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Feasibility Study for the use of Anaerobic Digestion and Biogas Energy Generation at a Meat Processing Facility

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Executive Summary

This study has investigated the feasibility of installing a free standing high rate anaerobic reactor for the treatment of meat processing wastes at a Victorian regional meat processor ("Processor"). A comparison of capital costs and expected asset life between traditional concrete construction and coated steel options has been undertaken in order to assess "whole of life costs", including cost benefits and risks, and the beneficial reuse of biogas. The study has defined the focus into 6 basic process flow Options.

- Option 1: Pre-screening (coarse) and maceration, high rate anaerobic digestion and clarification, with sludge treatment via either belt press dewatering or centrifugation;
- Option 2: As for Option 1 but with additional pre-treatment by fine screening and DAF treatment prior to high rate anaerobic digestion providing for a smaller anaerobic digestion system;
- Option 3: As for Option 1 but with addition of trickling filter treatment and clarification of wastewater downstream of the high rate anaerobic digester;
- Option 4: As for Option 2 but with addition of trickling filter treatment and clarification of wastewater downstream of the high rate anaerobic digester;
- Option 5: As for Option 1 but with addition of activated sludge treatment and clarification downstream of the high rate anaerobic reactor; and,
- Option 6: As for Option 2 but with addition of activated sludge treatment and clarification downstream of the high rate anaerobic reactor.

The final options analysis and Net Present Value ("NPV") comparisons, and commercial risks identified are specific to the Processor. However, these options and risks (and associated costs) provide a guideline which can assist analysis at other sites.

The study has established that the use of steel structures for high rate anaerobic digestion in a meat processing plant will provide lesser "Whole of Life" cost than concrete structures, and is potentially viable.

The comparison capital and NPV costs for the 6 basic process options incorporating concrete and steel, but excluding downstream Victorian Water Corporation ("VWC") costs are:

Capital costs and NPV's (excluding downstream VWC costs)

Option	Capital Cost (Steel)	Capital Cost (Concrete)	NPV (Steel)	NPV (Concrete)
1	$4,573,830	$5,292,055	-$4,877,670	-$5,369,362
2	$4,521,850	$5,042,005	-$5,585,689	-$5,788,247
3	$5,213,870	$5,932,095	-$5,558,155	-$5,884,700
4	$5,791,037	$6,311,192	-$6,882,127	-$6,995,716
5	$5,790,120	$6,508,345	-$7,173,282	-$7,463,564
6	$5,919,387	$6,439,542	-$7,843,648	-$8,029,527

However, investment in high rate anaerobic digestion is very dependent on the external (downstream) costs for final treatment and disposal, both existing and into the future.

For this particular Processor the NPV's inclusive of downstream VWC costs are:

Capital costs and NPV's (including downstream VWC costs)

Option	Capital Cost (Steel)	NPV (Steel)	Payback Period (Years)
1	$4,573,830	$8,791,125	5
2	$4,521,850	$8,507,080	5
3	$5,213,870	$10,362,529	4+
4	$5,791,037	$8,534,772	5
5	$5,790,120	$9,542,180	5
6	$5,919,387	$8,871,815	5+

This analysis shows that for the projected volumes and biological loads of the discharged effluent and the present charges which the VWC are implementing, the most attractive Option is Option 3. This Option involves an increased capital spend but has an earliest payback period of just over 4 years. Further analysis of commercial and operational risks is required in order to provide a commercial comparison.

In addition, greenhouse gas and energy savings are possible through the associated generation of biogas for onsite use.

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1 Background

The use of anaerobic digestion for waste treatment is proven technology and is used widely both within Australia and internationally (*Othman and Woon)*. High rate anaerobic digestion involves the processing of wastes in a vessel which is mixed and heated to the optimal temperature for mesophilic anaerobic digestion (approximately 37° C). At this temperature the anaerobic digestion process proceeds much more rapidly than is the case in low rate processes which operate under ambient conditions. However the use of high rate anaerobic digestion is not common in the meat processing industry in Australia. This is most likely due to the following:

- Availability of land at low cost (most meat processors are regionally located) which has historically made low rate processes such as open anaerobic and facultative lagoons more economic;
- The lower cost and lower complexity of covered anaerobic lagoons (where sufficient land is available);
- The complexity and higher operational costs of high rate anaerobic digesters;
- High fat content in meat processing wastewater;
- The high construction cost of concrete digesters and complex steel roof structures; and,
- In Northern Australia, higher ambient temperatures.

In Europe and the US in the last 10 -20 years (and more recently in Asia due to increasing environmental controls), limited land areas, environmental regulations and the availability of low cost construction techniques has led to an increase in the use of high rate digesters.

An initial feasibility study was completed by this meat processor (“Processor”) into actions and options to address broader wastewater treatment cost and service limitation issues. Consequent negotiations with the wastewater service provider (a Victorian Water Corporation (“VWC”)) are continuing in relation to achieving a commercially acceptable overall solution. The investigation of the high rate anaerobic digestion has been undertaken in parallel with a broader analysis of water usage and wastewater production and treatment by the Processor.

2 Projective Objectives

This project has been driven by a number of factors including:

- The commencement of a substantial processing expansion at the site by the Processor;
- The present wastewater service provider, the VWC, has recently substantially increased fees for waste treatment (approximately 100%);
- The VWC does not presently have sufficient capacity at their waste water treatment plant (“WWTP”) to allow the increased waste from the Processor to be treated and discharged without causing a non-compliance with their Environmental Protection Authority (“EPA”) licence conditions; and,
- The VWC does not have any capital allowance included within their “W*ater Plan 2013-2018”* (as accepted by the pricing regulator, the Essential Services Commission), (“ESC”), and have also advised that they are presently very capital constrained.

One of the technical options identified in the initial feasibility study, was the construction of an anaerobic digester at the Processors site, with the resultant effluent either being discharged to the VWC storage and irrigation system (which will require expansion) or to a Processor developed storage and irrigation site.

This study provided critical input into establishing an environmentally and financially sustainable solution for waste management for the Processor and provide wider industry benefits in relation to analysing the incorporation of a high rate anaerobic digester as part of a total waste solution. The suitability of high rate anaerobic digestion for waste treatment use at a particular meat processing site is subject to many factors. This study provides a conclusion which is particular to the Processors site. However the methodology and “whole of solution” analysis will be of assistance to other meat processors in relation to their particular situation.

The purpose of this study is therefore not to assess the technical suitability for this application. The intent is to assess latest construction techniques which can reduce capital costs and to ascertain if the incorporation of high rate anaerobic digestion with associated biogas generation and use in a meat processing facility is an economic and environmentally appropriate approach to waste management.

The project objectives for this study are therefore as follows:

- Assessment of costs and suitability of the process (a free standing anaerobic reactor) to provide a “least cost” whole of life solution for treatment of meat processing wastes (including offal wastes).
- Assessment of low cost construction methods for an anaerobic digester.
- Assessment of improved environmental outcomes.
- Issues and risks associated with the use of site production of biogas for energy attractive use.

3 Methodology

The methodology of the study is based primarily on a Laurie Curran Water Pty Ltd ("LCW") assessment of best practice developments in lowest capital cost methods of digester construction, in conjunction with the combined assessment and relative output performance of associated alternative pre and post treatment options. This involved workshopping by the study team of EPS Consultants ("EPS") and LCW to develop projected future waste flows and loads, and a range of potential process flow arrangements. The Processor was involved in the workshop process in relation to projections of the future waste flows and loads and establishing potential asset locations and available areas. A specialist peer review of the workshop outcomes was then undertaken by an independent experienced wastewater engineering specialist and refinements and suggestions further assessed. The estimated capital costs, operational and maintenance costs, and asset life projections were prepared by the study team and modelled to produce comparative "Whole of Life" Net Present Value ("NPV") costs.

Technical and Commercial risks were assessed incorporating a similar approach involving a study team workshop (EPS, LCW and the Processor) with a peer review by an independent experienced wastewater engineering specialist and refinements and suggestions further assessed by the study team.

There are a number of high rate anaerobic processes, the most common being:

1. Up-flow Anaerobic Sludge Blanket (UASB) and Expanded Granular Sludge Bed (EGSB) reactors;
2. Conventional high rate anaerobic digesters in fully mixed and heated reactors where the sludge age and hydraulic retention time are identical; and,
3. Conventional high rate anaerobic digesters in fully mixed and heated reactors followed by a settling process enabling the sludge age and hydraulic retention time to be controlled independently of each other.

For this study we have investigated the third process as it has the lowest construction cost using a steel tank.

The workshop and peer review process established the following Options for further analysis:

- Option 1: Pre-screening (coarse) and maceration, high rate anaerobic digestion and clarification, with sludge treatment via either belt press dewatering or centrifugation;
- Option 2: As for Option 1 but with additional pre-treatment by fine screening and DAF treatment prior to high rate anaerobic digestion providing for a smaller anaerobic digestion system;
- Option 3: As for Option 1 but with addition of trickling filter treatment and clarification of wastewater downstream of the high rate anaerobic digester;
- Option 4: As for Option 2 but with addition of trickling filter treatment and clarification of wastewater downstream of the high rate anaerobic digester;
- Option 5: As for Option 1 but with addition of activated sludge treatment and clarification downstream of the high rate anaerobic reactor; and,
- Option 6: As for Option 2 but with addition of activated sludge treatment and clarification downstream of the high rate anaerobic reactor.

Flow diagrams for these Options are included as Appendix A. There are various alternative processes including proprietary options which could also have been assessed. However the primary aim was to assess the potential feasibility of low capital cost high rate anaerobic digestion. The Options selected provided sufficient information to assess this feasibility. Should the project proceed to the detailed design stage, further analysis would be given to other potential pre and post digester treatment options and proprietary systems.

Additionally, the resultant waste stream post high rate anaerobic digestion, for this specific situation, can be directed to the existing VWC WWTP (which is in close proximity to the Processors plant) with or without individual post digestion treatment. This decision will be made on an economic and risk assessed basis. (ie: if the VWC service is considered cost competitive in relation to the Processor undertaking on site treatment and the service offered is at equal or less business risk then the post treatment will be completed by the VWC at its plant).

4 Discussion

4.1 Overview

The Processor has a throughput of 4,000 cattle and 25,000 small stock per week. No rendering is undertaken on site. Potable water usage and consequently wastewater production is low on a comparative kL/t Hot Standard Carcase Weight (HSCW) basis in relation to other processors. The Processor presently uses 3kL of potable water per tHSCW in comparison to the 2010 industry average of 9.4kL/t (*MLA)* . This is assumed to be due to cost and restrictions on water use and wastewater discharge by the VWC, which have been subject to constraints due to drought and environmental discharge restrictions for many years. The Processor therefore has a culture which has focussed on water and waste minimisation. This has the implication that the wastewater may be more concentrated than for processors with higher water usage. It should also be noted that the Processor presently has AQIS Tier 1 export status but is in the process of being granted Tier 2 status. This will increase water usage due to AQIS washing requirements.

In applying the learnings from this study to other sites, the comparative financial assessment between the respective construction and process options will have relevance, however variations in biological loads and concentrations may affect some of the relativities associated with process options.

It should also be noted that the Processor is continuing with investigations into separation of waste streams including differing environmental requirements for “green” and “red” waste streams; potential benefits of part site treatment and reuse; further water minimisation actions; and the availability of Government funding support. These factors will be included in further analysis and decision making in relation to the broader wastewater management process, and may impact any final decision including variations to any detailed design of anaerobic digestion.

4.2 Materials

With rising energy prices and the increased focus on energy generation from waste, the number of bioenergy plants across the world are increasing rapidly. However, there are a number of basic choices when it comes to construction materials.

Three materials dominate the world market, concrete, carbon steel and stainless steel, with the steel variants having a variety of coatings and construction techniques to choose from as well. As noted above, most high rate anaerobic digesters in Australia are concrete structures and this remains the primary method of construction today.

4.2.1 Concrete

Depending upon the nature of the feedstock, the anaerobic digestion process can produce gases (such as H_2S) and conditions which give rise to chemical attack on concrete. The substrates and gases involved in the processes can lead to a reduction in the expected lifespan of the tank.

In addition to the high cost of concrete water retaining structures, another consideration is the overall build time which affects the total project cost.

Traditionally, where digesters have been constructed using reinforced concrete they have an expected design life of 40-60 years. However, the development of process technology and revised environmental approaches is generally shorter than this with substantial technological and commercial changes occurring over 20 year timeframes or less. In addition, the meat processing industry is high volume/low margin with substantial commercial risks which may not suit high cost, long life assets.

Concrete does however hold the extra benefit of being a good insulator reducing the necessity for insulation in cool climates. In the temperate climate of Australia this is obviously of more relevance in the southern states.

The main difficulties in the use of concrete for this application are:

- high construction costs, particularly where smaller diameter and deeper tanks are preferred for space reasons or for cheaper roof construction reasons; and
- ensuring that chemical attack does not cause degradation (particularly at water level and above from H_2S).

More reinforcing steel, protective coatings, post tensioned designs and thicker tank wall sections are all used to manage these problems, however in practice all of these issues are very reliant on quality in both design and construction. For example, LCW have recently undertaken a project for a VWC in regional Victoria where the steel roof required replacement. On removal of the roof, it was found that substantial concrete degradation had occurred to the structure and extensive and expensive concrete repairs were necessary. The structure had been in operation for 25 years. It did not have a protective lining. The repair works were expensive ($100,000+) and the effectiveness of rectification works on chemical attack on the concrete structure is difficult to ascertain. Based on LCW experience, the best estimate is that a further 15 to 20 years life may be achieved.

From discussions with a number of other experienced wastewater engineers however, there are many concrete digesters still operating effectively after 30-40 years. For example, a municipal concrete digester constructed in Ayr, North Queensland in the early 1970's was removed from service in the early 2000's for work to be undertaken on the roof system. The digester had been epoxy lined and the lining and the concrete were reportedly still in very good condition.

4.2.2 Steel

One alternative to the concrete tank is to use carbon steel which can be coated with glass linings or epoxy paint to prevent corrosion. The tanks are made from rectangular panels which can either be welded or bolted together, however both of these systems can be prone to leakage and seal deterioration. Any sealant, gasket or fastener used in tank construction needs to be properly evaluated to ensure a long service life.

The positive aspects of steel construction are:

- the structure can be raised, enlarged, reduced, replaced or dismantled at any time;
- the structure can be limited in diameter and increased in height should site space be limited;
- site construction time is lower than for concrete tanks;
- ease of modification of pipework or other connections; and
- potentially lower cost.

The steel tank technologies which can provide a cost effective construction alternative to reinforced concrete include:

- glass-fused-to-steel;
- epoxy coated steel;
- stainless steel; or;

- a combination (hybrid) tank to suit different operational conditions in the liquid and gas phases of the digester.

The actual life achieved by steel tanks is expected to be dependent on the selection of the most suitable material in relation to corrosion resistance which the digester will be exposed to, as well as the quality of the plate manufacture and coating system; and the quality of construction including coating damage protection and plate sealants. From the research undertaken in Europe by LCW, including assessing the operating life of tanks in similar operating regimes, a minimum asset life in this application is expected to be 25 years subject to high levels of design and construction quality. Further, according to LCW, it is generally accepted in Europe that glass fused to steel technology is preferred to epoxy coating systems because of the higher resistance to wear and excellent anti-corrosion performance of the glass. Epoxy coatings tend to be more easily damaged during installation and, while they can have good longevity, some damage will usually occur over extended periods of time. The technology of glass fusing to steel is well proven, providing a robust product with long life and a very high level of corrosion protection. Stainless steel and hybrid tanks are more expensive than glass fused steel and have therefore been excluded from the comparison.

Of course, in cooler climates, such as those encountered in Victoria, bolted steel tanks require insulation which adds to the construction costs. For this study, the cost of the required external tank insulation has been included in the steel tank cost options. For other applications in Northern Australia, consideration could be given to excluding the insulation which could provide additional cost savings.

4.3 Other Construction Aspects

4.3.1 Digester Roofs

A significant cost item on any digester is the roof, and there are many factors which influence the type of roof, chief among them being the gas holding system provided for any plant.

Traditionally, either fixed roof digesters with separate gas holders or floating roof digesters have been provided. In the case of the former, roofs have usually been constructed in either concrete or coated mild steel while floating roofs used as gas holders are invariably fabricated in coated mild steel.

Factors such as pressure, mixing types, access and the kind of waste being digested have a major influence on roof selection as this top part of the tank has the most aggressive operating environment containing the biogas, which can have a very corrosive composition.

In recent times, it has become more common for "Biodome" type roofs to be provided on digesters because of their low capital cost, speed of installation and ability to handle corrosive atmospheres. Such domes are generally manufactured in a PVC coated polyester fabric and comprise an inner dome which holds the gas and an outer dome with pressurised air introduced between the inner and outer domes to set the operating pressure. For this study, we have assumed the use of a Biodome roof (*CST)*.

Based on advice from experienced wastewater engineers, most roofing systems have an actual life of 25 years subject to the original construction and coating systems being of high quality.

4.3.2 Bunding/Overflows

It may be a requirement of the environmental regulator for bunding or other form of overflow protection to be provided. It is important overflows be dealt with appropriately to avoid uncontrolled discharge to the environment. In most municipal applications, overflows are taken to a low level pumping station or lagoon. In this particular situation we have assumed that a small overflow lagoon with short term capacity will be incorporated. This would be monitored for level in order to sense if an overflow is occurring.

4.3.3 Foundation Design

The concrete base design assumes design to AS3735 requirements *("Concrete structures retaining liquids"*). If a bolted steel tank is used, the tank designer will stipulate the ring beam design to suit their design.

For comparison purposes we have assumed potential designs and costs based on the most likely conditions expected at the site.

4.3.4 Design and Construction Warranties

For comparison purposes, we have assumed similar defect liability provisions for both options. In practice, it may be possible to negotiate additional warranty provisions from manufacturers/constructors at additional cost or via longer term more complex Project Deeds for either materials option. However, this is not considered to affect the comparison at this stage.

4.4 Risks

Materials/construction risks have been covered in the Materials discussion above, and these cost impacts are covered in the costing analysis in terms of differing asset life and longer term maintenance requirements.

Further assessment of operational and commercial risks in order to provide a qualitative comparison is included as Appendix B. This includes potential causes of operational failure of the anaerobic digestion process, regulatory risk in relation to construction approvals, risk reduction associated with removing the need for major rendering on or off site, gas management, VWC cost interface risk, etc. Some major risk items are further discussed below and provide background detail in relation to the main areas of difference between the assessed Options.

4.4.1 Regulatory Approvals for disposal of DAF sludge/wastes

The Processor's present dissolved air flotation ("DAF") unit is overloaded and poorly designed and only removes small amounts of fats, oils and greases ("FOG"). No chemicals are used in the DAF. The waste removed is included with other solid wastes and transferred to a third party for rendering. This is an acceptable risk at this time as the third party is prepared to accept the waste as part of the rendering materials. However, the renderer has indicated that larger quantities and additional chemicals may make the waste unacceptable for their process. Experience from other meat processing sites where efficient DAF units are in operation indicates that in Victoria there is an increasing issue with disposal of DAF wastes. The Victorian EPA for example has an overarching "wastes hierarchy".

That principle states:

"Wastes, including contaminated soils, should be managed in accordance with the following order of preference:

1. *avoidance*
2. *reuse*
3. *recycling*
4. *recovery of energy*
5. *treatment*
6. *containment*
7. *disposal.*

The classification was published in the Victorian *Government Gazette No. S195* 2011." (*EPA Victoria).*

Some sites presently dispose of DAF waste/sludge to landfill. This is the lowest order of priority for the Victorian EPA and is also subject to rapidly increasing fees from landfill owners. Difficulties also exist in relation to reuse (eg: odour and impacts on land where beneficial reuse is attempted involving undigested DAF waste which can be extremely odourous and which contains concentrated FOG's). There is therefore a higher level of regulatory/disposal risk with DAF wastes than with digested sludge from anaerobic digestion.

There is continuing development in this area including pasteurisation and closed vessel composting, both of which can produce products which can be beneficially reused (*HotRo*t) However these processes involve further capital expenditure and operational/and or third party servicing risk. Therefore unless an existing efficient DAF is in place, the lower risk option in relation to management of resultant solids is to incorporate a high rate anaerobic digester to undertake the complete digestion cycle.

4.4.2 Rendering

The Processor does not undertake rendering on site. This has not been undertaken due to the relatively large capital expenditure required. However off site rendering provides a commercial risk as there are limited rendering services available and any difficulties in accessing rendering services would have significant impacts on the business. The lowest risk options in relation to this aspect are those involving the processing of all wastes through anaerobic digestion without pre-treatment via DAF. Under these options, only unprocessed meat wastes go to external rendering with a high acceptance level and value for renderers. However, the adverse impacts of FOG's on the operation of the high rate anaerobic digester need to be considered.

4.4.3 Anaerobic Process

Anaerobic digestion is a biological process that requires the appropriate environment to be maintained within the digester. If the appropriate environment is not maintained, then the digestion process will be adversely affected. These risks are well known and understood and are addressed through good design, operation and maintenance of the works. However, in a meat processing plant where complex treatment processes may not have been previously installed and operated, the operational risks need to be considered in making an investment decision.

Some examples of these operational risks include:

- A failure of the biological process due to the adverse impact of accidental chemicals (eg: a large quantity of chlorine or cleaning agent used in the processing facility). Although this risk is considered to be extremely low, in any final design the use of two digesters (which is the approach suggested for this Processor) could involve the treatment of separate waste streams in order for potential emergency backup being provided by one digester for a short term whilst the biological failure is overcome in the other unit. It may also be prudent to negotiate an emergency arrangement with any downstream service provider if that is possible, or consider the use of buffering storage upstream of the digester;
- Digester over loading – large “dumps’ from the processing facility;
- Digester under loading – eg: after a Christmas shutdown;
- Mechanical failure of heating or mixing systems;
- High levels of FOG’s (in excess of design and mixing capabilities);
- Prolonged power outage;
- Under-performance of the settling process; and,
- Operator error. (eg: One municipal digester failure was reportedly caused by an operator leaving a tap running – the digester received a large volume of cold water and so stopped working).

Another of the key operational risk issues in high rate anaerobic digester operation is the propensity for FOG’s to solidify and gradually find their way to the top of the digester, aggregating to form a crust on the surface of the digester. Not only does this provide operational problems, but it deprives the process of a source of carbon. This is particularly related to the mixing system provided for the digester and its ability to break up material which accumulates on the surface. This is a similar problem to “foaming” in municipal digesters which is generally addressed by including a “spill and fill” system consisting of a weir at surface level where surface material is wasted. This option would need to be assessed for suitability in relation to the Biodome installation (*CST)*.

There are a number of mixing systems available commercially, which can broadly be classified into two categories:

- Mechanical mixing systems which provide mixing energy by mechanical means, either by withdrawing sludge from the reactor and returning it via jet mixing nozzles or by a vertical shaft and propeller mechanical mixer mounted on the tank roof, and,

- Gas mixing systems which use biogas drawn from the gas space at the top of the digester and inject it into the digester via a number of nozzles.

The advantage of vertical shaft and propeller mechanical mixing systems is that they are simple and the mixing technology is well understood. The disadvantages are that they are prone to out of balance issues and damage which can occur if solids (such as rags, string, plastics and the like) accumulate on the propeller blade, and they can be difficult to access for maintenance.

LCW advise that sludge recirculation mixing systems have become more popular in recent years because they withdraw sludge from the tank and return it through jet mixing nozzles so there are no moving parts within the tank. Further, the sludge mixing pumps have a macerating capacity so the chances of blockages are minimised.

Gas mixing systems have the advantage of not having moving parts within the digester, but they do need gas injection pipework which can be problematic with solids accumulation. The principal disadvantage of gas mixing systems lies with the long term issue around handling the biogas which is quite dirty and can be corrosive. The compressors needed for the mixing system must be able to handle the gas and significant gas conditioning equipment is generally required. They are also maintenance intensive,

In recent years, Landia have developed a gas/liquid mixing system which incorporates the benefits of liquid mixing, with external pumps and internal jet mixers, with a gas mixing system which uses a venturi system using pumped sludge for motive power and draws gas from the gas holding area and injects it into the digester. The combination of gas and liquid mixing and the ability to vary the periods of liquid only and gas/liquid mixing provides an excellent means of ensuring FOG does not solidify and aggregate on the surface of the digester but is mixed thoroughly with the biomass.

The preliminary designs for the anaerobic digester under this study allow for Landia type gas mixing systems as these are presently considered to provide the best mitigation of FOG risks (*Landia).*

Another, similar system which has been used and is installed locally is a pump mix system using Vaughan chopper pumps (*Vaughan).*

4.4.4 Biogas Safety

One of the key engineering aspects of the anaerobic digester design relates to the safety issues around biogas handling.

Biogas systems have been in operation for many years in the broader wastewater treatment sector and, in particular the municipal sewage treatment sector where anaerobic digestion has long been the process of choice for volume reduction and stabilisation of primary sludge and waste activated sludge.

The safety issues around biogas are controlled under a strong regulatory framework which covers matters such as:

- Hazardous area assessment in order to ascertain the safety parameters and controls within specific areas of a biogas facility.
- Electrical design requirements which arise from the hazardous area assessment
- Gas Safety requirements which arise from the hazardous area assessment and the specific regulatory requirements

Each state jurisdication in Australia has slightly varying requirements insofar as the implementation of the necessary controls are concerned, but each requires signoff by independent parties in respect of the standard of the electrical system installation and gas handling and combustion equipment.

The Australian Meat Processor Corporation ("AMPC") have recently published a guidelines paper which summarises applicable regulatory requirements for industry reference. (*AMPC).*

4.5 Gas Production

For comparison, assumptions have been made in relation to estimated gas production from the high rate anaerobic digestion process. However, due to the gas heating requirements of the anaerobic digestion process, the quantity of gas produced which can be used beneficially will vary considerably due to factors specific to a processor. These include:

- Ambient temperature
- Temperature of incoming process water
- Process impacts on temperature of the effluent entering the anaerobic digester.

These variables do not substantially impact the relative NPV comparisons in this study (Reducing estimated gas benefits at 50% of the assumed figures reduces NPV's of all options by a similar amount and extends payback periods by approximately 6 months). However, from a commercial risk perspective they would need to be assessed at both the detailed design stage, and also in relation to later process changes on a particular site. For example, gas production for beneficial use elsewhere on a site may be very low during colder winter months. To more accurately estimate gas available for beneficial reuse elsewhere on the site, temperature monitoring of process water and effluent temperature at the delivery point to the planned digester would be required over a 12 month period as a minimum, with historical water supply and ambient temperature records used for further sensitivity analysis.

On an ongoing operational basis, any changes in process which reduce the temperature of the effluent to the digester would also need to be considered in relation to their impact on gas production.

4.6 Cost Comparisons between Identified Options

Capital cost and operating and maintenance cost estimates have been prepared for each of the six process options, incorporating both concrete and glass fused steel construction for the high rate anaerobic digester (effectively 12 options).

4.6.1 Design Parameters

As noted in the Section 4.1, the Processor is a very low user of potable water in comparison to other processors and consequently has a similarly low wastewater discharge quantity. The Processor also has extensive historical data on a daily basis. The design hydraulic retention time is 14 days and there is low variance in COD over this period. (COD loads on a daily basis have been between 2,000mg/L and 17,000mg/L. However the average loading over any 14 day period is generally between 4,000mg/L and 6,000mg/L). The study has been carried out based on projected future loads with a design margin of 15%-20% above the long term average, in line with the Processors intended expansion aims.

The present site processing facilities include only minimal pre-treatment of waste prior to discharge to the VWC sewer system. The site facilities consist of a contra-shear, followed by DAF treatment.

Photo 1: Existing Contra-shear in foreground with DAF at rear.

The contra-shear is a rotating drum with a perforated screen which removes some of the heavier solids by allowing the liquid fraction to fall through the apertures. The DAF partly clarifies the wastewater by removing suspended matter (oil or solids). The removal is achieved by dissolving air in the wastewater under pressure and then releasing the air at atmospheric pressure in a flotation tank. The released air forms bubbles which adhere to the suspended matter causing the suspended matter to float to the surface of the water where it is removed by a skimming device.

In order to undertake the analysis for the various wastewater treatment options, the project team developed an initial projected base position for volume and load parameters of the wastewater. This was a conservative projection and is in excess of the detailed projections which have been further developed during the study. Using the conservative figures does not cause any issues as all of the options are being compared on the same basis. As noted in Section 1, the final commercial overall wastewater commercial solution also remains to be resolved and design parameters will be further refined in the future should a formal decision be made by the Processor to design and construct an anaerobic digester.

The initial base volume and flow data used for the analysis is detailed in Table 8:

Table 8: Base Data assumptions

Wastewater (kl/day)	COD (mg/l)	SS (mg/l)	P (mg/l)	N (mg/l)	Salinity (Ec)
650	7000	2500	100	700	2000

The figures assume that little benefit is presently being achieved by the existing DAF unit which is very inefficient (5% reduction in load parameters at best). For the various options considered in this report where a DAF is included within the process this incorporates the construction of a new efficient DAF.

For the estimated flows and loads, tanks for the high rate anaerobic digester with a volume of approximately 9 ML are initially estimated to be required (two digesters of 4.5 ML each) with solids capture and recycle. Based on the design flow assumption (650 kl/day), the digesters provide a retention time of 14 days. The solids capture and recycle will enable a solids retention time greater than 14 days to be provided. Again, this is suitable for comparison purposes at this stage, but should the use of a high rate anaerobic digester proceed, more detailed analysis of sizing and feedstock streams is needed at the detailed design stage.
Tank sizes, retention times, sludge removal design etc.have been established based on the above initial assumptions. Full details of these design parameters are detailed in Tables 1-6 below:

Table 1: Option 1 - Screening and Anaerobic Treatment

Parameter	Units	Value
Screen capacity	m3/hr	32.5
Screen aperture	mm	1-2
Anaerobic reactor volume	m3	9000
Anaerobic reactor hydraulic residence time	days	14
Anaerobic reactor sludge residence time	days	50 – 60
Sludge yield	kg/kgCOD	0.35

Table 2: Option 2 - Screening, DAF and Anaerobic Treatment

Parameter	Units	Value
Screen capacity	m3/hr	32.5
Screen aperture	mm	1-2
DAF Solids Loading Rate	kg/m2/hr	4.0
DAF Hydraulic Loading Rate	m3/m2/hr	3.0
DAF Recycle Rate	%	50
DAF area	m2	16
Anaerobic reactor volume	m3	6000
Anaerobic reactor hydraulic residence time	days	14
Anaerobic reactor sludge residence time	days	50 - 60
Sludge yield	kg/kgCOD	0.35
Biogas yield (70% methane)	m3/kgCOD	0.45

Table 3: Option 3 - Screening, Anaerobic Treatment and Trickling Filter

Parameter	Units	Value
Screen capacity	m3/hr	32.5
Screen aperture	mm	1-2
Anaerobic reactor volume	m3	9000
Anaerobic reactor hydraulic residence time	days	14
Anaerobic reactor sludge residence time	days	50 - 60
Sludge yield	kg/kgCOD	0.35
Biogas yield (70% methane)	m3/kgCOD	0.45
Trickling filter media specific surface area	m2/m3	98
Trickling filter wetting rate	m3/m2/hr	40
Trickling filter COD loading rate	g/m2/d	2.1
Trickling filter NH3 loading rate	g/m2/d	1.5
Trickling filter volume	m3	1500

Table 4: Option 4 - Screening, DAF, Anaerobic Treatment and Trickling Filter

Parameter	Units	Value
Screen capacity	m3/hr	32.5
Screen aperture	mm	1-2
DAF Solids Loading Rate	kg/m2/hr	4.0
DAF Hydraulic Loading Rate	m3/m2/hr	3.0
DAF Recycle Rate	%	50
DAF area	m2	16
Anaerobic reactor volume	m3	6000
Anaerobic reactor hydraulic residence time	days	14
Anaerobic reactor sludge residence time	days	50 - 60
Sludge yield	kg/kgCOD	0.35
Biogas yield (70% methane)	m3/kgCOD	0.45
Trickling filter media specific surface area	m2/m3	98
Trickling filter wetting rate	m3/m2/hr	40
Trickling filter COD loading rate	g/m2/d	2.1
Trickling filter NH3 loading rate	g/m2/d	1.5
Trickling filter volume	m3	1500

Table 5: Option 5 - Screening, Anaerobic Treatment and Activated Sludge Treatment

Parameter	Units	Value
Screen capacity	m3/hr	32.5
Screen aperture	mm	1-2
Anaerobic reactor volume	m3	9000
Anaerobic reactor hydraulic residence time	days	14
Anaerobic reactor sludge residence time	days	50 - 60
Sludge yield	kg/kgCOD	0.35
Biogas yield (70% methane)	m3/kgCOD	0.45
Activated sludge hydraulic retention time	days	4.5
Anoxic zone volume	m3	1500
Aerobic zone volume	m3	1500

Table 6: Option 6 - Screening, DAF, Anaerobic Treatment and Activated Sludge Treatment

Parameter	Units	Value
Screen capacity	m3/hr	32.5
Screen aperture	mm	1-2
DAF Solids Loading Rate	kg/m2/hr	4.0
DAF Hydraulic Loading Rate	m3/m2/hr	3.0
DAF Recycle Rate	%	50
DAF area	m2	16
Anaerobic reactor volume	m3	9000
Anaerobic reactor hydraulic residence time	days	14
Anaerobic reactor sludge residence time	days	50 – 60
Sludge yield	kg/kgCOD	0.35
Biogas yield (70% methane)	m3/kgCOD	0.45
Activated sludge hydraulic retention time	days	4.5
Anoxic zone volume	m3	1500
Aerobic zone volume	m3	1500

4.6.2 Cost Estimates

The capital cost figures are based on information from design and construction projects undertaken by LCW to date for both Government and private sector entities across a broad range of process requirements. The costs are considered to provide a P80 estimate at this stage which is considered a high level of accuracy for a project at concept design stage (ie: 80% probability that the final cost will be below the estimated figure). This accuracy level is due to the process design detail completed by LCW and their established construction costing data base and experience. These capital costs are provided in Tables 7-13 below. It should be noted that the costs do not include indirect costs such as planning approvals, and “in house” costs but they do include design, commissioning etc. The NPV rankings are not affected by the exclusion of the indirect costs.

The capital and operating costs of the production of Class A recycle water has not been included in this comparison although the potential use of high quality recycled water in place of potable in the cooling towers is an additional potential the Processor is considering, and is detailed on the process flow diagrams (Appendix A). The inclusion/exclusion of the Class A recycle process does not affect the comparison between concrete and steel anaerobic digester construction options.

The NPV comparisons of whole of life costs have been prepared based on the projected design life of 25 years for glass fused steel, and 40 years for reinforced concrete. The reinforced concrete option includes an allowance for concrete repairs to be undertaken in 25 years based on the experience noted above. An unlined concrete tank system is considered the most appropriate approach for comparison purposes in this situation due to the high initial cost associated with lining systems and the shorter return on investment/design life requirements for meat processors as compared to municipal wastewater infrastructure. The NPV’s for the concrete option are therefore potentially conservative for comparison purposes due to a 40 year life probably being unnecessary in a meat processing plant. Operation and maintenance cost estimates are detailed in Table 7.

Table 7: Operation and Maintenance Cost Estimates ($/annum)

Item	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Chemicals*	$2,975	$2,975	$2,975	$2,975	$2,975	$2,975
Power	$55,988	$60,227	$60,067	$64,817	$114,675	$104,849
Labour/Parts	$76,200	$76,200	$76,200	$76,200	$91,500	$91,500
Sludge removal †	$26,000	$26,000	$26,000	$26,000	$26,000	$26,000
Total	**$161,163**	**$165,402**	**$165,242**	**$169,992**	**$235,150**	**$225,324**

Notes: * No chemical usage in DAF to ensure minimal limitations on disposal

† Sludge removal covers transport costs only, assumed end user benefits at nil cost

As noted above, the Options analysed are:

- Option 1: Pre-screening (coarse) and maceration, high rate anaerobic digestion and clarification, with sludge treatment via either belt press dewatering or centrifugation;

- Option 2: As for Option 1 but with additional pre-treatment by fine screening and DAF treatment prior to high rate anaerobic digestion providing for a smaller anaerobic digestion system;
- Option 3: As for Option 1 but with addition of trickling filter treatment and clarification of wastewater downstream of the high rate anaerobic digester;
- Option 4: As for Option 2 but with addition of trickling filter treatment and clarification of wastewater downstream of the high rate anaerobic digester;
- Option 5: As for Option 1 but with addition of activated sludge treatment and clarification downstream of the high rate anaerobic reactor; and,
- Option 6: As for Option 2 but with addition of activated sludge treatment and clarification downstream of the high rate anaerobic reactor.

The cost comparisons reflect the relative differences between process trains and the use of steel or concrete for construction of the anaerobic digester. At this stage, the glass fused steel options provide a substantial cost advantage on a whole of life basis as well as the lowest capital costs.

The relative impacts of costs for further treatment and disposal/reuse of the final discharged effluent by the VWC for this particular Processor have been included later in the report. These costs differ in relation to the volume and biological load discharged to the VWC service provider, and therefore indicate a potential preferred position specific to this Processor. Similar adjustments have been made in relation to the removal of the present substantial quantities of waste to offsite rendering. All NPV's include for the beneficial reuse of digested sludge off site to farm land.

The comparison capital and NPV costs (excluding downstream treatment costs by the VWC, but including biogas values) are detailed in Table 8 below.

Table 8: Capital costs and NPV's (excluding downstream VWC costs)

Option	Capital Cost (Steel)	Capital Cost (Concrete)	NPV (Steel)	NPV (Concrete)
1	$4,573,830	$5,292,055	-$4,877,670	-$5,369,362
2	$4,521,850	$5,042,005	-$5,585,689	-$5,788,247
3	$5,213,870	$5,932,095	-$5,558,155	-$5,884,700
4	$5,791,037	$6,311,192	-$6,882,127	-$6,995,716
5	$5,790,120	$6,508,345	-$7,173,282	-$7,463,564
6	$5,919,387	$6,439,542	-$7,843,648	-$8,029,527

The NPV costs have been calculated using a MLA advised standard Weighted Average Cost of Capital ("WACC") of 7%. The WACC for different Processors may vary substantially from 7%, however the relative position between the various options are not impacted by substantial changes in the WACC in any case. The steel options are therefore substantially preferable to the concrete options with lower capital costs and better NPV's.

4.7 Biogas Generation and Reuse

One of the side benefits of anaerobic digestion is the production of biogas which contains approximately 65% methane (*Barber)* and which can be used for energy, either through power generation or for hot water heating.

Depending on the treatment system adopted and the energy requirements associated with the high rate anaerobic digestion process (which operates at approximately 35°C), it is estimated between 5.3 and 8.2 GJ/annum of energy would be available for use elsewhere in this Processors facilities. A more detailed analysis of site ambient and waste temperatures would be required to more accurately assess digester heating requirements at the detailed design stage. The present gas usage (which is mainly used for hot water heating) is 16-20 GJ/annum. Calculations of gas production and estimated value are detailed in Tables 9 and 10.

Table 9: Estimated Gas Production and Value (Options 2, 4 and 6)

Item	Unit	Quantity
Flow	kld	650
COD in	mg/l	4900
COD out	mg/l	1000
COD destruction	mg/l	3900
COD destruction	kg/d	2535
COD destruction	kg/annum	646425
Yield CH4 to COD	m3/kg	0.3
Yield CH4 to COD	m3/annum	193928
Estimated energy yield	MJ/year	7097747
% consumed for heating	%	25%
Estimated energy yield for use in plant	MJ/year	5323310
Estimated gas cost	c/MJ	1.6
Estimated gas value	$/annum	$85,173

Table 10: Estimated Gas Production and Value (Options 1, 3, and 5)

Item	Unit	Quantity
Flow	kld	650
COD in	mg/l	7000
COD out	mg/l	1000
COD destruction	mg/l	6000
COD destruction	kg/d	3900
COD destruction	kg/annum	994500
Yield CH4 to COD	m3/kg	0.3
Yield CH4 to COD	m3/annum	298350
Estimated energy yield	MJ/year	10919610
% consumed for heating	%	25%
Estimated energy yield for use in plant	MJ/year	8189708
Estimated gas cost	c/MJ	1.6
Estimated gas value	$/annum	$131,035

Given the Processor currently uses natural gas for heating of hot water to approximately 95^{o}C in three hot water heaters, it would seem sensible and more cost effective from a capital investment point of view to use biogas for water heating rather than power generation, although the decision one way or the other would depend on relative power versus natural gas costs in the future.

Rather than convert existing heaters to allow for dual fuel operation, it would be simplest from a technical viewpoint and reasonably cost effective to provide a separate hot water heater which would operate on biogas. From an operational risk perspective, maintaining the existing natural gas heaters and installing an additional biogas heater which would be used for pre heating provides less operational risk. This arrangement would also provide the ability to manage the biogas volume variation expected due to variations in ambient and potable water temperature over a 12 month climate cycle. In the case of a supply failure of either gas system, a level of production could also be maintained. For the initial NPV analysis, no allowance has been included within the cost comparisons for the provision of a biogas hot water system as the costs are the same for all options. This would require inclusion in any formal consideration of implementation of anaerobic digestion by the Processor.

4.8 Emissions Reduction Fund

The Federal Governments Emmissions Reduction Fund (“ERF”) has yet to provide any indication as to what financial benefits may be obtainable under the auction approach for Australian Carbon Credit Units (“ACCU’s”). Under the previous Carbon Tax legislation, the amount was a pre set figure which in 2013-2014 was $24.15 per tonne of carbon. The carbon tax legislation has been repealed effective 1 July 2014.

Under the ERF, individuals and organisations taking part can earn ACCUs. One ACCU is earned for each tonne of carbon dioxide equivalent (tCO2-e) stored or avoided by a project. ACCUs can be sold to generate income, either to the Government through a carbon abatement contract, or on the secondary market. The price of an ACCU will be set at auctions sales, with the first auction set for April 15th and 16th 2015. The price of an ACCU will vary at each auction and will be established by the lowest 80% of bids offered below a benchmark figure (the benchmark figure is to be set by the Clean Energy regulator and is unknown). From information provided at briefings by the Carbon Market Institute in February 2015, the initial price is totally dependant on an unknown market and could be anywhere between $3 and $40 per tonne. To be eligible for the ERF, projects must also provide a minimum of 2000 tonnes per annum in carbon dioxide equivalents. The methodology for calculation of emission quantities for the establishment of ACCU's is also still being progressively developed by the Department of Environment (*Department of the Environment)*, although previous work may assist (*Hutton et al).*

It is therefore difficult to ascertain the financial benefits available from ACCU's for a project at this time. In addition, each auction may produce differing ACCU prices. The best commercial approach may therefore be that processors establish a bid price which would reduce the payback period on a potential project to an acceptable level. If that price for ACCU's is not achieved at auction, then the processor may elect not to proceed with the investment (*Clean Energy Regulator).*

4.9 Specific Processor Cost Analysis (including downstream costs)

As noted in Section 2, the present wastewater service provider (the VWC) has recently imposed increases in the order of 100% in charges for treating the Processors wastewater. These cost increases are being phased in over a five year period. The phasing-in involves a progressively reducing discount by the VWC for both volume and biological load. The full cost analysis undertaken in this section includes the phasing-in discounts from the VWC service provider as well as consideration of differences in operational and commercial risks.

This cost analysis is therefore only of direct relevance to this particular Processor, however the principles can be used for options analysis at other specific sites in relation to external (downstream) costs and risks, whether they be by third party service providers, or where further disposal costs are undertaken by a particular processor in relation to further treatment, or winter storage and irrigation disposal.

Each of the Options 1 to 6 under consideration involve the production of effluent streams with differing biological compositions which impact the "whole of treatment" costs. The resultant differing expected biological loads in the discharged effluent are detailed on the process flow diagrams (Appendix A). The resultant NPV's show the NPV position which is the overall value to the Processor using a 7% WACC and are positive as they include the benefits from cost savings obtained by reducing biological loads to (and therefore charges from) the VWC. The charging regime from the VWC includes various charges for:

- Volume;
- Availability (volume related);
- COD;
- Suspended Solids;
- Phosphorous; and
- Nitrogen.

Table 11: Capital costs and NPV's (including downstream VWC costs)

Option	Capital Cost (Steel)	NPV (Steel)	Payback Period (Years)
1	$4,573,830	$8,791,125	5
2	$4,521,850	$8,507,080	5
3	$5,213,870	$10,362,529	4+
4	$5,791,037	$8,534,772	5
5	$5,790,120	$9,542,180	5
6	$5,919,387	$8,871,815	5+

This analysis (as detailed in Table 11 above) shows that for the projected volumes and biological loads of the discharged effluent and the present charges which the VWC are implementing, the preferred (non-risk adjusted) Option is Option 3. This Option involves an increased capital spend but has an earliest payback period of just over 4 years. Further analysis of commercial and operational risks is required in order to provide a commercial comparison.

These risks have been broadly assessed for each Option (Appendix B). Options 1 and 3 are assessed as the lowest risk Options. Option 1 involves coarse screening, maceration, AD, and sludge processing. Option 3 is identical but with the addition of a post AD trickling filter and clarifier. A potential commercial solution for the Processor therefore involves staging by commencing with the initial Option 1 process, and with the future addition of the post AD trickling filter and clarifier once the Option 1 process has been proven and output performance known.

An initial feasibility was completed into actions and options to address the broader issues, and negotiations with the VWC are continuing in relation to achieving a commercially acceptable overall solution for wastewater treatment. An alternative option to the Processor undertaking the construction of an anaerobic digester with final waste servicing by the VWC, is for the Processor to undertake the following:

- Option 7: Treatment and disposal of all waste by Processors own infrastructure (lagoon treatment system, wet weather storage on a farm site, pasture irrigation on farm);
- Option 8: Construction of a new DAF at the Processors site and discharge final effluent to VWC without further treatment; and,
- Option 9: Construction of anaerobic digester on Processors site and discharge to Processors own infrastructure (wet weather storage on farm, pasture irrigation on farm).

As detailed in Table 12 below, the broader Options for this particular Processor show that a shorter term Option which may be considered is Option 8 (construction of a new DAF and continued discharge of remaining effluent to the VWC). This has a low capital cost with a payback period of 2 years. However the NPV is significantly less than the two preferred anaerobic digestion Options 1 and 3. In addition, the risk issue of disposal of the DAF waste/sludge needs to be mitigated.

However this provides a potential staging approach for this Processor which would provide benefits in a short time frame.

This could involve:

1. Construction of a new DAF immediately (subject to the establishment of an acceptable process for disposing of DAF wastes);
2. Further negotiations with the VWC over the next 2 years in relation to reducing VWC waste processing charges;
3. If reduction in VWC charges cannot be negotiated by 2018, commence design and planning for the high rate anaerobic digester and assess/access any potential funding assistance, GHG benefits etc;
4. Construct and commission the high rate anaerobic digester, and potentially remove the DAF from service (2019-2020) (Note: A further assessment would be made at this time in relation to risk issues, particularly the impact of FOG's on the digester and the costs of disposal of waste/sludge from the DAF in relation to retaining or

removing the DAF from service. To reduce the risk associated with FOG's adversely impacting on the digester, the digester could be designed to process all waste without an upstream DAF (a capacity increase at marginal cost) and the DAF removed from service to assess the digester performance, but retained for recommissioning until the anaerobic process proves successful.

5. Consider the installation of (post anaerobic digestion) trickling filter and clarifier at a later date following proof of performance of the anaerobic digester.

A further commercial risk remains in relation to any of the Options involving the Processor undertaking further treatment on site. The pricing of the VWC service provider is subject to change after each 5 year Water Plan cycle (as approved by the regulator). The VWC could substantially increase pricing for volume/availability if revenue from biological load drops significantly. Should this occur, the Processor may be forced to provide their own infrastructure totally (lagoon treatment, wet weather storage and farm disposal (Option 7)) and any investment previously undertaken on site treatment may be of no use and would need to be written off. Negotiations are therefore also continuing with the VWC focussed on establishing a longer term pricing agreement (this is possible within the regulatory regime).

Should a long term agreement not be achieved with the VWC, and indications be made that further volume price increases are likely, then Option 7 may need to be considered despite its relatively high initial capital cost and extended payback period.

Option 9, (High rate anaerobic digestion and a Processor provided lagoon final treatment, wet weather storage and farm irrigation disposal) shows that this Option is not attractive (high capital cost and 9 year payback period) due to the only benefits being from gas production from the digester and a smaller lagoon.

Table 12: Capital costs and NPV's for Alternative High Level Options

Option	Capital Cost	NPV	Payback Period (Years)
7	$9,693,000	$9,865,791	7
8	$479,000	$4,400,256	2
9	$13,257,000	$8,196,429	9

The project objectives for this study were:

- Assessment of costs and suitability of the process (a free standing anaerobic reactor) to provide a "least cost" whole of life solution for treatment of meat processing wastes (including offal wastes).
- Assessment of low cost construction methods for an anaerobic digester.
- Assessment of improved environmental outcomes.
- Issues and risks associated with the use of site production of biogas for energy attractive use.

All of these objectives have been achieved.

5 Conclusions/Recommendations

The study has established that the use of steel structures for high rate anaerobic digestion in a meat processing plant is of lesser cost than concrete structures, and is potentially more economically viable. However, investment in high rate anaerobic digestion is very dependent on the external (downstream) costs for final treatment and disposal, both existing and into the future. The steel construction option offers lower capital and whole of life costing than concrete structures.

In addition, greenhouse gas and energy savings are possible through the associated generation of biogas for onsite use.

Assessment of the potential investment in high rate anaerobic digestion for a specific site would be dependent on issues such as:

- Third party (downstream service provider) costs, or downstream processor costs for further treatment and disposal;
- The assessment and mitigation of future downstream cost increase risks;
- The impact of ambient and process temperature on biogas production volumes;
- Availability and cost of land for plant and downstream assets;
- Government subsidies to reduce the payback period to meet standard processor investment parameters (if required);
- Proximity of neighbours and potential for odour nuisance;
- Ability to beneficially use the sludge rather than dispose to landfill;
- Reduced odour and corrosion issues in the downstream service providers system;
- Benefits from any Government energy or greenhouse gas policies (the roll out of direct action programs under the Federal Government Emissions Reduction Fund (“ERF”) are now underway), and;
- Benefits or costs associated with any existing site treatment facilities and rendering plant.

At this point, the value of biogas produced for other site use does not, in itself, provide a sufficient enough cost benefit to warrant the investment. However the cumulative qualitative environmental benefits including:

- Greenhouse gas/carbon price savings;
- reduced operational risks associated with rendering; and,
- Beneficial reuse of digested sludge,

should be considered when assessing such an investment. Future disposal of undigested sludge from DAF units will increasingly become more difficult and costly which may also drive the investment in high rate digesters on some sites.

6 Key Messages

The progress in development of lower cost anaerobic digestion process design and construction, including developments in mixing methods and equipment to address issues with difficulties with FOG's, should continue to be assessed by meat processors. Increasing environmental requirements and disposal costs mean that alternative options need to be reassessed progressively to ascertain the best investment approach.

Disposal of DAF sludge (which is not digested and is odourous) is becoming increasingly difficult due to environmental regulations. The use of anaerobic digestion for processing of a total meat processing waste stream without pre treatment via a DAF will provide digested biosolids which can be beneficially reused. The potential process impacts of FOG's on the anaerobic process may now be overcome with appropriate design and appropriate mixing equipment, however further proof of performance is required.

Undertaking studies into alternative full or part treatment options for waste streams, can also be critical in negotiating reduced third party (downstream) costs where those services are provided by monopoly service providers. This can form the basis of a pseudo competitor position to ensure third party prices are commercially acceptable.

7 References

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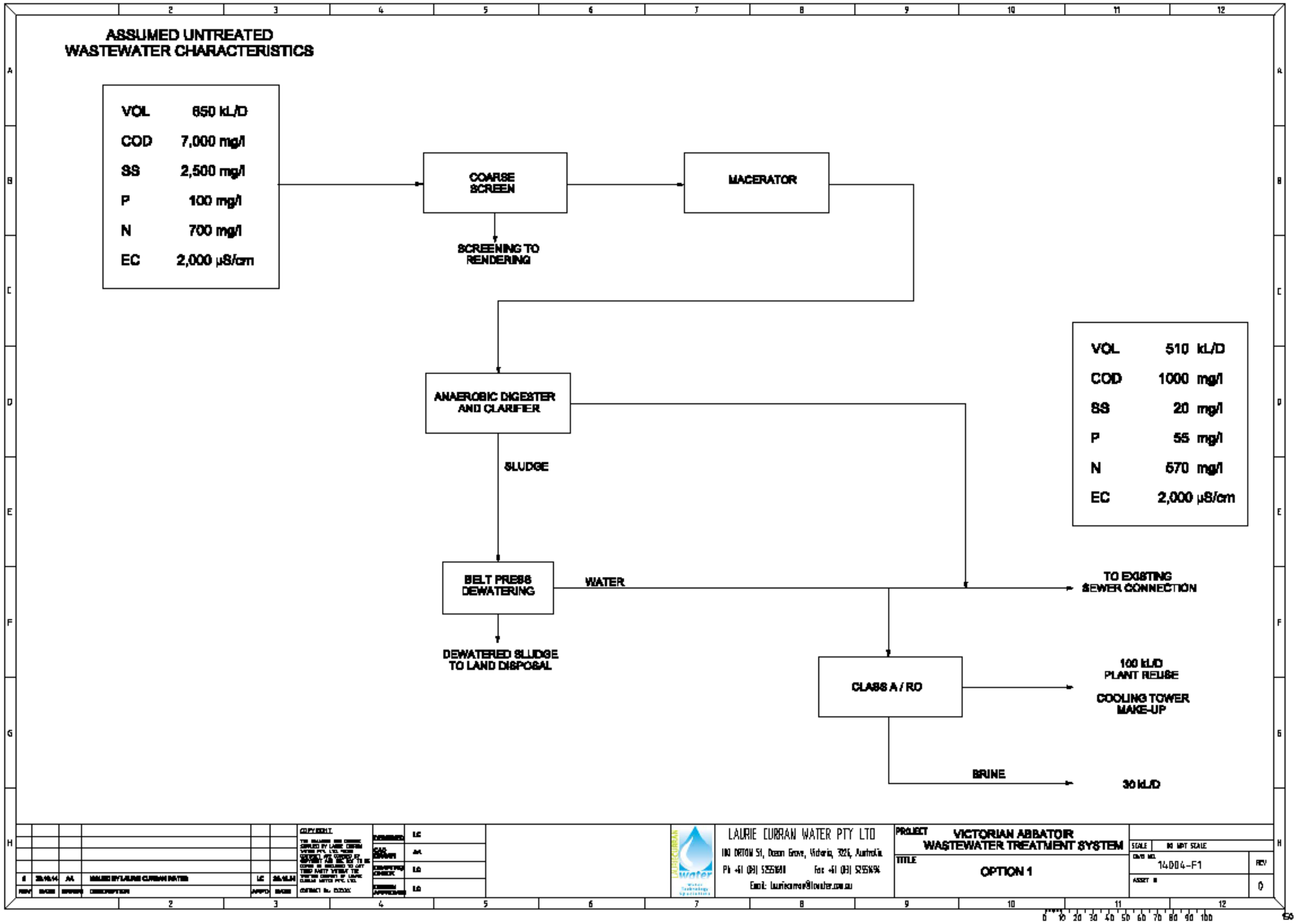
8 Appendicies

Appendix A: Flow Charts



Appendix B: Risk Matrix

Appendix B: Risk Summary

Risks:

Low	Medium	High	Very High

Technical	**Option 1**	**Option 2**	**Option 3**	**Option 4**	**Option 5**	**Option 6**
Poor construction quality control impacts AD life and costs	Simplest process with lowest construction risk	Increased risk due to addition of Fine screen and DAF	Similar to Option 2 due to post AD process.	Further increased due to inclusion of fine screen, DAF and post AD process.	Similar to Options 2 and 3 with post AD processing	Highest risk with combination of pre and post AD processes
Failure of process to achieve design outputs	Similar risk assessment to construction risks above due to process					
Biological failure of AD	Reduced risk of AD failure where DAF is installed and therefore provides a level of buffering	DAF		DAF		DAF
Failure to obtain and achieve regulatory approvals	Same risk in all Options re AD (odour), but this option has lowest risk re sludge removal approvals.	Additional sludge removal from DAF (fats, oils and greases) may be difficult to obtain approvals	Similar risk to Option 1.	Similar risk to Option 2	Similar risk to Option 1	Similar risk to Options 2 and 4
Operational Risk	Reasonably complex plant	Reasonably complex plant	Reasonably complex plant	Reasonably complex plant	Increased complexity	Increased complexity
SUMMARY TECHNICAL RISKS	**Low**	**Medium**	**Medium**	**High**	**Medium**	**Very High**

Commercial	**Option 1**	**Option 2**	**Option 3**	**Option 4**	**Option 5**	**Option 6**
Construction costs increase significantly	Similar relative assessment to construction quality risk in technical assessment, as cost over-run risk increases with process plant complexity and numbers of processes					
Investment risk			Shortest payback period Option			Longest payback period Option
O&M costs significantly higher than estimated	Similar relative assessment to construction costs, as O&M cost over-run risk increases with process plant complexity and numbers of processes (except for Option 5)				Increased risk assessment to construction cost comparison due to activated sludge inclusion	
Gas production less than estimated, gas revenues lower than expected.	Gas costs are not likely to drop due to international demand					
External rendering risks. Processor relies on external service provider who requires appropriate quality materials.	Low risk Option as only coarse screen materials go to render	Coarse and fine screen materials to render, and also DAF sludge. Higher risk with DAF sludge (fats,	Same as Option 1	Same as Option 2	Same as Option 1	Same as Option 2

		oils, greases) and treatment chemicals (if used)				
Digested AD sludge disposal costs/site availability						
SUMMARY COMMERCIAL RISKS	**Low**	**High**	**Medium**	**High**	**High**	**High**
OVERALL SUMMARY RISK RATING ORDER	**1**	**4**	**2**	**5**	**3**	**6**