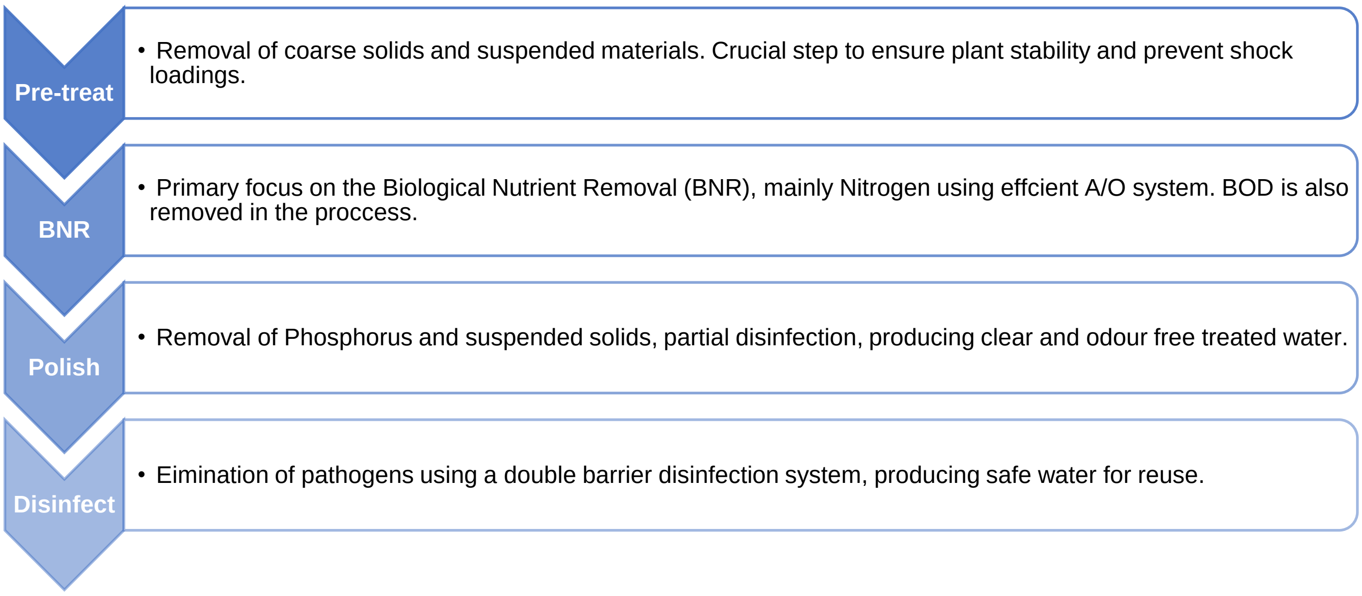

Figure 7. Summary of steps considered on the WWTP design.

[4] https://www.mla.com.au/research-and-development/Environment-sustainability/carbon-neutral-2030-rd/cn30

[5] Guidelines for the Non-potable Uses of Recycled Water in Western Australia

The following sections describe specifications of individual equipment and processes. Refer to Appendix 2, Technical Drawings:

- 210615-V&V-FEED-WWTP-DW-001 for General Arrangement and Plant Layout
- 210615-V&V-FEED-WWTP-DW-002 to 006 for Process Flow Diagram

The effluent treatment plant is designed to equalize the screened daily effluent flow using the balancing tank, and then continuously operate at balanced flow rate (68 kL per hour). The plant is designed in two modules of same capacity running in parallel (34 kL per hour capacity each). V&V Walsh has requested to implement two modules, working completely independently from each other, starting from the balancing tank, aiming to increase process robustness and reliability.

The existing processing plant layout mergers all wastewater into one location, going to Rotary Screen/Save-all. The existing Rotary Screen and adjacent Effluent Sump was maintained. Subsequent equipment selection and design is presented. The following sections describes the rationale behind the design of the different process and operations in the WWTP.

5.4.1.1 Pre-treatment

Rotary screen (existing RS.001 and RS.002)

Also known as a rotary drum, they are rotating wired cylinder screens which separates the liquid entering in the centre from the solids being discharged at the other end. Easily cleaned, can handle flow surges/variations and are more efficient with fatty effluent than other screens. Regular cleaning is required, and solids removal is dependent of the screen characteristics.

Wastewater originated from the facility is direct to existing rotary screens as a first separation step for suspended solids removal. The rotary screen removes the bulk of solids reducing the load on the downstream treatment. Currently, there are two screens operating in series, which will remain in operation: first screen of 3 mm aperture and the second screen with 1.5 mm aperture. The screened wastewater from the Save-all Pit 1 (old) flows by gravity to the Save-all Pit 2. From the Save-all Pit 2, the wastewater flows by gravity to the transfer pump station TK.001 (New Pit 3). The rotary screens will remain in operation until reaching maximum capacity, upgrade is required for future flow rates. Previous selection criteria and existing specifications are as follow:

Tags	Design conditions	Basic Specifications
RS.001	Peak flow rate design = Unspecified Operational hours = 10 hours	3 mm screening Pit volume = 17.2 kL
RS.002	Peak flow rate design = 125 kL/h Solids concentration = 3,000 mg/L Effluent velocity (prior screen) = 0.667 m/s Recommended coarse screening upfront Operational hours = 10 hours	Aperture = 1.5 mm Vee-Wire Screen Drum Drum diameter = 1.2 m Pit volume = 10.9 kL Material = SS 304

Solids originated from the rotary screen, beef paunch and sheep paunch; are currently collected in skip bins and disposed off-site. This will remain in place until biogas plant installation. To direct the solids to the biogas, plant a sump was designed. The details of the sump was developed on the MS5.

Transfer pumping station (TK.001)

After the screening process the water flow by gravity to the TK.001 (New Pit 3), where it was pumped to the equalization tanks. The current transfer pumping station is equipped with 3-Flygt submersible pumps which are activated by level switch system and effluent was transferred to the equalization tanks at various flow rates. From the equalization tanks, the subsequent process will operate at average flow rate.

Tags	Design conditions	Basic Specifications
TK.001	Peak flow rate design = 164 kL/h Operational hours = 10 hours peak and 14 hours non-peak 3 – 5 minutes holding capacity	Radius: 0.91 m Depth: 2.5 m Operational Depth: assumed 1.25 m Operational Volume: 3.3 kL
Pump set	164 kL/h flow rates – 20% safety excess flow = 197 kL/h	3 x Flygt 3153 185 Pumps are currently selected to operate at 72.9%, 12.9 m head and ~130 kL/h each

After decommissioning the existing DAF, the pipeline transporting the effluent to the treatment plant must be re-arranged and a pump or pressure booster shall be implemented in line transporting the effluent to the top of equalization tanks. An alternative is to re-use existing pumping well for DAF bottom sludge disposal as interim pumping well before sending to the equalization tank. If pumped maximum flow (1,640 kL/day) in a 10-hour period from TK.001 to equalization tanks top using a HDPE100 DN=225 mm for total distance of 242 m and estimated level difference of 9.0 m including tanks height (topographical survey required), the total power required was 22 kW. Current pumps are only 7.5 kW .

Balancing tank (TK.002 and TK.006)

Variations in the influent-wastewater flow is common in a variety of situations and industries. The flow equalization is used to overcome operational problems caused by flow variations, improve treatment performance downstream, minimize costs and size of subsequent treatment steps. It also serves to minimize temperature of the effluent. An in-line balancing tank shall be used for flow equalization achieving required average hourly flow, calculated for subsequent treatment stages. The tank is mixed/aerated to avoid any anaerobic process starting at the wastewater, minimizing odour emissions. The balancing tank also offer the opportunity of pH analysis and adjustment (at the outlet - in case required).

For flow equalization purposes two equalization tanks (TK.002 and TK.006) are planned after the transfer pumping station (TK.001). Previous "Milestone 2 Report" have presented assumptions made for flow projection and equalization purposes. The Equalization tank is projected for 1.5 days hydraulic retention time of the current maximum effluent daily peak flows (1,449 kL/day). For the WWTP operating 5 days a week, flow of 1,640 kL/day the equalization tank will have ~35% (minimum required 30% extra holding capacity) with 1.35 days hydraulic retention time. The total required tank volume was 2,245 kL. From the equalization tank the wastewater was fed continuously to the WWTP with an average flow rates of 68 kL per hour (recommended operational capacity divided into two modules).

Two tanks was implemented for balancing the effluent volume. This is enough to hold the equalisation volume required and maintain a minimum capacity of 30% of amortisation volume. To avoid occurrence of anaerobic process, material deposition, maintain the effluent mixed and oxygenated a coarse bubble diffuser was installed at the equalization tanks with power equivalent to 10W per kL of tank. With 50% safety for the air distribution system, a 50kW blower will deliver air to coarse bubble diffuser at the tank both tank's bottom.

Tags	Design conditions	Basic Specifications
TK.002	Amortisation volume 820 kL/day Operational hours = 24 hours Minimum Holding Capacity = 1.35 days	Diameter: 17.1 m Total Height: 5.7 m Operational Height: 5.2 m Operational Volume: 1,181 kL Material Glass Fused Steel with epoxy coating – covered top Coarse bubble diffuser = 25 kW Blower
TK.006	Amortization volume 820 kL/day Operational hours = 24 hours Minimum Holding Capacity = 1.35 days	Diameter: 17.1 m Total Height: 5.7 m Operational Height: 5.2 m Operational Volume: 1,181 kL Material Glass Fused Steel with epoxy coating – covered top Coarse bubble diffuser = 25 kW Blower

At the equalization tanks' inlet, a static screen will receive wastewater from pumping station, and the combined wastewater was divided into two streams for subsequent parallel treatment trains 1 and 2.

After the equalization tanks, the two subsequent treatment trains will operate independently with average flow rate of 34 kL/h over 24 hours 5 days a week, with lower flow rates during weekend periods (or kept in recirculation mode). A transfer pump is required to directed equalized wastewater flow to the next stages of treatment. External centrifuge pump sets (1.5 kW each) was positioned at the outlet each tank and was responsible for transporting the effluent to the DAF.001-003 systems.

Dissolved air flotation (DAF.001 and DAF.003)

The DAF uses pressurized air to float fats and solids to be removed, this can be achieved by using coagulants/flocculants. The tannin-based coagulants/flocculants have presented excellent results of removal for BOD, COD, P and N (ongoing application – refer to pre and post DAF effluent analysis Milestone Report 2). In addition to the efficiency for fat removal, a chemical DAF also effectively removes solids, BOD, and nutrients. The process is reliable, has relatively small footprint and chemical dosing needs to be adjusted to avoid excessive sludge production. It can recover more than 90% of fats.

Two sets of package DAF.001 and DAF.003, was placed after the equalization tanks receiving balanced effluent transferred by feeding pump sets. The DAF systems act as the primary treatment for BOD, TSS, Oil and Grease, Nitrogen and Phosphorous prior to the Biological Reactor. The equipment will have mixing (flocculation), air saturation system and chemicals storage tanks. A chemical dosing skid is part of the DAF system and includes coagulant/flocculant dosing, and polymer dosing all via static mixer in the inlet pipeline. A recirculation pump will feed treated wastewater (or clean water) for the air saturation system. The excess solids leaving the DAF have been estimated in ~ 50kL/d at 1.2%. This was sent to dewatering process (with other sludge effluents), prior disposal off site. Following implementation of the Biogas plant these solids was processed in the anaerobic digester. The sludge was transported in a pressurized pipeline to the dewatering process.

Design Assumptions

Based on existing analysis and Coagulant/Flocculant usage (Tanfloc + Drewfloc), it has been assumed that the new DAF will have a minimal removal efficiency of 50% for BOD, 50% for SS, 50% for TN, 50% for TP of the non-soluble part of BOD, TSS, N and P. And more than 80% for O&G. DAFs are designed to cope with ultimate flow rates (including implementation of the third module of Biological Nutrient Removal). Below is the DAF selection criteria:

Tags	Design conditions	Basic Specifications
DAF.001	Ultimate inlet flow rate = 51 kL/h Recirculation rate = 30% Application rate = 3.5m/h (low application for higher removal efficiency) Average flow rate design = 66 kL/h (including recirculation) Minimum area required = 19.0 m^2	Length: 9.0 m Total Height: 2.5 m Width: 2.2 m Material: Stainless Steel
Dosing point 1	Coagulant Dosing Tanfloc Polymer Dosing Drewfloc	Range from 0 to 300 L/hr Range from 0 - 5 L/hr
DAF.003	Ultimate inlet flow rate = 51 kL/h Recirculation rate = 30% Application rate = 3.5m/h (low application for higher removal efficiency) Average flow rate design = 66 kL/h (including recirculation) Minimum area required = 19.0 m^2	Length: 9.0 m Total Height: 2.5 m Width: 2.2 m Material: Stainless Steel
Dosing point 2	Coagulant Dosing Tanlfoc Polymer Dosing Drewfloc	Range from 0 to 300 L/hr Range from 0 to 5 L/hr

Distribution tank (TK.003)

After the DAF systems the effluent will flow by gravity to be merged into a distribution box. The distribution box will allow operational flexibility for the initial two treatment trains (and third module in the future) with maximum of 15 min HRT. Two pump sets was installed to operate simultaneously (calibrated for with the same alarm sets and flow rate – with option to switch off for treatment train maintenance), sending effluent to the biological nutrient removal steps. The following step is designed to operate at average flow rate of 34kL/hour over 24 hours 5 days a week, with lower flow rates during weekend periods (or kept in recirculation mode). A transfer pump is required to direct the effluent to the next stages of treatment. Two submerged pump sets was placed in the distribution box and was responsible for transporting the effluent to the Anoxic Reactors (R.001 and R.003) at 34kL/h each pipeline.

Tags	Design conditions	Basic Specifications
TK.003 Section A+B	Ultimate inlet flow rate originated from both DAFs = 102 kL/h Hydraulic Retention Time = 15 min	Length: 3.0 m Total Height: 4 m Width: 3.0 m Material: Concrete
Pump set A Train 1	Flow rate 34 kL/h flow rate	2 x 3.0 kW pumps (duty, stand-by) Total head = 11 m
Pump set B Train 2	Flow rate 34 kL/h flow rate	2 x 3.0 kW pumps (duty, stand-by) Total head = 11 m

5.4.1.2 Biological Nutrient Removal | A/O Reactor

The A/O reactor is one of the variations of the activated sludge process composed by: Anoxic and Aerobic zones; offers a robust solution for nutrients removal, with high level of operational flexibility (Metcalf & Eddy, 1991). The system is designed for removal of BOD, SS, nitrogen and phosphorous (chemical addition might be necessary for ultimate phosphorous removal). The proposed reactor was designed in two modular stages:

(i) pre-denitrification (conversion of nitrate into gaseous nitrogen) and

(ii) nitrification process (oxidation of ammonia to nitrite and then to nitrate).

The system has two recirculation lines:

- Activated sludge return line from the secondary DAF to the anoxic zone;
- Recirculation from the aerobic zone back into the anoxic zone to maximise denitrification/nitrification.

The activated sludge variation Anoxic/Aerobic (Pre-denitrification/Nitrification) was designed with in two modular stages starting with anoxic zone upstream (pre-denitrification conversion of nitrate into gaseous nitrogen) followed by aerobic (nitrification oxidation of ammonia to nitrite and then to nitrate).

Design assumptions: The system has taken into consideration a robust, efficient, and yet conservative design. The key assumptions are presented in Appendix – Basis of Design.

Anoxic Stage (R.001 and R.003)

The first stage of the process (anoxic zone) is designed for the denitrification process, by recirculating nitrates from the outlet of the aerobic stage. A total volume of 800 kL is required. Two 400 kL glass fused steel tanks with Epoxy Coating is proposed for the anoxic tank for the pre-denitrification stage. Open circular tanks were designed with same dimension: 10.24 m diameter and 5.66 m total height. To maintain mixing and anoxic conditions in the tank two submerged mixers with 2 kW of power each were assumed for each tank. The third module will have same specifications.

Tags	Design conditions	Basic Specifications
R.001	Refer to Appendix 1 – Basis of Design. Operational hours = 24 hours	Diameter: 10.2 m Total Height: 5.7 m Operational Height: 5.4 m Operational Volume: 442 kL Material Glass Fused Steel with epoxy coating – open top Top entry submerged mixer power 2 x 2 kWh
R.003	Refer to Appendix 1 – Basis of Design. Operational hours = 24 hours	Diameter: 10.2 m Total Height: 5.7 m Operational Height: 5.4 m Operational Volume: 442 kL Material Glass Fused Steel with epoxy coating – open top Top entry submerged power 2 x 2 kWh

The wastewater will flow from the anoxic tank to the aerobic by gravity with individual pipes running in parallel from each reactor.

Aerobic Stage (R.002 and R.004)

The aerobic reactor (2,400 kL) is responsible for most of the BOD removal and for the nitrification process. Two open circular glass fused steel tank with Epoxy Coating with dimensions of 17.1 m diameter and 5.7 m height are required. The tanks will include aeration system to meet oxygen requirements (nitrification and BOD removal). The tanks was segment (using internal baffles) in three stages of equivalent area for optimized aeration. The aeration system adopted is composed by air diffusers (insert specs) installed at the bottom of the tank and four blowers with 70 kW of power each with capacity to deliver a total of ~268,000 Nm^3 air/ day, was centralized to deliver air for both tanks. The third module will have same specifications.

Tags	Design conditions	Basic Specifications
R.002	Refer to Appendix 1 – Basis of Design. Operational hours = 24 hours	Diameter: 17.1 m Total Height: 5.7 m Operational Height: 5.3 m Operational Volume: 1,204 kL Material Glass Fused Steel with epoxy coating – open top Segmented with baffle curtains Equipped with bottom air diffusors connected to blower system
R.004	Refer to Appendix 1 – Basis of Design. Operational hours = 24 hours	Diameter: 17.1 m Total Height: 5.7 m Operational Height: 5.3 m Operational Volume: 1,204 kL 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 = 5 Nm^3/h Diffusers' density in the tank = 20%	Disc Diameter = 229 mm Disc Material = EPDM Total number of diffusers = 2,330
Blowers	Air flow rate = 268,576 Nm^3/day	4 blowers with 70 kWh each

The wastewater was pumped by a 3 kW pump set to from the aerobic tanks to the secondary DAFs clarifiers.

BNR Recirculation Pump Sets

The biological nutrient removal process requires to lines for recirculation of nitrified effluent and for sludge. The Internal recirculation line, starting at the end of the aerobic stage and returning to the start of the anoxic stage, requires flexibility in flow rates which can vary from 2 up to 5 times in relation to the plant inlet flow rate. The Sludge recirculation line varies from 0.5 to 1.0 time in relation to the plant inlet flow rate. The set was per treatment train and specifications for each recirculation line and pump sets are as follow:

Tags	Design conditions	Basic Specifications
IN-Recirc. R.002 to R.001	Average design flow rate = 34 kL/h Recirculation from 2 to 5 times Recirculation flow range 68 to 170 kL/h 2 pipelines (pump sets running in parallel)	Pump power (each): 11 kWh Total head: 7.5 m Number of pumps: 3 (duty, duty. Stand-by)
IN-Recirc. R.004 to R.003	Average design flow rate = 34 kL/h Recirculation from 2 to 5 times Recirculation flow range 68 to 170 kL/h 2 pipelines (pump sets running in parallel)	Pump power (each): 11 kWh Total head: 7.5 m Number of pumps: 3 (duty, duty. Stand-by)

Secondary clarifier (DAF.002 and DAF.004)

A secondary DAF system is proposed to separate the sludge from the treated wastewater and is part of the biological nutrient removal stage. The process has a smaller footprint when compared to a conventional secondary clarifier (operated based on sludge settling). Compared to clarifiers, the DAF also allows higher application rates and significantly more operational flexibility, via recirculation and coagulants/ polymer dosing possibilities. DAF is also very effective in the summertime when sludge tends to naturally float to the surface. A chemical dosing skid will include coagulant and polymer dosing all via static mixer into the inlet pipeline. This will increase the removal of phosphorous. A recirculation pump will feed treated wastewater for the air recirculation system.

Two sets of secondary packaged DAF systems are designed to separate the sludge from the clarified wastewater in the biological nutrient removal stage. The process has a smaller footprint when compared to a conventional clarifier. The DAF allows higher application rates and significantly more operational flexibility, via recirculation rates and coagulants/polymer dosing possibilities. DAF is also very effective in summertime when sludge tends to naturally float to the surface.

A chemical dosing skid will include coagulant and polymer dosing all via static mixer into the inlet pipeline. A recirculation pump will feed treated wastewater for the air saturator system. A recirculation pump will feed treated wastewater for the air saturation system.

Part of the thickened sludge is recirculated to the system (using a pump-set of 2.5 kW for each train), and the excess sludge was sent out for dewatering and for disposal off-site (sent to the biogas plant in the future). A sludge generation rate of ~32 kL /day is estimated assuming sludge total solids (TS) concentration of ~6.2% (adjusted according to operational requirements and efficiencies). The clarified effluent was transferred by gravity to a common buffer tank (TK.004) preceding the advanced treatment stage.

Tags	Design conditions	Basic Specifications
DAF.002	Ultimate inlet flow rate = 51 kL/h Recirculation rate = 30% Application rate = 5m/h (low application for higher removal efficiency) Average flow rate design = 74 kL/h (including recirculation) *Sludge concentration increased by 9 times and SL. Recir. has decreased 9 times Minimum area required = 15m^2	Length: 7.0 m Total Height: 2.5 m Width: 2.2 m Material: Stainless Steel
Dosing point 3	Flocculant Dosing	Range from 0 to 5 L/hr
DAF.004	Ultimate inlet flow rate = 51 kL/h Recirculation rate = 30% Application rate = 5m/h (low application for higher removal efficiency) Average flow rate design = 74 kL/h (including recirculation) *Sludge concentration increased by 9 times and SL. Recir. has decreased 9 times Minimum area required = 15m^2	Length: 7.0 m Total Height: 2.5 m Width: 2.2 m Material: Stainless Steel
Dosing point 4	Coagulant Dosing	Range from 0 to 5 L/hr

5.4.1.3 Polishing stage

Buffer tank and chemical dosing (TK.004)

The buffer tank is designed to stabilize the flow rate and accumulate enough water volume for the membrane filtration process. The tank also offers the opportunity to dose necessary chemical additives and prepare the effluent for the membrane filtration step (as per membrane manufactures requirements). The TK.004 will have 30 minutes holding capacity, 35 kL volume which is required for feeding the UF system. In the polishing stage, phosphorous was removed by precipitation with ferric chloride (or other metallic coagulant), using an in-line static mixer. A provision for dosing sodium hydroxide for pH adjustment is included in the design, however all jar tests to date indicate that pH adjustment not required.

Tags	Design conditions	Basic Specifications
TK.004	Amortization volume 1,640 kL/day Operational hours = 24 hours Minimum Holding Capacity = 30 minutes	D: 3.5 m H: 3.5 m Volume: 36.8 kL Material Concrete Spaced with baffles
Dosing Point 5*	Ferric Chloride Dosing Sodium Hydroxide dosing Sodium hypochlorite dosing	Ferric Chloride (TBC) Sodium Hydroxide (provision only) Chlorine Dosing (TBC)

* Dosing rates was confirmed by the membrane supplier.

Ceramic Membranes Ultra-filtration (UF.001 and UF.002)

Designed to treat water with low TSS from 30mg/L to 50 mg/L. The final filtration stage of the wastewater treatment process includes a ceramic membrane filtration unit. We have preliminarily selected modular ceramic membrane ultrafiltration (UF) process to provide water with non-potable reuse characteristics. The main characteristics of the process include:

- Low pressure rates (0.5 to 1.0 bar) when compared to RO (>15 bar)
- Pore size 0.1µm
- Efficient removal for: TSS, turbidity, macromolecules, colloids, and protein.
- Typical log removal value (LRV) for germs and bacteria > 5

Ferric Chloride dosing will take place just before the membrane system (as needed) for ultimate phosphorous removal. The membranes are periodically back-flushed with filter permeate water and then back-flush water sent back to the treatment.

Two skid mounted ceramic ultrafiltration systems was used as a main polishing stage for treated water. The filtration rate adopted for the design 133 LMH, resulting in 84 membrane modules with 6 m^2 each. The membrane pore size is 0.1µm, and membrane material is Ceramic. The system outlet water will have a permeate with turbidity bellow < 0.1 NTU. The system was designed for a recovery ratio of 95 - 98% of water. Feed water requires pre-conditioning with pH adjustment, chlorine, and coagulant/flocculant dosing. Two pump sets are required to pump the water into the membrane modules (as per manufacturer specifications). The system includes cleaning chemical dosing set, service water tank and chemical preparation tank.

Tags	Design conditions	Basic Specifications
UF.001	Average inlet flow 802 kL per day Filtration rate = 133 LMH Rejection (backwash requirements/phosphorous removal) = 2 -5%	Number of towers per train = 6 Number of modules per tower = 7 Total modules per train = 42 Filtration area per module = 252 m^2
UF.002	Average inlet flow 802 kL per day Filtration rate = 133 LMH Rejection (backwash requirements/phosphorous removal) = 5%	Number of towers per train = 6 Number of modules per tower = 7 Total modules per train = 42 Filtration area per module = 252 m^2
Power requirements	Including = filtration, backwash, blower and cleaning chemicals dosing	As per manufacturer 35 – 40 kWh /day

5.4.1.4 Double-barrier disinfection

Further removal of pathogens is ensured by using a double disinfection process. Following UV irradiation, and chlorination for disinfection will take place prior entering the storge tank.

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 dose residual > 2.0mg/L for water storage for and further reuse.**

UV- Disinfection (UV.001 and UV.002)

The UV system will work as a safety barrier for removal of remaining virus, protozoa, and bacteria after UF system. Located in-line right after Ultrafiltration system, it is assumed minimum UV transmittance of 90% for the water. The UV dosage of 100 mJ/cm^2 was considered for equipment selection. By applying this dosage, the system will guarantee 2 LRV of Virus and was sufficient for 4.5 LRV of Protozoa and 5.0 for Bacteria. The selected model includes 2 units with 2.5 kW MP UV Lamps.

Chlorination - Disinfection (DI.001)

Sodium Hypochlorite was dosed after the UV disinfection system to maintain a minimum of 2.0 mg/L of chlorine residual in the water. Sodium Hypochlorite was dosed via dosing pumps and inject will static mixer installed in-line; the storage tanks right after the chlorine dosage is designed to allow min of 30 min contact time, resulting in a CT of 60 mg.min/L, which is a conservative approach for <0.2 NTU, pH <7.5 and temperature <15˚C (AASI, 2017).

Considering the UF system, the UV system and the chlorination, combined processes will guarantee required treated water quality parameters.

Process	Log Removal V		
Description	**Virus**	**Bacteria**	**Protozoa**
Ceramic UF	1	5	5
Ultraviolet	2	5	4.5
Chlorination	3	3	3
Total	**6**	**13**	**12.5**

5.4.1.5 Reverse Osmosis (RO) – optional

The design will consider space and connections for the future installation of a modular Reverse Osmosis plant in case higher reuse purposes are to be considered. These include applications inside the processing plant, and green hydrogen production. However, if an RO system is implemented there will an issue to be addressed with regards to brine disposal. The estimate is that around 300 – 350 kL per day of brine would have to be processed or removed from site, defeating our resource recovery outcomes. Therefore, from a designer point of view, our recommendation is to prioritise fit for purpose uses of high-quality treated wastewater without resorting to the use of RO.

5.4.1.6 Treated Water Storage – (TK.005)

After disinfected and chlorinated treated water was stored in a treated water tank (covered), with total capacity of 440 kL, equivalent to ~6 hours storage. The tank will have low level alarm offering at least 30 min hydraulic retention time to achieve minimum contact time for chlorination. From the storage tanks the water was pumped to required uses, both on site and for irrigation purposes.

5.4.1.7 Sludge dewatering

A Screw Press was installed to receive combined sludge form primary DAF, secondary DAF and UF backwash result in ~115 kL/d at 1.5%. The centrifuge was responsible for concentrating the sludge to ~20% of TS prior sending of site for disposal. This will minimize the amount of sludge to be sent out of site to approximated 12m^3 per day. The dewatering process adopted is via a Screw Press Huber RoS3Q 440 Inclined Sludge Press (ISP). The equipment allows to feed hydraulic loads from 4-8 kL/hour and dry solids load from 70 to 140 kg/hour, being adequate for the WWTP sludge dewatering purposes. Excess water was returned to wastewater equalization tank (T.001) via pressurized pipeline. The centrifuge will have a polymer dosing system to improve the sludge thickening process.

Tags	Design conditions	Basic Specifications
SP.001	Hydraulic loading = 115 m^3/d = 8 kL / hour Solid's content = 1.46% Dry solids loading = 1.68 ton/d = 120 kg/h Operation = 14 hours	RoS3Q 440 ISP or similar Installation Dimensions Length = 6.1m Width = 2.5 m Height = 2.8 m
Dosing point within unit	Polymer Dosing	Polymer to be adjusted during operation dosing volume TBC with screw press supplier
TK.006	Sludge storage tank	Volume sufficient to store waste from primary DAFs, secondary DAFs and filtration systems for minimum of 10 hours.

A sludge storage thank for waste from primary DAFs, secondary DAFs and filtration systems was incorporated in the design. Tank dimensions was specified once conversations with suppliers progress.

5.4.2 Biogas plant process design description

This section describes the main parameters and assumptions made during process design stages. The complete basis of design is in Appendix. The Biogas plant process cascade was designed based on a combination of unit operations, aiming for optimization of combined solid waste treatment and high methane yield, as described in Figure 8.

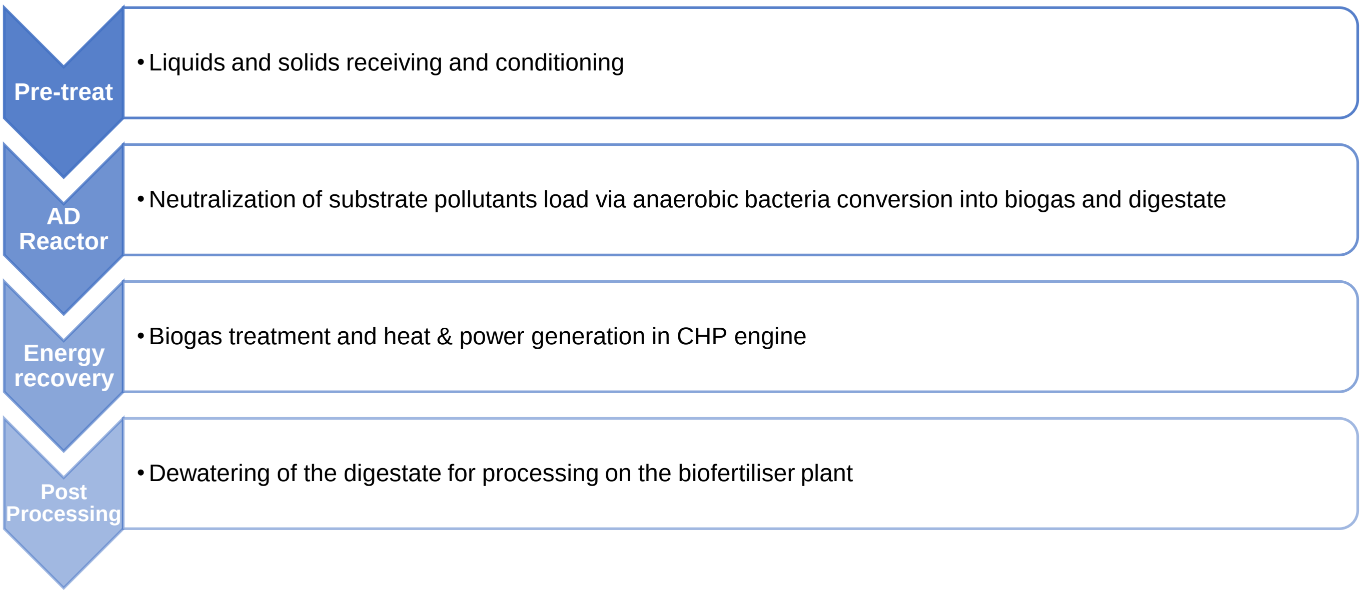

Figure 8. Summary of steps considered on the Biogas plant design.

The following sections describe specifications of individual equipment and processes. Refer to Appendices, Technical Drawings:

- 210615-V&V-FEED-BG-DW-001 for General Arrangement and Plant Layout
- 210615-V&V-FEED-BG-DW-002 for Process Flow Diagram

Process Concept Design

The adopted process configuration is a Wet Co-Digestion Biogas Plant with up to ~65 days hydraulic retention time (HRT) operating in a Mesophilic temperature range (37°C). By-products originated from this plant includes fuel (biogas), energy (heat and electricity); and biofertiliser (in the form of slurry or pellets). Initial estimates have considered a facility able to process a total of 69 tonnes of combined organic waste per day (equivalent to 25,185 tonnes per year). The plant supports gradually feeding of additional organic wastes (conditioned to Characterisation and suitability/compatibility with existing substrates and anaerobic digestion process), and depending on the characteristics of the additional substrates, HRTs could be reduced to ~40 days and plant capacity is increased without need for expansion.

For the selected process configuration Continuous Stirred Tank Reactor (CSTR), the feeding solids content cannot exceed 12% and the reactor preferably operates around 10% of total solids. Adjustment in the substrate feeding solids content is possible due to flexibility in the substrate pre-conditioning system. The designed Organic Loading Rate (ORL), which is the organic dry mater content has adopted a conservative approach with ORL of 1.6 kg/m3 .day, allowing plant to increase capacity and support substrate load variations without need for expansion. This type of plants can operate from 1 up to 4 kg/m3 .day. Both, HRT and ORL and interconnected and must be evaluated concomitantly and are conditioned to the solids content feeding the reactor.

5.4.3 Pre-treatment

The waste receiving station, pre-treatment and feeding system was located at an enclosed shed protecting the streams from environment conditions, such as rain water and wind. The shed also offers the opportunity for receiving different streams with potential to feed the digestor. To have flexibility with the types of substrates handled, the system will include a liquid receiving station and a solid receiving area. After receival, solids and liquids are mixed by using a specific feeding hopper and then fed into the digester. The shed will have

Liquid receiving tank (TK-019)

The liquid streams such as sludges originated from the WWTP, was pumped into the liquid receiving tank. The tank will also be equipped with a cam-lock fitting with potential for receiving other liquid streams via tanker trucks. The tank allows control of mixing ratios that will feed the digestor. The tank was designed with a total of 145 kL. The tank was equipped with a side entry mixer to avoid material deposition/ settling at the tank bottom with minimum power of 30 W per KL of tank – a 5 KW side entry mixer was adopted.

Tag	Design conditions	Basic Specifications
TK.019	Operational volume 145 m3 Maximum Holding Capacity = 145 kL	Diameter: 6.83 m Total Height: 4.3 m Operational Height: 4.0 m Operational Volume: 145 kL Material Glass Fused Steel with epoxy coating – covered top Side entry mixer = 5 kW

Solids Receiving (SR-001)

A solids receiving bay with capacity up to 50 m3 per day of solids was made in concrete and located inside the shed. The solids receiving bay allows receiving of solids material such as manure paunch content and/or other external solids suitable for feeding the biogas plant.

Tag	Design conditions	Basic Specifications
SR.001	Operational volume 25 to 50 kL per day Maximum Holding Capacity = 145 kL	Width: 9.0 m Total Height: 2.5 m Depth: 4.0 m Divided into 3 bays with same dimensions

Receiving/Feeding Hoper (U-002)

The solids streams, placed at the solids receiving bay, was loaded to the Receiving hopper by a loader truck. The feeding hopper is equipped with rotating screw at its bottom allowing solids to move toward the “mixing head”. The feeding hopper also provides an efficient defibration of the biomass via an integrated macerating function. At the “mixing head” solids was blended with liquids (from TK-006), then going to the mixing tank prior feeding the digester. The hopper can receive up to 16 m^3 of solid streams per load. The mixing head was able to operate via the feeding or liquid recirculation pumps.

Tag	Design conditions	Basic Specifications
U.001	Hopper capacity: up to 16 m^3 per load	TBC with supplier

Blending Tank (TK-020)

Liquid and solid stream (mixing at feeding hopper) are directed to the blending tank. The blending tank will allow the solids and liquids to achieve required homogeneity and appropriate Total Solids content ratios, prior being fed to the anaerobic digester. The blending tank was equipped with a side entry mixer at the tank bottom with 5 kW power. A recirculation line located at the tank bottom, allows recirculation of the substrate through the “mixing head” to improve substrate pre-treatment. The tank was designed with 145 kL adding extra buffer capacity prior feeding substrates into the digester.

Tag	Design conditions	Basic Specifications
TK.020	Operational volume 145 m^3 Maximum Holding Capacity = 145 kL	Diameter: 6.83 m Total Height: 4.3 m Operational Height: 4.0 m Operational Volume: 145 kL Material Glass Fused Steel with epoxy coating – covered top Side entry mixer = 5 kW

5.4.4 Anaerobic Digester

Biodigester and ancillary equipment (R.005 and R.006)

The proposed configuration for the Biogas plant includes two main reactors operating in-series with equal volume and hydraulic retention time. By using this configuration, enough hydraulic time was provided to the substrate for optimum generation of biogas and fully digestion. The reactors will operate in mesophilic range (temperature set at 37˚C), which is less sensitive when operating at higher temperatures. The digesters are equipped with heating coil in the inner wall. The required heat is transferred for heater exchanger and set to 37˚C. The digesters will have 2,160 kL each with total capacity of 4,320 kL. In order to maintain the substrate homogeneous mixing the digester was equipped with four side entry mixers. The power requirement is equivalent to 30 kW per kL of digester; each side entry mixer will have 16 kW power with a total of 64 kW power per digester. The biogas double membrane gas holder dome will have a holding capacity of 1,300 kL of biogas per tank. Digesters are also equipped with external blowers to maintain adequate pressure in the double membrane gas holders. Based on substrates availability and characteristics, as per

Table 15 above, both digesters combined will produced ~6,460 Nm^3 of Biogas per day (270 Nm3 of Biogas per hour). The digesters are designed to treat 69 tonnes of substrate per day with estimated digestate production of 61 tonnes per day.

Tags	Design conditions	Basic Specifications
R.005	Refer to Appendices – Basis of Design. Operational hours = 24 hours	Diameter: 20.48 m Total Height: 7.06 m Operational Height: 6.56 m Operational Volume: 2,160 kL Material Glass Fused Steel with epoxy coating Double dome membrane gas holder: diam = 20.48m x h = 7.00m; vol = 1,300 kL ; including supporting system (belts, safety nets, belt clips, support column Equipped with internal heating coil Equipped with air pressure booster system to ensure minimal membrane pressure 2.5 mBar Safety valves Four mixers of 16 kW each
R.006	Refer to Appendices – Basis of Design. Operational hours = 24 hours	Diameter: 20.48 m Total Height: 7.06 m Operational Height: 6.56 m Operational Volume: 2,160 kL Material Glass Fused Steel with epoxy coating Double dome membrane gas holder: diam = 20.48m x h = 7.00m; vol = 1,300 kL ; including supporting system (belts, safety nets, belt clips, support column Equipped with internal heating coil Equipped with air pressure booster system to ensure minimal membrane pressure 2.5 mBar Safety valves Four mixers of 16 kW each

5.4.5 Energy recovery system and Gas treatment

Gas treatment (GT-001)

Biogas produced by the anaerobic digester, usually is saturated with water and might present high H_2S contents. To achieve a suitable quality for use (either boiler or CHP feeding), the biogas has to go through a minimum pre-treatment for removal of humidity (de-humidification process) and removal of H_2S and Siloxanes. For this purpose, the Biogas produced (usually at 38 to 40˚C) has its temperature reduce to around 3-5˚C on an air-cooled water chiller, integrated with a water/biogas heat exchanger plus and a knockout drum filter condensate discharge. For H_2S removal, active carbon filter was implemented. Gas treatment system are equipped with biogas pressure booster to feed CHP engines/boiler at adequate pressure and flow rate. The gas treatment system is designed for up to 300 Nm3 of biogas per hour. Ferric Chloride dosing is also being considered for minimizing H_2S content formed during the digestion process. The Ferric chloride can be diverged from the Chemical house from the wastewater treatment plant.

Tags	Design conditions	Basic Specifications
GT-001	Maximum flow rate: 300 Nm3 of biogas per hour	Biogas relative humidity: 100% (saturated) Biogas source: AD system Average CH4 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 content ~ 500 ppm (TBC) Siloxanes ~ 1 ppm (TBC)

Flare (FL-001)

The biogas flare is adopted in case there is a need to consume surplus of biogas produced by the anaerobic process, as a safe disposal of the biogas in case of equipment failure or maintenance (gas treatment system, CHP boiler, etc).

Tags	Design conditions	Basic Specifications
FL-001	Flow rate range: 250 to 300 Nm3 of biogas per hour	Pressure: 60 to 120 mBar Gas pipe: 80 mm Flame Pipe: 700 mm

CHP Engine (CHP-001)

The combined heat and power unit (CHP) is an alternative to produce electricity and thermal heat from treated biogas. A preliminary assessment of adoption of a CHP unit as an alternative for the biogas utilization was made. By adopting a CHP with engine size of 550 kWe, the Biogas consumption of the engine was up to 226 Nm3 of biogas per hour. The unit was able to produce 550 kWe of electric power and 526 kWt of thermal power. For optimum usage the engine should run 24 hours and the total biogas consumption was ~5,420 Nm3 per day. The remaining Biogas produced (~1,040 Nm3 per day) can be directed to other uses such as the industry boiler or to the Biofertiliser plant producing required thermal heat for the biochar process (assessment in future milestones report). The electricity produced can be used locally for the WWTP and Biogas plant equipment, also thermal energy can be used for heating the Anaerobic Digesters. A further assessment of final use of Biogas utilization must be made during detail design stages including boiler location, minimum gas quality requirements, settings, configuration, operational periods, etc.

Tags	Design conditions	Basic Specifications
CHP-001	Gas consumption: 226 Nm3 of biogas per hour Biogas Methane content: 60%	Efficiency Thermal: 42.5% Efficiency Electrical: 40.6% kWe produced per hour: 550 kW kWt produced per hour: 526 kW
E-001	Heat exchanger integrated with CHP	Keep reactor temperature at 37˚C

5.4.6 Digestate storage and dewatering

Digestate Storage

The digestate produced by the Anaerobic Digesters was directed to a final storage with 312 kL operational volume, offering 5 days buffer capacity to the system (based on a digestate production of 61 kL per day). From the storage tank the digestate was directed either to the dewatering system and the Biofertiliser facility (MS6 report).

Tags	Design conditions	Basic Specifications
TK.021	Max Operational volume 312 kL Maximum Holding Capacity = 5 days	Diameter: 10.24 m Total Height: 4.3 m Operational Height: 3.8 m Material Glass Fused Steel with epoxy coating – covered top Side entry mixer = 10 kW

Solid/ Liquid Separator

The detailing of the dewatering step was incorporated into the Milestone Report 6 (Biofertiliser); since this is based on the type of technology selected for the Biochar process, and, if, for processing the digestated was preferred as it comes from the Digestor or dewatered to reduced water content. In case of dewatering the slurry content, a Moving Bed Bioreactor (MBBR/ Anitamox) was designed to deal with the relatively small portion of water originated from the dewatering process, minimizing NH_4-N content, and returning the water to the process.

5.4.7 Pumping system

Pumping system

Due to the solids content the plant was dealing with (up to 12%), the pumping and recirculation systems opted includes progressive cavity pumps. The pumps vary in sizes and type depending on location and function in the plant. Progressive cavity pumps allow pumping high solids content at low rates and easy maintenance.

5.4.8 Infrastructure Requirements

The implementation of the Biogas Plant adjacent to the WWTP will required and share the infrastructure requirements as per detailed in MS3 report.

5.4.9 Process recovery Outcomes

Based on the information detailed on this report, Table 17.presents a summary of the process recovery outcomes.

Table 17. Summary outcomes of the Biogas Facility

Item	Value	Units
Treatment Capacity	25,185	Tonnes per year
Substrate Solids Content	< 5 %	Of Total solids
Biogas Production	6,460	Nm^3 per day
Energy Equivalent	50,688	GJ per year
Digestate production for Biofertiliser/Biochar Processing	22,325	Tonnes per year

5.5 Cost estimate and economic analysis

The total capital expenditure (CAPEX) based on a +/-30% cost estimate is of $16.5M. The investment is planned to occur in stages, over 5- 6 years, as per suggested on Table 1:

Table 18. Summary of estimated capital investment over the next six years.

		2022	2023	2024	2025	2026	2027	2028
Stage 1 – Wastewater treatment plant	$7.31M							
Stage 2 – Biogas Plant	$5.95M							
Stage 3 – Biofertiliser plant	$3.37M							
Total	$16.63M							

The streams generating revenue, based on conservative assumptions, are presented on Table 2:

Table 19. Summary of revenue streams.

Income	Start	$/annum
Recycled water	2024	393,600
Energy From Biogas (Combined)	2025	989,250
Biochar	2027	523,200
Savings from disposal	2027	875,000
Carbon credits	2028	177,600
Total revenue per annum		**$2.96 M**

The economic analysis (using the Net Present Value method) considered the capital expenditure, Operating costs based on a percentage of CAPEX, and the estimated incomes. The outcome is net positive, over a 25 year's total project life, with a Net Present Value of $28.9M. The payback time is estimated to be 10 years, with an annual ROI of 2.7%. Table 3 presents the summary of the Economic Analysis of the implementation of the Integrated Waste Management system.

Table 20. Summary of Economic Analysis of the implementation of the Integrated Waste and Wastewater Management system.

Item	Value
Net Present Value	$ 28,9 M
PV of Costs (CAPEX & OPEX))	$ 30,3 M
ROI 25 years	95.4%
Annualised ROI	2.72%
Payback time	~10 years

Based on the technical and economical outcomes presented in this report, the implementation of the Integrated Waste and Wastewater Management system will result on:

- The integrated system is self-sufficient in terms of power, the entire system can be powered by biogas, with a surplus of energy in the form of heat
- The income generated by side-streams will offset costs (CAPEX and OPEX). The estimated return on investment is 2.7% per annum, when traditionally waste/wastewater management is a cost (negative ROI).
- The biogas system is designed to receive additional feedstock, with a potential to double the energy output by adding high carbon wastes (such as food waste, breweries waste, etc.).
- The methane produced in the biogas system can be used for producing Hydrogen if that is desirable.
- The facility will offset carbon, contributing for V&V Walshe's net zero carbon programme.

5.5.1 Cost estimate WWTP

The summary of the +/-30% Cost estimate is presented in Table 21. The detailed cost estimate breakdown is presented in Attachment 2.

Table 21. Summary of the Cost Estimate for the V&V Walsh Wastewater Treatment Plant.

Description	Total (AUD)
Preliminaries	329,872
Site preparation[6] (not including pond rehabilitation)	30,000
General civils	173,006
Mechanical and electrical equipment	5,101,905
Modular buildings	60,000
Fire Services	9,750
OH & Profit	372,000
Sub Total	***6,076,533***
Design Contingency	121,531
Construction Contingency	151,913
Headworks	Excluded
Installations & commissioning	292,303
Design & Planning	607,653
Regional loading	Excluded
Escalation (1%, Commence Sep 2022)	60,765
TOTAL FOR BUILDING & COMMISSIONING	**$7,310,699**

The cost presented in Table 21 was validate using the cost curve proposed by Jalab et al (2019) for similar systems (including nutrient removal and membrane treatment), and the result is:

CAPEX (US$) = 167 $Q^{-0.462}$

Q =Daily flow in MLD = 0.001171 ML/day (=1,171 kL/day)

CAPEX = US$ 4,421,810

[6] Not including Pond 0 rehabilitation and earthworks for area levelling, cut and fills

CAPEX = AUD 6,145,432 [7]

Considering the cost curve is from 2019, the Cost estimate of $7.3 M seems slightly higher, however accurate for the current Australian economic reality and considering the effects of pandemic on labour shortages and supply chain disruptions.

5.5.2 Cost estimate biogas system

The summary of the +/-30% Cost Estimate prepared based on a bottom-up approach is presented in Table 22. The detailed cost estimate breakdown is presented in Appendices.

Table 22. Summary of the Cost Estimate for the V&V Walsh Biogas Plant.

Description	Total (AUD)
Preliminaries	308,372
Site preparation[8] (not including pond rehabilitation)	93,750
General civils	173,006
Waste receiving, pre-treatment and feeding	575,000
Anaerobic Digestion System	1,684,190
Biogas Handling and CHP	1,236,360
Pipework, electrical, control and services	718,250
Sub Total	***4,615,922***
Design Contingency	92,318
Construction Contingency	115,398
Headworks	Excluded
Installation & commissioning	219,227
Design & Planning	461,592
Regional loading	115,398
Escalation (2%, Commence Sep 2024)	92,318
TOTAL FOR BUILDING & COMMISSIONING	**$ 5,712,174**

The cost presented in Table 21 was validated using the costs for similar biogas systems, the cost total should be around $4,500. For instance, the Richgro system, operating in Jandakot (WA), processing 137 ton/day, costed $8M (without sludge dewatering). Considering the reference is from 2017, the Cost estimate of $5.7 M seems slightly

[7] Exchange rate 1 USD = 1.3898 AUD on 18 Jan 2022.

[8] Not including Pond 0 rehabilitation and earthworks for area levelling, cut and fills

higher, however accurate for the current Australian economic reality and considering the effects of pandemic on labour shortages and supply chain disruptions.

5.5.3 Cost estimate biochar system

The summary of the +/-30% Cost Estimate prepared based on a bottom-up approach is presented in Table 23. The detailed cost estimate breakdown is presented in Appendix.

Table 23. Summary of the Cost Estimate for the V&V Biochar Plant.

Description	Total (AUD)
Preliminaries	148,354.00
Site preparation[9] (not including pond rehabilitation)	Excluded
General civils	78,983
Packaged Biochar Plant (powered by biogas)	2,400,000
Pipework, electrical, control and services	Included
Sub Total	***2,627,337***
Design Contingency	80,000
Construction Contingency	82,000
Headworks	75,000
Installation & commissioning	Included
Design & Planning	228,000
Regional loading	159,000
Escalation (2%, Commence Sep 2025)	114,000
TOTAL FOR BUILDING & COMMISSIONING	**$3,365,337**

Several Australian biochar plant suppliers are emerging, and we recommend continuing the investigations over the next few years aiming to select the appropriate local supplier.

5.5.4 Income Assumptions

Income assumptions were developed for the complete system (including a CHP engine) and a sensitivity analysis was conducted aiming to understand the possible ranges or return on investment based on several variables. The sources of incomes considered in the analysis were:

- Recycled Water
- Biogas

[9] Not including Pond 0 rehabilitation and earthworks for area levelling, cut and fills

- Biochar
- Disposal costs
- Carbon credits

5.5.4.1 Value of non-potable water

Currently, V&V Walsh disposes their treated wastewater via irrigation and land disposal, free of cost. However, with the improvement of the treated water quality the produced water become more valuable, presenting the possibility for income. The treated water is suitable for several applications including irrigation, firefighting, general industrial uses, civil construction, vehicle washing, water features augmentation (lakes, water fountain features, for example),

The non-potable water market in Western Australia is emerging, and there are no regulated fees that can be adopted across the board. The price of non-potable water and non-residential water supply around Bunbury was gauged.

We contacted several suppliers of non-residential water in the region, starting with Harvey Water, who operate the non-potable network across the Southwest WA, for both industrial and irrigation applications. Harvey Water pricing for industrial non-potable water is currently $1,200 per ML. We have also consulted with Water Force WA10 for bulk non-potable water delivery in trucks, and their cost is currently $150 per 14,000 L, or $ 10,715 per ML (near Serpentine WA).

We compared these costs with Aqwest non-residential water rates in Bunbury area, $2,900 / ML. Busselton Water charges $1,820/ML for non-residential users. Therefore, the value of water will depend on finding the right market to buy it in long-term. Based on the above, a range of comparative prices was used to estimate the value of the water to be produced by V&V Walsh.

Figure 9. Ranges of prices found in the Southwest WA (January 2022).

A conservative value of **$1,200/ML** was adopted for the Economic Analysis purposes, and the sensitivity analysis considered the wider range of prices.

Long-term forecast: The trend is for the price of non-potable water to increase, and eventually become a valuable commodity. At the same time, public acceptance and regulation are both progressing for making the use of this valuable resource a common practice in the coming years.

Bunbury non-potable water scheme

Aqwest Bunbury Water Corporation is currently in design and approvals stage for building a non-potable water distribution network starting at the wastewater treatment plant in Dalyellup extending all the way to Bussell Highway at the Turf Club. There is a potential opportunity for V&V Walsh to sell its treated wastewater and connect to the non-potable network, with an extra 4 km of pipeline.

[10] https://waterforcewa.com.au

5.5.4.2 Biogas

Biogas is a source of energy that can be used in various ways. Rich in methane (CH_4) biogas can be used directly as a replacement for natural gas, used as fuel for a combined heat and power engine (CHP). In some countries, biogas is further purified and used as fuel for vehicles. More recently methane is being successfully converted into hydrogen via pyrolysis, as is the case being trailed currently at Water Corporation's Woodman Point WWTP.

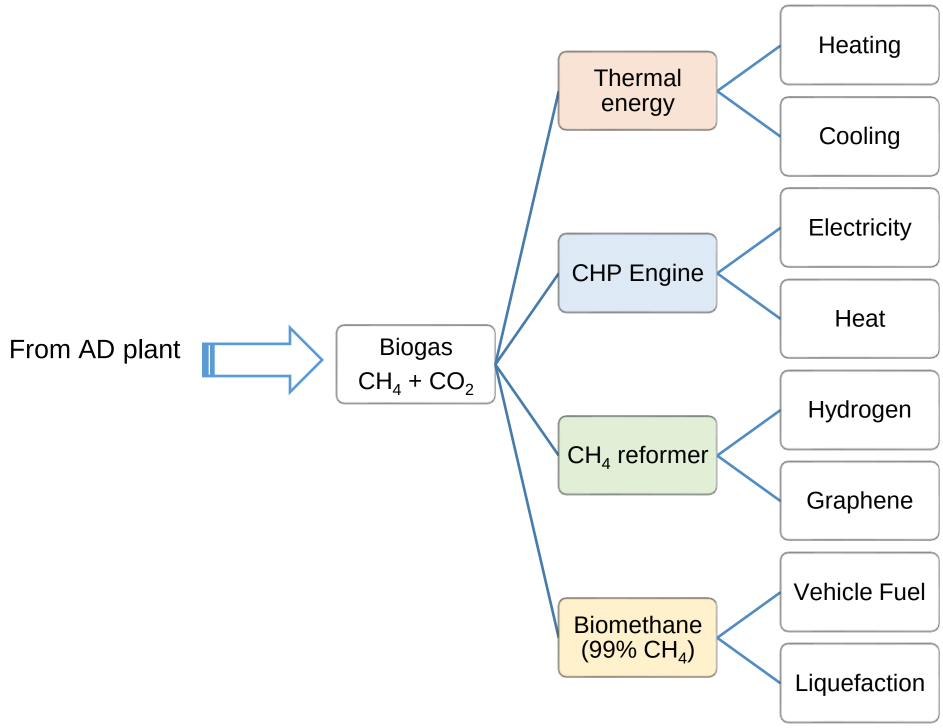

Figure 10. Various possible uses of biogas.

The value of biogas is associated to the type of energy being produced and its uses. In the case of the V&V Walsh Integrated Waste Management system, the biogas produced in the AD system is sufficient to provide the entire electricity and heat to run the system, including the Wastewater Treatment Plant (WWTP), the Biogas plant itself, and the Biofertiliser plant. The Combined Heat and Power Engine can provide up to 680kWh electricity, using the biogas produced in the plant.

Adopted values - energy

For the purposes of the Economic Analysis, we adopted the current price paid by V&V Walsh for energy (Table 24).

Table 24. Current V&V Walsh energy demand and associated costs.

Source of Energy	Unit	Total annual use	Annual cost per unit
Electricity	kWh per year	11,424,513	$0.14
Natural Gas	GJ per year	54,342.81	$6.49
LPG	litres per year	16,777	$1.09
Diesel	litres per year	27,263	$1.10

Therefore, we recommend using biogas for electricity and heat, in the following way as per the energy balance presented in Figure 11:

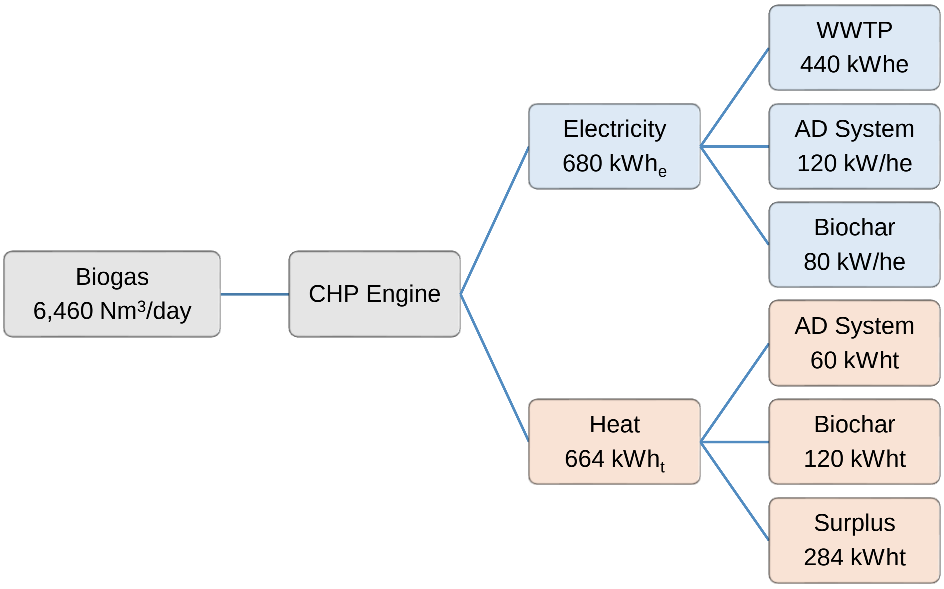

Figure 11. Energy balance from biogas at V&V Walsh integrated Waste Management system.

The system's energy requirements breakdown is presented in Table 25.

Table 25. Integrated Waste Management system electricity demand breakdown.

Location	Installed Capacity	Unit	Including	Comments
WWTP	440	kWh	Pumps, dosing pumps, instruments, blowers, UV system, screw press, ancillaries	Not all pumps work 24/7
Biogas	120	kWh	Pumps, mixers, membrane pressure boosters, ancillaries	Not all mixers and pumps work 24/7
Biofertiliser	80	kWh	Conveyor, fans	Operating 10h / day
Site ancillaries	10	kWh	Site lighting and alarms	Assumed
Total	**650**	**kWh**		**Installed capacity**

Therefore, the Integrated Waste Management is energy positive with a surplus of thermal energy that can be used at the processing plant. This brings considerable benefits in terms of carbon footprint, withing the net zero carton aspirations within the red meat industry (CN30).

5.5.4.3 Biochar

Biochar is a high value product, with a wide range of applications, such as:

- Additive to composting
- Agriculture & horticulture
- Carbon sequestration
- Livestock farming
- Bedding material

The price of biochar is variable depending on how it is sold. Typically, 20L (10kg) bags are commercialised for $22,00, reaching up to $90 per 20L, depending on how it is marketed. This is equivalent to prices in the range of $2,200 to $9,000 per tonne of the product. When sold in Bulk, Biochar price gets a discount and is usually commercialised at $880 per 1000 L (550 kg).

We would recommend V&V Walsh consider entering arrangements with a third party interested in commercialising the biochar in small packages, targeting the domestic public, due to the relatively small amount produced, and the better pricing outcomes.

We adopted the conservative value of **$1,600 per tonne** the Economic Analysis purposes, and the sensitivity analysis considered the wider range of prices.

5.5.5 Sludge disposal costs

Disposing of the organic solids and sludge produced by abattoirs has been a grey area historically. The Waste Authority WA has issued the Waste Avoidance and Resource Recovery Strategy 2030[11], where it sets directives for increased costs of waste disposal to be in place in the next few years, aiming to incentivise sustainable practices. The Department of Water and Environmental Regulation has issued a consultation paper in February 2020[12], and the new legislation is being produced.

The trend nation-wide is to make waste disposal practices stricter, in line with the "end of waste code", already in place in Queensland. This will result on increasing costs and lower availability of disposal facilities, due to regulatory restrictions.

Along with that, implementing the upgraded wastewater treatment system will result in an increase of sludge production, consequently increasing the costs of sludge disposal.

The current amount paid by V&V to dispose of their wastes is around $ 150 per tonne. Based on the regulatory scenario and the strong indication of higher costs, and also the prices being in place for neighbour abattoirs, we chose to adopt a conservative amount of **$250 per tonne** of wet spadable sludge (15% solids), in line with the current charges practice by Cleanaway in the southwest for organic wastes.

5.5.6 Carbon credits

According to Financial Review[13],companies voluntarily buying up carbon offsets amid a flurry of pledges to hit net zero emissions by 2050 have pushed up Australia's official carbon price by 180 per cent over the past year. The rising demand from companies under pressure to reduce their emissions has paved the way for a market "supercycle" that could lift Australian Carbon Credit Unit (ACCU) spot prices to $60 a tonne. The Australian rally in 2021 has surpassed even the 146 per cent increase in the European carbon market, where prices recently dramatically rose from €50 in late July to a high of €90.75, before falling back toward €80 (A$126).

For the effect of this exercise, a conservative value of **$96/ tonne CO_2** was adopted, equivalent to €50. We are working to provide more detailed information to the consultants from Ndevour, aiming to assess more accurately what are the effective opportunities for CO_2 income after the implementation of this project. The numbers can be refined during detail design stage.

These assumptions were used to calculate the potential incomes to be produced by the implementation of the project, as detailed in

[11] https://www.wasteauthority.wa.gov.au/images/resources/files/2019/10/Strategic_Direction_-_Waste_Avoidance_and_Resource_Recovery_Strategy_2030.pdf

[12] https://consult.dwer.wa.gov.au/waste-policy/review-of-the-waste-levy/user_uploads/review-of-the-waste-levy---consultation-paper-.pdf

[13] https://www.afr.com/policy/energy-and-climate/australian-de-facto-carbon-price-surges-180-per-cent-20211221-p59jal

Table 26. Income Assumptions applied to the Economic Analysis of the Integrated Waste Management system.

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Table 26. Income Assumptions applied to the Economic Analysis of the Integrated Waste Management system.

Output	Value[14]	Unit
Recycled water production	328	ML/year
Recycled water income	**393,600**	**$ / year**
Available energy from Biogas	50,688	GJ/year
Biogas Income	**989,250**	**$/year**
Biochar production	327	tonne per year
Biochar Income	**523,200**	**$/year**
Wet biosolids production	3,500	tonne/year
Savings on waste disposal	**875,000**	**$/year**
CO_2 reduction	1,850	ton CO_2/year
Carbon credits	**177,600**	**$/per year**
Total income	**2,958,650**	**$/per year**

5.5.7 Economic Analysis

The economic analysis (using the Net Present Value method) considered the capital expenditure (reported in previous reports, MS4 and MS7), Operating costs based on a percentage of CAPEX, and the estimated incomes, as presented in section 5.1 above. The outcome is net positive, over a 25 year's total project life, with a Net Present Value of $28.9M. The payback time is estimated to be 10 years, with an annual ROI of 2.7%. Table 27 presents the summary of the Economic Analysis of the implementation of the Integrated Waste Management system.

Table 27. Summary of Economic Analysis of the implementation of the Integrated Waste Management system.

Item	Value
Present Day Costs (Capital Expenditure)	16,626,210
PV of Capital Expenditure	16,474,302
Present Day Costs (Operating Costs)	16,626,210
PV of Operating Costs	16,474,302
Present Day Income	71,030,651
PV of Income	59,192,394

[14] All costs are presented in Australian Dollars. Conversion Rates: 1 USD = 1.3912 AUD; 1 Euro = 1.5756 AUD @19 January 2022.

NPV	**28,902,118**
PV of Costs (Excluding Income)	30,290,276
Treated water cost $/ ML	1,061
Energy (Biogas) cost $/GJ	5.87
Biochar cost $/ton	572
ROI 25 years	95.4%
Annualised ROI	2.72%
Payback time	~10 years

5.5.8 Sensitivity Analysis

The sensitivity analysis was performed by varying those parameters that can be somehow controlled, including CAPEX, Price of Water and Biochar. The analysis show that all variables impact the overall result of the project, and this will have to take into consideration during detail design stages.

Table 28. Sensitivity analysis responding to variations on CAPEX, price of water and price of biochar.

Location	CAPEX		Water		Biochar	
	-30%	+30%	Zero	$10k/ML	Zero	$9k/tonne
NPV	38.0	19.8	19.8	95.8	18.4	77.7
Water cost $/ ML	742.96	1,379.78	1,061.4	1,061.37	1,061.4	1,061.4
Energy cost $/GJ	4.11	7.63	5.87	5.87	5.87	5.87
Biochar cost $/ton	400.23	743.28	571.75	571.75	571.75	571.75
ROI	179%	50%	6%	316%	61%	256%
Annualised ROI	4.2%	1.6%	2.0%	5.9%	1.9%	5.2%

6 Discussion

Not applicable.

7 Conclusions / Recommendations

Under the old, traditional, perception waste and wastewater streams were something undesirable, ugly, dirty. Most industries used to deal with wastes as a pure liability, planning treatment systems aiming for the minimal conditions for short-term environmental compliance. However, more recently the value of recycled water and energy bearing by-products has caused a 180-degree shift in paradigm, and materials considered as waste are highly desirable.

The concepts of Resource Recovery and Circular Economy are now widespread, and industries of all sectors have increasingly strict Environmental, Social, and Governance (ESG) targets demanded by their investors. In this context, the entire agri-food industry needs to go through a quantum leap and adapt to this new way to deal with their by-products streams. In the Water sector, utilities are rebranding their Wastewater Treatment Plants as "Resource Recovery Facilities".

The Wastewater Resource Concept includes advanced treatment of wastewater for reuse and/or source augmentation, storage in natural landscape, biogas production and biosolids management via composting the facility is also designed on a way to facilitate guided tours, welcoming all sorts of visitors. The concept of the Digital Model is inspired in the same stream of thought, where unlocking the value of waste streams and recycled water is as important as achieving a robust environmental compliance.

In this context, the Concept Design proposed for this project has taken into consideration the production of recycled water compliant with medium and high exposure quality, and production of biogas and fertiliser from mixed solid waste streams from V&V Walsh Abattoir. The process integration, along with resource recovery and combining the treatment of both solid and liquid streams is an innovative concept in the Australian red meat industry resulting in positive environmental, economic, and social outcomes.

The concept to be used in the design considers engineered biological reactors for adequate management of wastewater and organic solid waste originated from the abattoir processing plant.

This design is for a new optimized and modular wastewater treatment plant with high flexibility of process control, focusing on developing new reuse and long-term disposal options for the meat industries wastewater. Design upgrades of the existing infrastructure will not be considered and the decommissioning of such infrastructure, existing ponds, was purposed after the implementation of new designed WWTP.

The new plant design is considering aspects such as nutrients (N, P) and other compounds removal from wastewater, with the possibility of irrigation and other water recycling uses (either Class C or Class A), within compliance. Additionally, the design of an integrated biogas plant will allow organic solid waste (currently disposed of off-site) and sludge from the WWTP, to be processed on-site for biogas production with potential for thermal and electrical energy applications. The incorporation of a biofertiliser plant design will consider upgrades of the digestate (resulting from the biogas plant) for conversion into an added value fertiliser product.

The result of this project, including the cost estimates for the plants, will then be used by V&V Walsh for the decision-making process for further stages of the plant implementation. These results will also support the Environmental Licensing application process. The proposed system has never been trailed in the Australian Red Meat Processing Industry and represents a quantum leap in terms of innovation and resource recovery.

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9 Appendices

9.1 Appendix 1 - Basis of design wastewater treatment plant

Item	Description	Design Basis	Comment
Future Production Capacity			
	Processing (cattle)	600 heads/ day	Information provided V&V Walsh
	Processing (lamb/sheep)	5,500 heads/ day	Information provided V&V Walsh
Climate Data			
	Annual average daily minimum ambient temperature	11.1˚	www.bom.gov.au
	Annual average maximum daily ambient temperature	23.2˚	www.bom.gov.au
	Average Rainfall	60 mm	www.bom.gov.au
	Local altitude	~ 15 m	google earth
Nutrients Loading Rate			
	TN, TP	Total Nitrogen - 600 kg/ha/yr Total Phosphorous - 180 kg/ha/yr	Department of Water, Environmental Regulation
Wastewater Characteristics			
	Raw Effluent Average Characteristics	BOD 1,733 mg/L - COD 4,300 mg/L TN 313 mg/L - TP 48 mg/L	based on set of analysis
	Effluent Temperature	approximately 60˚ to 70˚	typical effluent temperature at disposal time
Wastewater Flow Rates			
	Maximum production flow rate	1,640 kL per weekday	based on a full operational day
	WWTP Operation average flow	1,171 kL per day	operating 7 days a week
	WWTP Operation Maximum flow	1,640 kL per day	Operating 5 days a week
	WWTP Operation Peak flow	1,968 kL per day	Considered temporary peak flows (+20% of Maximum flow)
Treated Water Quality - after treatment process (polishing ultrafiltration, ultraviolet and chlorination disinfection systems)			
	BOD	0.86 mg/L	based on Biowin modelling operating at 1,640 kL per day
	TSS	0.32 mg/L	based on Biowin modelling operating at 1,640 kL per day
	TN	17 mg/L	based on Biowin modelling operating at 1,640 kL per day
	TP	0.03 mg/L	based on Biowin modelling operating at 1,640 kL per day

	pH	7.1	based on Biowin modelling operating at 1,640 kL per day
	Virus	6 LRV	based on manufactures specifications for UF and UV and typical chlorination LRVs
	Protozoa	12.5 LRV	based on manufactures specifications for UF and UV and typical chlorination LRVs
	Bacteria	13 LRV	based on manufactures specifications for UF and UV and typical chlorination LRVs
Recycled Water Quality			
	Soluble BOD TSS pH Turbidity TN TP UV dose UV transmittance Residual chlorine E.coli Virus Protozoa Bacteria	20 mg/L 30 mg/L 6.5 5 in 95% of sampling 20 mg/L 1.5 mg/L 40 – 70 mj per cm2 75 % 0.2 - 2 mg/L 1 CFU per 100 ml 5 LRV 3.5 LRV 4 LRV	The equivalent reuse described in the (NRMMC, 2006), is presented at the table 3.8 of the respective guideline, named as: à Municipal use — open spaces, sports grounds, golf courses, dust suppression, etc or unrestricted access and application): and combined to the reuses with Medium risk from the Guidelines for non-potable uses of recycled water in Western Australia (2011); which includes: urban irrigation with some restricted access and application, fire-fighting, fountains and water features, industrial use with potential human exposure, and, dust suppression.
Buffer Tank (WWTP)			
	Equalization tank Inlet WWTP	Minimum 1 day equalization of peak flow and approx. 1.5 days for maximum flow	maximum flow 1,640 kL / d and peak flow 1,980 kL per day
	Buffer tank inlet of UF system	Minimum 30 min buffer average WWTP flow rate	68 kL per hour
Dissolved Air Flotation (1) (WWTP)			
	Application rate	3.5 m/h	Metcalf & Eddy, (1991)
	Removal efficiency	removals primary treatment assumed at 50% (considering 25% safety)	assumptions based on DAF process with Tanfloc dosing and available removal results
Activated Sludge (A/O) Nitrogen removal (WWTP)			
	MLVSS (XV)	2,500 mg/L	Metcalf & Eddy, (1991)
	Total θc	10.8 days	
	BOD removal ratio anoxic/aerobic zone	0.7	
	Sludge recirculation	100%	
	Aerobic to anoxic recirculation	up to 500%	

	Average DO in the anoxic zone	2 mg OD/L	
	OD consumption	assuming 100% nitrification	
	Nitrifiers growth rate	0.5 /d	
	Denitrification anoxic zone	0.08 $mgNO_3$-/mgVSS.d	
Dissolved Air Flotation (2) (WWTP)			
	Application rate	5 m/h	Metcalf & Eddy, (1991)
Sludge Handling (WWTP)			
	Centrifuge or Screw Press	Processing capacity 4-8 kL of sludge/ hour	Considering sludge production (115 kL/day), depending operational conditions (e.g recirculation rates) - possibility to recirculate water to the system
	Sludge disposal	off-site, after increasing solids content	considered interim stage until implementation of biogas plant
Mains Power Supply			
	New electrical service connection	3 phase 400V	Assuming new service connection in the facility entrance. TBC after power load calculations
Potable Water Supply			
	New water service connection	50mm service connection	Assuming new service connection in the facility entrance water storage tanks.
Redundancy			
	Pumps	duty/standby	
	Aerators/Blowers	duty/standby	
	Diesel generator	70 kVA	Assumed Generator to run the main components in the WWTP plant for outage of up to 12 hrs; TBC after power load calculations
Control & Measurement			
	Process control	Equipment was controlled to maintain key process parameters with defined range.	
Alarms			
	Process control alarms	Key process control parameters out of range	
	Aerators/Blowers	Aerators/Blowers failure	
	Pump	Pump failure	
	Tank levels	High Level, High High level and Low Level	
Infrastructure - Design Life			
	Process plant	production increasing up to 600 heads of cattle and 5,500 head of lamb (per day) over the next 10 years	

	Pipes	50 years	
	Tanks (above ground)	20 years	
	Tanks (below ground - septic)	15 years	
	Civil structures (ponds, embankments etc)	50 years	
	Mechanical equipment	15 years	
	Communication / control equipment	10 years	
	Electrical equipment	15 years	
Material / Product Selections			
Civil Components			
	Tank materials (above ground)	>60kL = steel with liner	
	Process pipework (below ground)	Polyethylene (PE100)	Electrofusion/butt fusion welded joints
	Process pipework (above ground)	Polyvinyl chloride (PVC-U)	<=150mm solvent weld, >150mm rubber ring jointed
	Below ground potable water reticulation	Polyethylene (PE100)	compression fittings <= 90mm OD, electrofusion >=90mm OD
	Gravity sewerage	Solvent weld PVC	Minimum pipe diameter 150mm
Mechanical Components			
	Isolation valves	< DN50mm = ball valves (plastic)	
	Isolation valves	> DN50 = gate valves (DI)	
	Altitude valves	DI (float controlled)	
	Reflux / non return valves	<DN50mm = plastic	
	Reflux / non return valves	>DN50mm = DI	
	Wastewater transfer pumps	(submersible) end suction centrifugal	
Electrical / Comms Components			
	Not part of the scope at this stage		

9.2 Appendix 2 - Biogas system equipment list

Table 29 presents a summary of all core equipment for the Biogas Plant.

Table 29. Biogas System Equipment List

Item	Drawing label	Equipment List	Description	Comments	Qty
1. Receiving, pre-treatment and feeding system					
1.1	SR.001	Solids Receiving Bays	Capacity: 25 to 50m3 /day Width: 9.0m (divided in 3 bays) Height: 2.5m Length: 4.0m	Solids receiving bays made in concrete. Divided into three compartments.	1
1.2	U-002	Receiving Hopper Powerfeed Duo	Hopper Capacity: 16m3 per load Powerfeed Capacity: TBC Powerfeed Power: TBC Mixing head capacity	Hopper + Powerfeed with mixing head able to operate via feeding or recirculating pump.	1
1.3	TK-019	Liquid Receiving Tank	Capacity: 145 kL Diameter: 6.83m Height: 4.3m Material: Glass fused steel	Receiving tank including camlock fitting for rapid connection and liquid effluent receival and shaft open at the top for slurry inlet, Fixed roof	1
1.4	A-005	Substrate mixing	Giantmix FR3 30° 110-275 3,0 3.0m tube Ø101.6x5.7mm POM Motor 7.5kW 400V 50Hz i=5.31 Propeller HD+750-8 ss304 Stiring direction SP30° ss304 1200x1200x8 R8 Textile Sealing membrane (2x) Upper link L=800 30° downwards mechanical seal SiC/SiC	Side entry substrate mixing at the tank bottom	1
1.5	P-071 P-072	Feeding pump	Capacity: 1 to 4 kL/h Head: TBC with manufacturer due to the pressure required by the powerfeed head. Power: TBC	Rotary Lobe / progressive cavity	2
1.6	TK-020	Blending Tank	Capacity: 145 kL Diameter: 6.83m Height: 4.3m Material: Glass fused steel	Fixed roof including gas collection	1
1.8	P-073 P-074	Recirculation pump	Capacity: 1 to 4 kL/h Head: TBC with manufacturer due to the pressure required by the powerfeed head. Power: TBC	Rotary Lobe / progressive cavity	2

1.8	P-075 P-076	Transfer pump	Capacity from 1 to 4 kL/h Head: 8 m Power: TBC	Rotary Lobe / progressive cavity	2
1.9	A-007	Substrate mixing	Giantmix FR3 30° 110-275 3,0 3.0m tube Ø101.6x5.7mm POM Motor 7.5kW 400V 50Hz i=5.31 Propeller HD+750-8 ss304 Stirring direction SP30° ss304 1200x1200x8 R8 Textile Sealing membrane (2x) Upper link L=800 30° downwards mechanical seal SiC/SiC	Side entry substrate mixing at the tank bottom	1
1. 10	TBC	Shaft Grinder via recirculation pump Inline	Capacity: 1 to 4 kL/h	Inline shaft grinder to be positioned in the recirculation line TBC if required based on substrate type	1
2. Digesters					
2.1	R-005 R-006	Anaerobic Digester Reactor	Capacity: 2,160 kL Diameter: 20.48m Height: 7.06m Material: Glass fused steel Foundation type: TBC	Anaerobic Digester Interior wall coating: Top ring(s): Permaglas™ Glass-fused-to-steel---Vitrium EN Remaining rings: Permaglas™ Glass-fused-to-steel---Vitrium (10-16mils) Exterior coating: Permaglas™ Cobalt Blue Glass-fused-to-steel (7 - 15 mils)	2
2.1.1		Ladders for top access, cage COD platform	Height: 7.0m Material: SS	Ladder to have access to the reactor top, main part for inspection, and/or maintenance areas	2
2.1.2		Double Membrane Roof Top mounted.	Capacity: Approx. 1,300 m3 storage Diameter: 20.48m Balloon Height: 5.0m Pressure: 5 mBar Flow: 170 Nm3/h Working Temperature: -30˚C to + 70˚C	Double membrane roof (2 layers: outer/inner membranes), biogas storage, anti-corrosion, explosive-proof, long life, safety easy installation, no frozen, light. Material: European standard membrane, anti-UV, self-clean (PVDF coating), anti aging, acidproof, alkaliproof, high strength	2
2.1.3		Supporting system		Belts, safety nets and belts clips (124 pcs) -TBC Support column	2
2.1.4		Display Panel	Pressure/ volume control display	LCC more than 20 functions Electric components SCHNEIDER or similar Sensor system: Laser level sensor, and SUS304 pressure sensor Output Terminal 9Nos.	2

2.1.5		Air booster (Pressure Balancer)	Capacity: 170 m3/hr Non-return valve Control box for automatic start and stop	Air boost Blower Siemens anti-explosion Non return valve Ensure minimal pressure between the membranes typically 2.5 mBar	2
2.1.6		Air pressure balancer	Capacity: 170 m3/hr Material: SUS 304 Stainless Steel	Air pressure balancer to keep pressure at fixed data while increasing pressure	2
2.1.7		Air pressure relief Valve	Capacity: 170 m3/hr Material: SUS 304 Stainless Steel	Air pressure relief valve to protect membrane damage from air over pressure	2
2.1.8		Over under pressure valve	Capacity: 170 m3/hr Material: SUS 304 Stainless Steel	Over under pressure valve to protect membrane damage from air over pressure	2
2.1.9		Heating system for digester	DN: 84.32 x 2 mm Material: SS304 - Length : 100m	Internal coil heating system	2
2.1.10		Air Blower for H2S oxidation	Capacity: 170 m3/hr Non-return valve Control box for automatic start and stop	Air boost Blower Siemens anti-explosion Non return valve Ensure oxidation of the H2S according to analyser commands	2
2.2	A-008 A-009 A-010 A-011 A-012 A-013 A-014 A-015	Mixers	Power: 18.5 KW Giantmix FR4 SP 150-275 4,0 4.0m tube Ø101.6x5.7mm POM Motor 18.5kW 400V 50Hz i=5.31 Propeller HD+850-8 ss304 Swivel plate +/-25° galv. SP ss304 1200x1200x6 R8 RE Sealing membrane EPDM60 (2x) Hydraulicly adj. downwards steel tank rubber buffer for steel tank		8
2.3	P-077 P-078	Recirculation pump	Capacity from 1 to 4 kL/h Head: 8 m Power: TBC	Rotary Lobe / progressive cavity	2
2.4	P-079 P-080	Recirculation pump	Capacity from 1 to 4 kL/h Head: 5 m Power: TBC	Rotary Lobe / progressive cavity	2
3. Gas Treatment system					

3.1	GT-001	Gas treatment unit	Biogas relative humidity (HR) : 100% (saturated) - Biogas source : Anaerobic Digestion - Level above see : 0 m - Average temperature : 5-30 °C - Average CH4 content : 60% - Overall biogas flow : 300 Nm3/hr (wet) - Biogas inlet temperature : 38°C - Biogas outlet temperature : 3°C - Biogas ΔT design : 35°C - Biogas conditions after blower : T≈ 20°C @ 120 mbar - Biogas inlet pressure : ≈ + 5 mbar - Pressure loss skid : ≈ - 15-20 mbar - Pressure available after the blower : ≈ + 120 mbar - Power supply : 220 V - 50 Hz - 3-phase	Preliminary coalescent filter Stainless Steel AISI 304 Heat exchanger (biogas- water) range 38-3 °C Knock out drum filter condensate discharge stainless steel AISI 304 By-pass stainless steel AISI 304, shut- off butterfly valves on the heat exchanger HE insulation + Insulation water circuit heat exchanger – chiller Chiller suitable x range 38-3 °C Connection refrigerated water circuit heat exchanger – chiller Biogas blowers 170 Nm3/h - ΔP=150 mbar (-30 / +120 mbar) with ATEX certified motor Common skid stainless steel AISI 304 for the above components Activated Carbon Filter stainless steel AISI 304 First filling Activated Carbon x H2S reduction for each filter	1

3.2	FL-001	Gas flare	Type : full enclosed flame low temperature . Temperature combustion : not detectable (T < 800 °C) . Flame detection : UV sensor . Max. Biogas flow : 300 Nm3/h . Min. Biogas flow : 30 Nm3/h . Biogas inlet pressure : 20 - 40 mbar . Power supply : 230 V - 50 Hz single phase . Total height : 5000 mm . Full stainless steel construction AISI 304 stainless steel (base plates, supporting frame, windshield) . AISI 304 Stainless steel combustion chamber D=900 mm H=3000 . Combustion chamber insulation with fiberceramic liners (Optional) . Main Gas line AISI 304 stainless steel . Inlet gas line with ATEX solenoid valve, . Pilot gas line with ATEX solenoid valve . UV sensor for continuous flame detection . In-line stainless steel mesh disk-type flame arrestor - (ATEX optional) . On-board IP 65 control box, PLC – controlled . Power supply / Pilot flame status / Flare status lamps	Biogas flare stack type BGM-EF-LT 300 Nm3/h AISI 304 stainless steel Insulation combustion chamber with refractory liner ATEX certified bidirectional flame arrestor DN 80 Side channel blower with ATEX motor Spare part kit (2 years operation)	1
4. Gas management system & CHP					
4.1	CHP-001	CHP unit	Capacity: 550 kW - 226 Nm3/h Electrical Efficiency:40.6% Heat Efficiency:42.5%		1
4.2	E-001	Heat Exchanger	Integrated with CHP Keep digester at 37˚C		1
5. Digestate handling system and storage					
5.1	P-081 P-082	Substrate Transfer pump	Capacity from 1 to 4 kL/h Head: TBC depending on the LLS requirements Power: TBC	Rotary Lobe / progressive cavity	2

5.2	Tk-021	Post Digester Buffer /Storage	Capacity: 312 kL Diameter: 10.24 m Height: 4.3m Material: Glass fused steel	Post Digester Buffer / Storage Fixed dome roof gas collection system Recirculation system Mixing Interior wall coating: Top ring(s): Permaglas™ Glass-fused-to-steel-VitriumEN Remaining rings: Permaglas™ Glass-fused-to-steel---Vitrium (10-16mils) Exterior coating: Permaglas™ Cobalt Blue Glass-fused-to-steel (7 - 15 mils)	1
5.3	A-016	Substrate mixing	Giantmix FR3 30° 110-275 3,0 3.0m tube Ø101.6x5.7mm POM Motor 11kW 400V 50Hz i=5.31 Propeller HD+750-8 ss304 Stirring direction SP30° ss304 1200x1200x8 R8 Textile Sealing membrane (2x) Upper link L=800 30° downwards mechanical seal SiC/SiC	Side entry substrate mixing at the tank bottom	1
5.4	LSS-002	BIOSELECT (Liquid Solids separator)	Capacity from 1 to 4 kL/h	Liquid Solids Separator to minimize digestate volume (TBC during Biofertiliser design)	1
5.5	P-083	Substrate Transfer pump	Capacity: (TBC during Biofertiliser design) Head: TBC Power: TBC	Rotary Lobe / progressive cavity	1

9.3 Appendix 3 - Biofertiliser equipment list

Table 30 presents a summary of all core equipment for the Biofertiliser Plant.

Table 30. Biofertiliser Equipment List.

Item	Drawing label	Equipment List	Description	Comments	Quantity
1. Dewatering					
1.1	LSS-002	Screw-Press	Hydraulic loading = 61 m^3/d = 4.4 kL / hour Solid's content = ~5% Dry solids loading = 3.05 ton/d = 218 kg/h Operation = 14 hours RoS3Q 440 ISP or similar Installation Dimensions Length = 6.1m Width = 2.5 m Height = 2.8 m	Dewatering to reduce digestate volume	1
2. N-rich side stream Treatment					
2.1	R.007 – MBBR Reactor	Reaction Tank	Diameter: 6.3 m Total Height: 6.5 m Operational Height: 6.0 m Operational volume: 185 kL Material Glass Fused steel with epoxy coating – open top Equipped with bottom air diffusors connected to blower system		1
		Media specifications	Surface area media: 800 m^2/m^3 Protected Surface area: 256 m^2/m^3		60 m^3
		Air flow rate per diffusers = 5 Nm^3/h	Disc Diameter = 229 mm Disc Material = EPDM		20
		Aeration requirement: Air flow rate = 2,000 Nm^3/day	Air can be diverged from Wastewater air blow or required implementation of a 4-5 kW blower		1
3. Dewatered cake processing into biochar					
3.1	Biofertiliser Plant based on Omega	Feedstock Metering system	Live-Bottom Metering Bin, fully-assembled with variable speed motor and drive, AISI 304L construction.		

	Thermal Solutions Group LCC		Metering Bin Transfer Screw, fully-assembled with motor and drive, AISI 304L construction. Pug Mill with variable pitch paddles, dual infeed and fully-assembled with motor and drive, AISI 304L construction. Rotary Dryer Infeed Screw, fully-assembled with motor and drive, AISI 304L construction.
	Biofertiliser Plant based on Omega Thermal Solutions Group LCC	Feedstock Dehydration system	Model RF4P 6-30 Rotary Dryer System, 6'(1.8M) diameter x30'(9.1M) long *reverse-flow* design dryer system, fully assembled, ASTM A36 construction. Hot Forged Drum Tracks, AISI 1045 construction. 3-piece track wedge assembly for securing the drum track to the drum. Flame Cut Drive Sprocket for engineered drive chain. Dryer Drum Drive, equipped with drive and idler sprocket assembly, drive and idler shafts (AISI 4140), fully-assembled on a robust base, ASTM A36 construction. Front Trunnion Base with trunnion wheel (AISI 1045 construction), trunnion wheel shaft (AISI 4140 construction), fully-assembled on a robust base, ASTM A36 construction. Rear Trunnion Base with trunnion wheel (AISI 1045 construction), trunnion wheel shaft (AISI 4140 construction), thrust wheel assembly to prevent drum lateral movement, fully-assembled on a robust base, ASTM A36 construction. Dryer Furnace (ASTM A36 construction), castable refractory lined.
		Dry Product collection System	Separator Assembly, with access for service, water deluge and thermocouple ports, AISI 304L construction. Rotary Dryer Separator Airlock, fully-assembled with motor and drive. Separator Transfer Screw, sectional flights, fully-assembled with motor and drive, AISI 304L construction. High Efficiency Cyclone Collector for dry fines, AISI 304L construction. Cyclone Collector Airlock, fully-assembled with motor and drive, AISI 304L construction. Cyclone Collector Transfer Screw with Abort, sectional flights, fully-assembled with motor and drive, AISI 304L construction.
		Dry Product Metering System	Dry Product Transfer Drag Conveyor, bottom loading, UHMW paddles, fully-assembled with motor and drive, AISI 304L construction. Dry Product Metering Bin with Live-Bottom, dual discharge, variable speed motor and drive assembly, AISI 304L construction. Dry Reclaim Transfer Screw, sectional flights, fully-assembled with motor and drive, AISI 304L construction. Dry Product Transfer Screw, sectional flights, fully-assembled with motor and drive, AISI 304L construction.

		Dry Product Thermal-treatment System	Reactor Infeed Airlock, fully-assembled with motor and drive, AISI 304L construction Reactor Infeed Screw, sectional flights, fully-assembled with motor and drive, AISI 304L construction. Pyrolysis Reactor with rotary drum 2' (0.6M) diameter x12'(3.65M) long, proprietary flight arrangement and discharge section, ASTM A515 or equivalent construction. Rotary Drum Inlet and Discharge Seals, high-temperature construction Reactor Separator Assembly (AISI 304L construction), insulated, including ports for water deluge and thermocouple and viewing. Reactor Stationary Furnace (ASTM A36 construction), refractory-lined with multiple hot gas inlet and outlet ports, front and rear furnace seals. Reactor Furnace Outlet Damper (Opposed Blade Design) with electric actuator Rotary Drum Drive, equipped with drive sprocket assembly, drive shaft (AISI 4140), fully-assembled on a robust base, ASTM A36 construction Reactor Front Trunnion Base with trunnion wheel (AISI 1045 construction), trunnion wheel shaft (AISI 4140 construction), thrust wheel assembly to prevent drum lateral movement, fully-assembled on a robust base, ASTM A36 construction Rear Trunnion Base with trunnion wheel (AISI 1045 construction), trunnion wheel shaft (AISI 4140 construction), fully-assembled on a robust base, ASTM A36 construction. Reactor Structural Skid, ASTM A36 construction Furnace Waste Heat Manifold, AISI 304L construction and insulated with thermocouple port. Reactor Separator Assembly Rotary Airlock, high-temperature construction, fully-assembled with motor and drive.
		Biochar Biofertiliser Cooling System	Hot Biochar Transfer Screw, sectional flighting, insulated, fully-assembled with motor and drive. Oscillatory Cooling conveyor with motor-driven eccentric shaft. Water fogging system with nozzles and piping. Water pressure Booster Pump. Water Vapor Stack. Water Flowmeter Cooled Biochar Transfer Screw, sectional flighting, fully-assembled with motor and drive.
		Thermal Energy System	Combustion Furnace (ASTM A36 construction), refractory lined and equipped with thermocouple ports. 5.0 MMBtu/hr (5.2 GJ/hr) Burner System with arrangement to combust BioGas and process Volatile Organic Compounds (VOC). Burner system equipped with Burner Management System and Flame Safeguard

			Burner system to include piped and pretested fuel train VOC ID Fan, high-temperature design, insulated, AISI 304L construction Waste Heat ID Fan, high-temperature design, insulated, ASTM A36 construction Hot Gas Temperature Control Dampers to Dehydration and Thermal-treatment System, opposed-blade design with electric actuator, AISI 304L construction.
		Ducting and Structural Support	14” ducting for dry product collection system upto 30 lineal feet, AISI 304L construction. Ancillary ducting for furnace Waste Heat and VOC. Structural Support for Dryer Furnace, Cyclone Collector and Thermal Energy System.
		Process Control System	PLC based control logic. Control System housed in a NEMA 4X (IP66) enclosure. Control Instrumentation. Motor Control Centre (MCC) rated for local power supply.

9.4 Appendix 4 - Technical drawings

Please see attached a set of PDF files including:

- 210615-V&V-FEED-BF-DW-001_B.pdf
- 210615-V&V-FEED-BF-DW-002_B.pdf
- 210615-V&V-FEED-BG-DW-001_B.pdf
- 210615-V&V-FEED-BG-DW-002_C.pdf
- 210615-V&V-FEED-BG-DW-003_B.pdf
- 210615-V&V-FEED-BG-DW-005_B.pdf
- 210615-V&V-FEED-WWTP-DW-001_C.pdf
- 210615-V&V-FEED-WWTP-DW-002_C.pdf
- 210615-V&V-FEED-WWTP-DW-003_C.pdf
- 210615-V&V-FEED-WWTP-DW-004_C.pdf
- 210615-V&V-FEED-WWTP-DW-005_C.pdf
- 210615-V&V-FEED-WWTP-DW-006_C.pdf
- 210615-V&V-FEED-WWTP-DW-007_C.pdf
- 210615-V&V-FEED-WWTP-DW-009_C.pdf