final report

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Organic Waste Value Adding and Cost Reduction

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Executive Summary

This report summarizes the findings of a cost-benefit analysis (CBA) for a project to generate value from the organic wastes generated at an Australian meat processing facility (the facility).

Note: cap ex estimates are budget guides only and require a detailed design stage and geotechnical analysis stage to achieve higher accuracy (e.g. +/- 10%) pricing.

The results of the decanter analysis are presented in the table below (where it is assumed that operating costs for a decanter and belt press are commensurate).

Decanter Scenario	Simple Payback	Estimated Cap Ex
20% solids cake, current scenario (36.4 m^3/h, 0.63% DS in WAS)	5.4	635,480
22% solids cake, current scenario (36.4 m^3/h, 0.63% DS in WAS)	4.7	635,480
At decanter capacity; expansion to 2018 scenario (40 m^3/h, 1% DS in WAS)	2.4	635,480

The results of the anaerobic digester analysis are presented in the table below. Key assumptions are that the compost handling is cost neutral i.e. dewatering and haulage costs equal the sale value.

Anaerobic digester scenario	Simple Payback	Estimated Cap Ex	Scale
Traditional AD: single CSTR for 10 khpw.	4.4 (at 600 kWe)	6,000,000	1000 kWe capacity, assume output of 600 kWe (future)
Traditional AD: Primary digester / separated liquid tanks for 10 khpw	3.3 (at 600 kWe)	4,436,060	Current:446 kWe Future: 600 kWe
Solid Phase Digestion	2.9	Current: 2,110,363	370 kWe
	2.7	Expansion to 10khpw: Additional 1,373,387	470 (370 + 100) kWe
	4.1	Current paunch to cogen: $960,000	50 kWe

The results of previous works are presented in the table below – there has been no change in the underlying assumptions. Based on available data, a new decanter has clear advantages of modest capital and would enable up to approximately 74% more solids removal at run at optimal capacity, there by taking load off the current belt press which could then be redeployed for DAF dewatering. Anaerobic digestion has strong potential but has a much higher overall capital outlay.

Description	Indicative Cap ex	Opex / Revenue / Savings	Indicative Simple Payback
Pre-treatment of mixed paunch and aerobic sludge followed by pelletizing and coal off-set.	$3.1 mil	$199,071 pa	15.6 yrs
Pre-treatment of paunch only followed by pelletizing and coal off-set.	$1.93 mil	$0.27 mil	9.3 yrs
Drying and milling only without pelletization. There are a number of technical risks including: - the lower density and smaller particle size of the biomass resulting in a lower residence time in the boiler and the potential for less than complete combustion which may increase particulates concentration in flue gas and a higher rate of ash generation. - the biomass powder will be highly hydrophilic and hence will not be able to be stored in the open due to the risk of water adsorption leading bridging / sticking of the biomass. - the ability to mechanically blend the biomass power and feed into the boiler will need to be confirmed. Modern boiler control technology will be able to manage variations in the feed stock calorific value.	$2.6 mil	$ 303,310 pa cost savings	8.7 yrs

Table of Contents

1 Introduction

1.1 Background

Meat processors are experiencing rising organic waste disposal costs as well as currently undertaking a review of energy expenditure at the Canon Hill facility. Paunch and sludge is sent for off-site landfill disposal with coal being purchased to fuel the on-site boilers: both are contributing to rising operating costs for the facility and have significant greenhouse gas emissions.

1.2 Scope of Works

The overall objective is to determine the most economically viable organic waste management strategy for the facility by evaluating some specific waste processing options. Specific objectives of the project will include estimating opportunities for:

i) Desk top review of the viability of the value adding options under consideration.
ii) Determine the Methane generation potential of feed stocks which will provide information for a more accurate feasibility study (size of fermenters and rate of biogas production).
iii) Facilitate decanter trials to determine the viability of reducing moisture content as a cost effective waste management strategy.
iv) Complete an analysis of the opportunities for value adding / reducing waste management costs for organic wastes, with a specific emphasis on digestion of aerobic sludge and paunch
v) Cost benefit analysis on the individual elements and the strategy for the aggregated plant.

1.3 Material Properties

Table 2.2: Key properties of current or potential boiler fuel and fuel feedstocks

Parameter	Aerobic Sludge	Paunch	Combined stream	Combined stream pellets	Biomass pellets	Bituminous Coal	Boiler fuel spec – coal
Moisture (% as delivered)	87.5%	50%	77.5%	~10%	~10%	3.3 - 11.7 weight% must be <12%	10%
HHV (GJ/t)	11.73 (11.16 – 23.24)	15.61	13.3 - 14	14.0	19	Assume 27.0 (23 – 32.54)	24.82
LHV (GJ/t) as delivered	~2 dw: 9.9–18.92	~10 dw:14.43	~5.4 dw: 12	10.3	17.9	25.9	23.54
Density (kg/m^3)	721	270	453		Bulk: 650 Pellet: 1100	Bulk: 673 - 913 Particle: 1346	
Dimensions (mm)				12 x 6	12 x 6	25 top size	
Moisture uptake	High	High	High	Low	Low	Very low	Medium
Volatiles (dwaf)						39%	49.9%
Fixed carbon (dwaf)	~27%	~38%	~31%	~31%		61%	50.1%
Energy density					12.4 GJ/m^3		
% fines					0 (steam exploded) to 13 (white pellets)		
C,H,N,S (% dw)	31,5,3,1	41,6,3,0.3	35,6,3,1			70 - 90,3,2,<1	
Ash (dw)	22%	9%	14.3%	14.3%	~15%	<7%	17%

1 "Use of paunch waste as a boiler fuel", AMPC / MLA report, 2011. http://www.ampc.com.au/site/assets/media/Climate-Change/On-site-Energy-Generation-Research/Use-of-paunch-waste-as-a-boiler-fuel.pdf

2 Okazawa, K., Henmi, M., Sota, K., "Energy Saving in Sewerage Sludge Incineration with Indirect Heat Dryer", Mitsubishi Heavy Industries Ltd, Japan, 1984

3 "Use of paunch waste as a boiler fuel", AMPC / MLA report, 2011. http://www.ampc.com.au/site/assets/media/Climate-Change/On-site-Energy-Generation-Research/Use-of-paunch-waste-as-a-boiler-fuel.pdf

2 Basis of Design and Assumptions

2.1 Basis of Design

The basis of design is for a 10,000 head per week facility. The scaling up of organic waste generation and plant utility requirements is outlined in detail in the appendix.

2.2 Assumptions

The key CBA assumptions that were made are as follows:

- Scenarios are for Earnings Before Income Tax, Depreciation and Amortization (EBITDA).
- 7% discount rate.
- 10 year plant life.
- Coal value of $AUS 80.79 /t (indexmundi.com.au, accessed 23 Jan 2015).
- Landfilling costs of $☐/t.
- All start-up costs are expended at the start of the first year of full scale operation.
- Paunch generated at 50% moisture, sludge generated at 12.5% moisture.
- Exchange rates: 1.00 EUR = 1.50418 AUD[4]

The basis for these assumptions and details of additional assumptions are outlined throughout the report.

[4] xe.com, accessed 19 Dec 2014.

2.3 Future Waste Water Treatment Plant Flows

Presented in Figure 3.1 below is a diagrammatic representation of the waste water treatment plant after the installation of the DAF and clarifier. This was generated to assist vendors with the WWTP monitoring and control project.

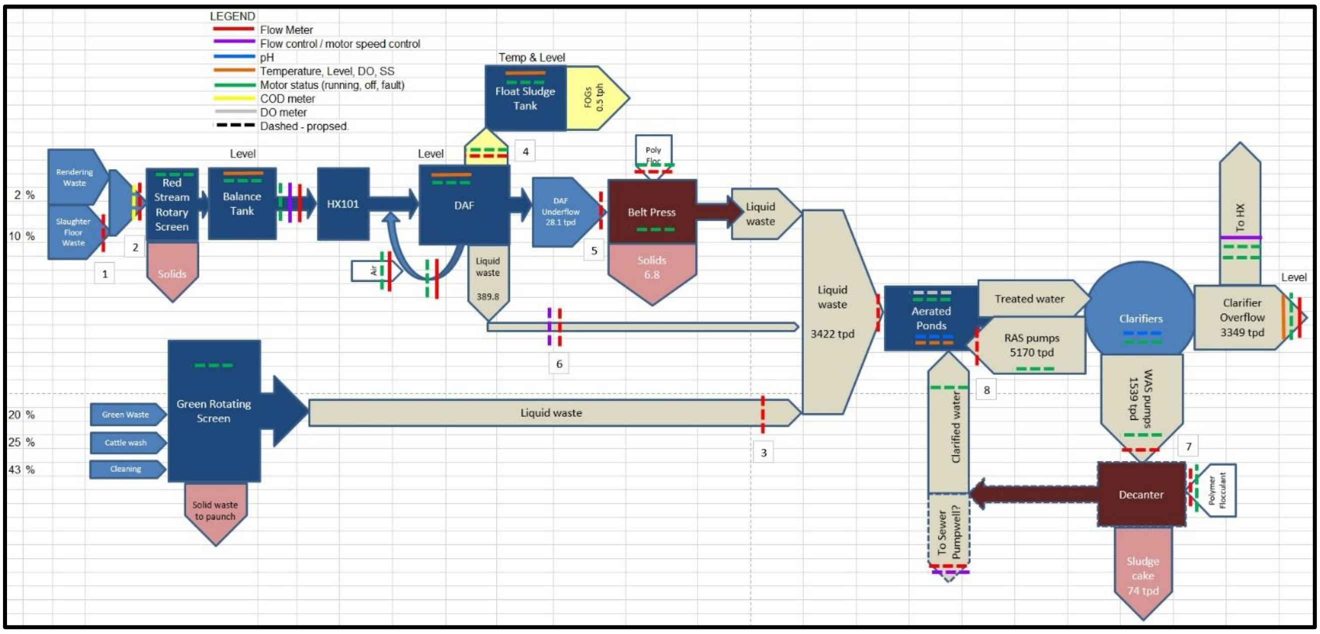


Figure 3.1: Diagrammatic representation of waste water treatment plant (WWTP) flows and associated solids percentages.

Table 3.1: Mass balance for existing system on a production day for water and solids associated with the WWTP (July 2015).

STREAM	total kLpd	Solids %	Solids tpd		Information	
Influent to ponds	1942	1.01%	19.61		Waste from plant	
Effluent from ponds	5708	0.44%	25.37		From ponds to clarifier	
Clarifier overflow	1901	0.07%	1.3		Exits WWTP loop	
Clarifier underflow	3807	0.63%	24.10	95%	% solids to underflow	Normally <98%
Recycle (RAS)	2934	0.63%	18.85	33	% to return activated sludge (RAS)	
To belt press	873	0.63%	5.53		15hrs of flow per production day	
Sludge (WAS)	42	12.50%	5.25	95	% solids capture via belt press	Normally 85-95%
Press filtrate	831	0.03%	0.28		Joins influent flow to Pond 1	

Table 3.2: Future estimated mass balance on a production day for a 10,000 head pa for water and solids associated with the WWTP

STREAM	total kLpd	Solids %	Solids tpd		Information	
Influent to ponds	3422	1.01%	34.56		Waste from plant	
Effluent from ponds	10058	0.44%	44.70		From ponds to clarifier	
Clarifier overflow	3349	0.07%	2.23		Exits WWTP loop	
Clarifier underflow	6708	0.63%	42.46	95%	% solids to underflow	Normally <98%
Recycle (RAS)	5170	0.63%	33.21	33	% to return activated sludge (RAS)	
To belt press	1538	0.63%	9.74		15hrs of flow per production day	
Sludge (WAS)	74	12.50%	9.25	95	% solids capture via belt press	Normally 85-95%
Press filtrate	1464	0.03%	0.49		Joins influent flow to Pond 1	

Table 3.2 extrapolates data from July 2015 and current HPW data to the 10,000 hpw scenario.

Restricting decanter use to 16 days per hour, 5 days per week results in the equipment being utilized 47.6% of its available time. By changing to 24/7 operation, the capital cost of the decanter is approximately halved. The calculations below are used to size an appropriate decanter, based on WAS feed rate assuming 0.63% solids:

Current 16/5: 54.56 kL / h (for 5 days per week, 16 hrs per day; 873 kL/day).

Current at 24/5: 36.38 kL/h (873 kL/day).

Current at 24/7: 25.98 kL/h.

Future 16/5: 87 - 96 kL / h (for 5 days per week, 16 hrs per day; 1392 – 1538 kL/day).

Future at 24/7: 41 - 46 kL/h.

Future at 24/5: 58 - 64 kL/h.

To cross reference this data on a per week calculation for data available 1 Jan 2015 to 23 June 2015:

Production rate for weeks 1 to 25 was 5459 head per week. Effluent flows equalled 1737 kL/day, averaged over all days (Document: "Pond Stats and By-products Monitoring Report.xls"). Assuming 5 out of 7 days are production days, effluent flow for production days equals 2432 kL/day. Sludge cake production per production day equates to 42 – 48 tpd (4 large green bins at 10.5 to 12 t solids cake per bin), or 210 – 240 tpw for 5459 head per week. At 10,000 hpw the sludge cake generation is expected to be 385 – 440 tpw. Assuming

12.5% solids in the cake, WAS at 0.63% solids in the WAS and a 95% recovery, this equals to a future WAS dewatering rate requirement of 49 – 55 kL/h. Where the WAS solids can be increased to 1% via the use of the new clarifier, the WAS dewatering requirement is estimated at 30 – 35 kL/hr.

Hence, the July 2015 is higher than the H1 2015 trend based on available data. However available date for the first week of July showed production at 5676 per week versus the H1 2015 average of 5476 per week. A key weakness in the above data is that sludge cake generation rates are assumed flat (4 bins per production day) whilst production and effluent rates vary.

At current dewatering rates, the WAS processing requirement at 1% solids is 16 – 19 kL/h for continuous dewatering or 35-39 kL/h for 5 days per week, 16 hours per day dewatering. At current rates, 4 bins are required per day. At 20% solid cake and current cake generation rates, 2.5 to 3 bins are required per day for operational days. For continuous dewatering, 1.8 to 2.1 bins are required per day.

Comments and opportunities for existing system:

- Decanter is able to take the clarifier underflow directly.
- By decanting the clarifier underflow, even when sludge for removal from the system is not required, a more concentrated cell stream will be able to be sent back to the ponds which may be able to dramatically reduce the hydraulic loading on the ponds as the decanter supernatant (clarified liquid) may be at a suitable composition for adding to the clarifier overflow. This would certainly be the case when there is excess decanter capacity during the ramp up stages over the next ~2 years.
- The sludge is anticipated to be at ~20% solids thereby reducing waste management costs.
- To achieve the shortest payback on a decanter, it should be run continuously at capacity. Hence, if the WAS is “thin” (i.e. less than 1.0% solids), then use of a drum thickener to achieve 1.0% solids (or higher) should be considered. For example: Aldrum G3 Mega Drum Thickener with Basic Panel.

3 Anaerobic digestion (AD)

3.1 AD Introduction

Anaerobic digestion is the processes in which microorganisms break down the biodegradable material in the absence of oxygen. Commonly used in industrial application to treat waste and/or produce fuels and energy.

A brief Explanation of the processes involved in the digestion are included below:

1. Bacterial Hydrolysis Insoluble organic polymers (Think Carbohydrates) are broken down to soluble derivatives opening availability to other bacteria.
2. Acidogenic Bacteria convert sugars and amino acids into Carbon Dioxide, Hydrogen, ammonia, and organic acids. The organic acids are broken down to acetic acid, ammonia, hydrogen and carbon dioxide[6]
3. Methanogens convert these compounds to methane and carbon dioxide[7]

Anaerobic digestion acts to reduce the emission of landfill gas and is widely used as a source of renewable energy. This process can be used to generate capturable biogas which consists of the methane and carbon dioxide as well as other trace gases.[1] This gas can then be fed through a generator in combined heat and power engines to offset emissions and reduce energy costs or alternatively be upgraded to biomethane. The digestate remaining can be utilized as a fertilizer. Improved technology has allowed for the reduction of capital costs and Germany, UK and Denmark especially has seen an influx of installation of these facilities and manufactures. [10] [11] [12]

3.2 Basis of Design

Current estimated tonnages:
[1] Dewatered aerobic sludge (from aeration pond to clarifier to belt press): 11 - 12.5% solids (TS), VS%: 86% (% of TS); 42 m3/d. BMP: 20.5 m^3 methane per tonne substrate as delivered.
[2] Paunch: 50% solids (TS), VS%: 82 - 92% (% of TS); 16 m3/d @ 50% TS. (note: TS% depends upon how well the screw press is working; can drop to 15% TS with associated m3/d increase). BMP: 26.6 m^3 methane per tonne substrate as delivered.
[3] Future DAF. They are laying the slab now so there is no specific site data yet, however using industry heuristics can assume 26 m3/d DAF system product containing 5% FOGs and 5% solids. One option is to decant FOGs to sell as tallow with remaining solids separated to a stream of ~12% TS via a belt press.

Notes:

- Once the DAF is installed, it would be expected that the aerobic sludge tonnage and VS% would be reduced.
- Site-wide expansion hence, AD design must be able to handle 60% more than the above tonnages by 2018.

- Part of the WAS is currently sent to a belt press for dewatering with centrate returned to the lagoon. Site is looking at a decanter option which may get the sludge up to ~18% TS.

3.3 Batch or continuous

The process can be completed in either a batch or continuous process each having their benefits when considering the application. Batch processes involve the prolonged sealing of biomass until digestion is complete. The fresh batch will need inoculation or contact with pre-processed material to kick start the anaerobic digestion. One commonly used technique referred to as in-vessel composting uses recirculated degasified percolate to catalyse a reaction. The biomass is kept in the reactor to be used in-vessel composting before being opened. [23] Less equipment to pump biomass and moving parts results in less capital and lower operating costs and is cheaper technique of digestion.[24] In contrast, continuous digestion is either constantly added or added in semi-continuous stages. The products from this system are removed at a constant rate and therefore replenished at a constant rate. Continuous stirred tank reactors, up-flow anaerobic sludge blankets, expanded granular sludge beds and internal circulation reactors are examples of these systems. [25][26]

3.4 Solid Phase Digestion (SPD)

A further definition needs to made when treating waste streams; High solids or dry fermentation digesters, also known as solid phase digesters (SPDs), are built to process waste streams with solids content of 25% and 40%. Dry systems use stackable substrate without the dilution of water to help the pumpable slurry. Vertical plug flow digesters (Continuous) and batch tunnel horizontal digesters are commonly used with dry feeds. Continuous vertical plug flow digesters are upright, cylindrical tanks where feedstock is continuously fed into the top of the digester, and flows downward by gravity during digestion. In batch tunnel digesters, the feedstock is deposited in tunnel-like chambers with a gas-tight door. Source:http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-9196/BAE-1764.pdf

Solid state digestion separates the fermentation from methanogenesis. The fermentation process occurs as the neutral pH and nutrient rich effluent passes through the stacked solids. This liquid is not allowed to accumulate and is captured and recycled through the base so this is where the name dry fermentation arises. The leached liquid from the stack yields biogas through the methanogenesis process and can take place in the same reactor or separate depending on the process. Removal of the leachate is critical to eliminate acid accumulation which results in silage.

Systems can be described as being single to two-phase systems Whether methanogenesis occurs in the same reactor or a separate reactor.

Bin Reactor: These reactors are essentially boxes with false bottoms, Dry fermentation takes place in material stacked on top of a perforated floor. Leachate passes through the pile and is collected below the floor. Leachate passes through the pile and is collected below the floor. In a single stage reactor leachate undergoes methanogenesis as it is collected in the bottom of the bin. In a two phase system, leachate would be pumped into a separate reactor for methanogenesis. In either system effluent is sprinkled on top of stacked organic matter. Bin Reactors are usually very large; therefore, they are sometimes called Bay Reactors.

Bay reactors are large enough for trucks and loaders to drive into and stack material inside the box. They are sealed with large air tight doors. Once the stacked material has been thoroughly fermented, it is either removed as is or is composted in place by blowing air through the false bottom. After the stack has been processed it is removed by the same equipment used for stacking. Cement trenches and containerized systems are part of the bin reactor class.

Silo Reactor: A silo reactor is a large upright cylinder. Stackable organic material is augered to the top of the silo. And digested material is removed from the bottom. The cylindrical shape of the reactors allows for the efficient leaching through the length of the pile. Methanogenesis takes place in a separate reactor and effluent is sprinkled on top of the pile stacked in the silo. Digested solids may be composted by blowing air upwards through the silo. Silo reactors also exist in single-phase configuration. A particular system mixes incoming dry material with leachate before pumping to the top of the silo.

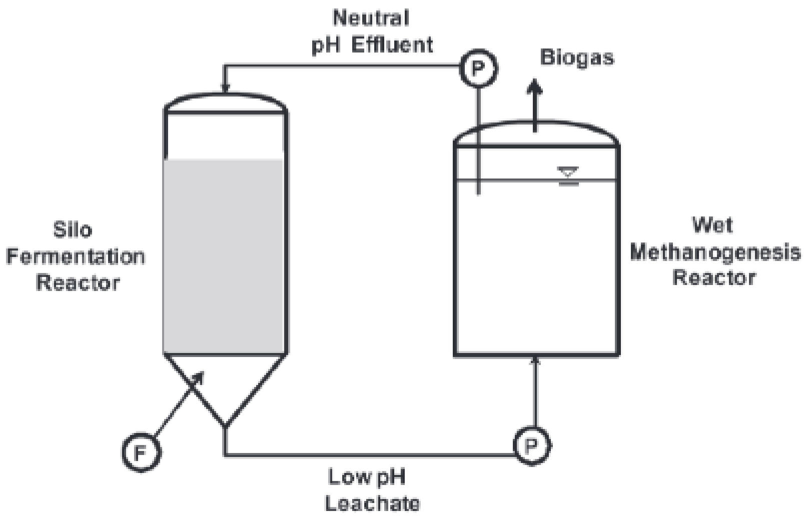


Figure 4.1: Schematic of a dry fermentation system.

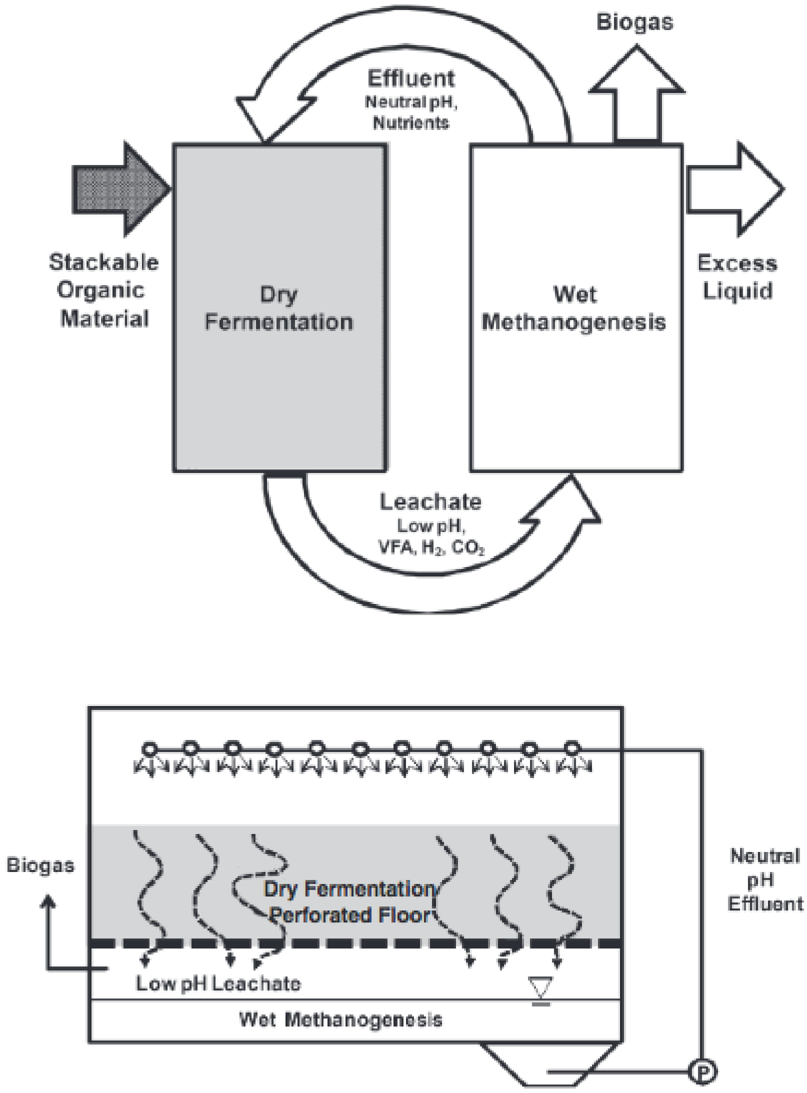


Figure 4.2: Schematic of a dry fermentation system.

Source: www.herhof.com/en/products/biogas-system.html

Advantages of dry fermentation compared to wet fermentation:

- Reduced Water requirement for dilution and washing of feed.
- Reduced operational energy since no mechanical mixing
- Reduced material wear from pumping and moveable components
- Reduced material costs from reduced acidification
- Increased CHP service life due to reduced sulphur content in gas
- Reduced Digester capital cost through smaller volume digesters with increased energy density of substrates
- Utilization of existing stacking and moving equipment reduces new purchase costs. (wheel loaders, tractors etc.)
- Simpler (stacking) Storage of fermentation residue

Steps of the process:

1. Loading into a dry fermenter (minimize compaction). After the organic waste is loaded into the digester, the digester hatch device is closed with a gas seal to ensure that process conditions are maintained and biogas cannot escape.
2. Pre-aerobic option in the closed dry fermenter to increase the temperature. The system pumps outside air into the organic waste material creating aerobic conditions that self-heat the material to process temperature before anaerobic conditions are created using energy from the system. Aerobic digestion generally last no more than 12 hours.
3. Anaerobic processing by means of percolation with process water Following the initial aeration of the organic material, the aerobic bacteria consume the remaining oxygen in the digester to establish anaerobic conditions. Under anaerobic conditions, the organic waste is finely sprayed with conditioned process water containing thermophilic microorganisms ('percolate') that decompose the waste and produce biogas. This percolate is pumped in a closed loop between the digesters and the heated and insulated percolate tanks located beneath the dry digester area is recharged with the thermophilic organisms required for digestion. High quantities of organic acids arising during the beginning of the process are stored and degraded in the percolate tank to ensure proper pH balance. This makes the percolate tanks very important.
4. The production of biogas begins quickly after percolation. Biogas is collected in an embedded piping system and stored in membrane bladders, located on the roof in some systems. Stored biogas is available for nomination into the CNG system of a CHP system. Expulsion of biogases, aerification of digestate, Optional aerobic post-processing to reduce water content odour removal. Removal of digestate.
5. Post-treatment of fermentation residue (e.g. hygienisation in boxes or maturation, screening etc. depending on the application)

References and additional reading:

http://zerowasteenergy.com/our-solutions/dry-anaerobic-digestion/

http://www.biofermenergy.com/wp-content/uploads/2008/12/Company-Brochure_BIOFerm-Energy-Systems.pdf Bio Ferm Overview of Dry fermentation Technology

http://zerowasteenergy.com/our-solutions/dry-anaerobic-digestion/

http://www.biofermenergy.com/wp-content/uploads/2008/12/Company-Brochure_BIOFerm-Energy-Systems.pdf

http://www.herhof.com/en/products/biogas-system.html

http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-9196/BAE-1764.pdf

1 National Non-Food Crops Centre. "NNFCC Renewable Fuels and Energy Factsheet: Anaerobic Digestion", Retrieved on 2011-11-22

6 Anaerobic digestion reference sheet, waste.nl. Retrieved 25.10.07.

7 Meisam Tabatabaei, Raha Abdul Rahim, André-Denis G. Wright, Yoshihito Shirai, Norhani Abdullah, Alawi Sulaiman, Kenji Sakai and Mohd Ali Hassan. 2010. Importance of the methanogenic archaea populations in anaerobic wastewater treatments (Process Biochemistry- 45(8), pp: 1214-1225)

10 Anaerobic Digestion Strategy and Action Plan, defra.gov.uk. Accessed 19.01.2012

12 Jyllands-Posten 29. December 2011. Australian

essed 19.01.2012 via Google Translate

23 aikantechnology.com Retrieved 10. Feb. 2012.

24 Anaerobic digestion, energy.ca.gov. Retrieved 18.06.09.

25 BIOPAQ IC, paques.nl. Retrieved 19.08.07.

26 Biological processes with Biomar technology envirochemie.com. Retrieved 24.10.2012.

3.5 Contact with W2E Vendors

The following waste management companies have been contacted by All Energy Pty Ltd in H1 2015 in relation to agri-waste projects. The various offering were considered in light of the facility's organic waste streams. Generally, the European and North American technology providers for SPD did not respond or were not offering a solution into the Australian market.

Company	Expertise	Contact	Summary
DGA Co Ltd	Biomass boilers	david.hall@auedr.com	Requires dry feed (<~25% moisture)
Aquatech Maxcon	Water	david.leinster@aquatecmaxcon.com.au	AD system
Biogass	AD	joseph.oliver@biogass.com.au	AD system
Coal Tec Energy	Gasification	mike@coaltecenergy.com / SAM956@aol.com	Gasification system cost $☐, installed and commissioned. 200 tpd.
Pyrocal	Pyrolysis / char	james.joyce@pyrocal.com.au	$☐ Big Char 2200. Supply ends with hot flue gas.
NorthMoreGroup	Power generation modules	craig@northmoregordon.com	Requires wood pellets
AirClean Technologies	Power generation modules	sales@aircleantech.com	Referred to Australian vendor - NorthMoreGroup
Utilitas	Bio-gas	fionaw@utilitas.com.au	Offered testing services
Centre for Solid Waste Bioprocessing	Solid state AD	william.clarke@uq.edu.au	Response received
Impacts	Solar thermal	trevor.powell@impacts.com	Declined due to inappropriateness of technology
MaxxTec	Boilers	maxxtec@maxxtec.com	No response
Ecoreps	Pyrolysis / char	jim.fader@ecoreps.com.au	$☐ pyrolysis 3250 tpa
Bigchar	Pyrolysis / char		Requires dry feed (<~10% moisture). $☐
BDI	Biomass boilers	bdi@bdi-bioenergy.com	No response
OWS (Dranco Farm system)	Plug flow AD	Bruno.Mattheeuws@ows.be	Preference for >20kt pa
Tenza		smachacek@tenza.cz	Declined due to unavailability of resources.
Bioferm	Dry fermentation	info@bioferm.de	No response
Zero Energy		info@zwenergy.com; ashley@enviro-rel.com	No response
Aikan		hmo@aikantechnology.com	No response
Erigene	Dry fermentation	contact@erigene.com	No response
PolyComp			No response
CN EastPower	Boilers		Declined due to inappropriateness of technology

BTG World		office@btgworld.com	No response
Ecoremedy		Dheck@enginuityenergy.com	No response
HOST Gasification	Gasification	chris.long@fligroupco.com	No response
Farm Pilot Project Coordination, Inc.		preston.burnette@fppcinc.org	No response
Xylowatt	Gasification	colard@xylowatt.com	No response
TBARapid		tblake@tbarapid.com.au	No response
Bekon		contact@bekon.eu	No response

4 Sludge Decanting

4.1 Decanter Technology Overview

Efficient separation of Solids and liquids in industrial application is more important than ever to meet the rising regulation, efficiency costs, disposal costs, and sustainability objectives of various industries. The separation of mixtures into their respective phases is important, not only from a cost saving on water treatment but through potential new revenue generations.

Within industrial processing, solid material is inevitably mixed with various liquid phase streams resulting in waste streams unsuitable for reintroduction into water supplies and can create sludge not suitable for disposal. A decanter and is a common feature in waste water facilities and the chemical, and food processing industries and helps with these kind of applications to separate the liquid from solid phase with high efficiency.

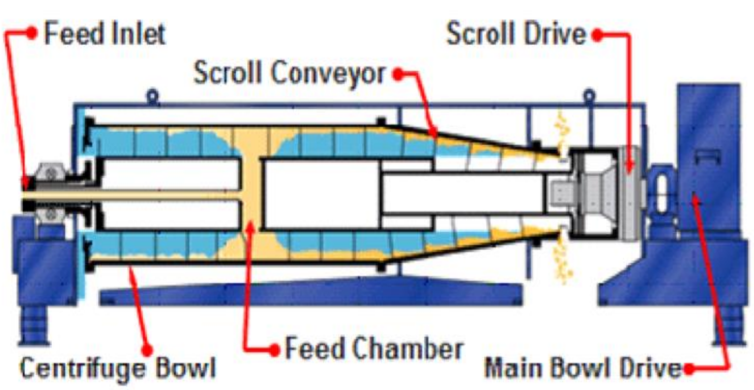
Centrifuges utilize high rotational speeds to separate the different components based on their densities. It is appropriate to consider the specific application of the technology and what the processing characteristics will be as multiple factors can affect the performance and design heuristics will need to be followed.

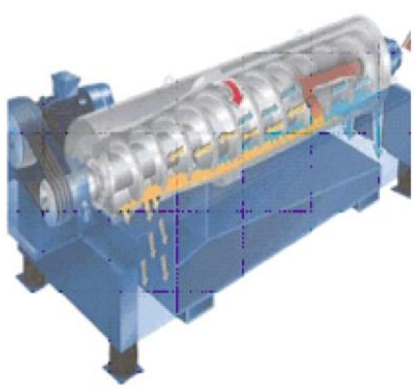
Operating Principal

Decanter Centrifuges operate using gravitational separation as the main separation mechanism. Small suspended particles can settle in seconds compared to hours or days. Not only is this process faster, but also greater control over operational parameters with a variable feed. Through the continuous rotational operation the system can generate gravitational forces equivalent to 1000-4000 times greater than naturally occurring gravitational force, driving higher density components to fall to the bottom of a particular mixture, with the less dense component suspended at the top.

Operating Process

The feed slurry is introduced into the feed chamber assembly by a stationary feed tube. It is accelerated up to speed in the feed chamber and discharged into the pond of the bowl through the feed ports.





The liquid flows from the point where it is introduced to the pond to the liquid weirs at the large end of the rotating assembly. As the liquid flows through the pond, the g force causes the solids to settle out of the liquid and to sediment against the bowl wall. This causes a blanket of solids to build up against the bowl wall.

The solids that build up against the bowl wall are pushed to the opposite end of the liquid discharge by the screw conveyor, which turns at a slightly different speed than the bow. The solids are pushed in the horizontal direction, up an incline and ultimately out of the liquid prior to being discharged from the bowl. Centrifugal force is constantly exerted on the solids in order to produce the desired solids in the discharged product.

Optimization of the decanter performance can be achieved by varying the following

- Bowl Speed, optimised separation through G-force to suit processing stream.
- Conveying speed, for optimized balance between liquid clarity and solids dryness, and inter-phase settings between the heavy and light liquid phases
- Feed flow [9]

Polymers

For a large proportion of operations decanter centrifuges require polyelectrolytes. When examining the life cycle costs of a centrifuge installation, the polymer cost is larger than the maintenance, power, and labor costs put together. The success of the centrifuge depends upon the reaction between the sludge and the polymer. The polymer cost is one of the largest in the plant. To minimize this cost, it is important to have a polymer system that can handle more than one form of polymer.

Polyelectrolytes are water-soluble molecules with active sites, which react with sludge particles. Dry, emulsion and liquid solution polymers exist and for any sludge, we can find polymers in two or even all three categories which are effective.

Economics

Based on total operating costs, the decanter centrifuge has significant advantages over the belt filter press. These are summarized as follows:

- Electrical costs – the belt filter press has an advantage in electrical consumption. However, this difference is between 2 – 5 % of the total operating cost of the system
- Conditioning costs – a centrifuge can be operated at slightly higher polymer dosage for much dryer cake solids or at lower dosage levels for the same cake solids level versus a belt filter press depending on whether cartage or conditioning costs are controlling.
- Operator attention – current estimates are that centrifuges require 1/4 the labor of belt filter presses.
- Major servicing for centrifuges
    - STC spray on conveyer tips with a useful life between 2,000 –8,000 hours depending on the application.
    - STC tiles would have a useful life between 15,000 – 40,000 hours depending on the application.
- Major servicing of belt filter presses
    - 2,000 – 3,000 per belt depending on the application.

Benefits and limitations

Benefits:

- Clean appearance and have little to no odour problems.
- Easy to install and fast at starting up and shutting down
- Small area for operation compared to other competitive processes.
- Versatile design with application specific selection of cylindrical bowl section length and the cone angle. Design curves to predict the sludge type can be pre-programmed providing advantages over the belt filter press where belt cannot be altered[1]
- The versatility allows various functions such as operating for thickening or dewatering.
- The machine can operate with a higher throughput capacity than smaller machines.[2]
- Simple to optimise and operate with few major variables and reliable feedback info[1]
- Reduced labour costs compared to other processes with low continuous maintenance and operator attention.
- Greater process flexibility and higher levels of performance compared to belt filter.
- Low maintenance with common twenty-four hours a day, seven days a week operation
- If a short-term run is required the feed pump may be switched off and the machine left running
- Belt presses designs have a limitation as to how much dewatering can occur within a certain floor space is determined by the belt width. The same is not true with centrifuges. The capacity/floor space footprint increases geometrically with the diameter of the bowl.
- In addition, centrifuges can be operated at higher flow rates, if necessary, by sacrificing cake dryness or by increasing the polymer dosage.
- Finally, a centrifuge can be installed outside in warm climates. This is not practical for belt filter presses which must be covered.

Limitations:

- The machine can be very noisy and can cause vibration.
- The device has a high-energy consumption due to high G-forces.
- Hard surfacing and abrasion protection materials are required for the scroll to reduce wear and therefore reduce the maintenance of the scroll wear driving up initial capital costs

Design

There are three commonly used Centrifuge designs, vertical orientation, horizontal orientation and conveyor/Scroll.

Horizontal design has bearings mounted on either end of the rigid frame and can provide effective sealing for high pressure applications[2]. The capacities of these machines range from 18,000kg solids/hr and liquid rates of 1.1m^3/minute[4].

Vertically orientated decanter centrifuges rotating assembly is setup with a single bearing supported at the top or bottom of the device[2]. This design allows for high temperature and/or high pressure operation attributable to the orientation and the type of rotational seals at the end of the device. This design is more expensive than the concurrent horizontal design which in contrasts is non-pressurised and open[3]. Less noise and vibration are created with the vertical design[3].

Process Characteristics

Centrifugal force (g-force), sedimentation rate, and separating factor, differential speed between conveyor and bowl, clarity of liquid discharge are all characteristics influencing performance. The radius of the centrifuge and the angular rotational speed determine the force exerted on the sludge. [5] Particle size, shape, comparative densities, and viscosity between particle and liquid influence the sedimentation rate. flocculating agents as well as adjustment to the centrifugal force can result in the desired setting time for the given feedstock and process throughput.

The exterior bowl and scroll conveyor rotate at different speeds and enable the sedimentation in the centrifuge cylinder. Increasing the differential speeds creates a lower residence time of cake sediment so important to keep cake thickness minimum to reduce impact on the discharge quality. The cake dewatering process efficiency is improved by minimizing the thickness so differential speed must be balanced around this process variable[6].

The volumetric flow rate influences the discharge clarity of the liquid.[2] Higher flow rate inevitably means sacrificing clarity to a certain degree. Differential speed will also influence the clarity. G force impacts the discharge clarity as well with higher G forces Increasing the clarity.[7]

Design Heuristics

Extensive industry research and feedback over the years has lead to the incremental performance increase. Design heuristics have been developed in regards to equipment sizing, operating parameters, and performance eliminating expensive processes for optimisation. A brief overview on some developments is important to keep in mind.

The scale of the process is important for selecting this technology as an efficiency in capital expenditure is captured when implementing above a certain size. [8]

The length to diameter ratio of the decanter centrifuge of 2, 3 and 4 are commonly used and dependant on the feed and throughout to optimise separation. Increasing the length with the same diameter would allow for higher solid percentage feeds. and effectively increase the settling efficiency of fine particles.[7]

The beach angle at the conical section of a decanter centrifuge is a design heuristic. A decanter centrifuge possessing a small cone angle is able to produce a lower slippage force compared to a large cone angle. Additionally, low cone angles result in a lower wear rate on the scroll and are beneficial when being used with very compact solids requiring a large magnitude of torque to move.[7]

The centrifugal force increases the dewatering but also hinders the transport of the cake within the beach area, the conveyance of the cake and the dewatering efficiency must have a trade-off given other process parameters.[2]

The differential speed controls cake transport. A high differential speed would give rise to a high solids throughput. A high differential speed also reduces cake residence time.[2]

Tri Canter and Two Phase Comparison

TriCanters use the same principles to two phase decanters but have the capability to separate into three phases (for example fat water and solids). [2] The solids accumulate on the wall of the bowl and are subsequently conveyed out of the centrifuge. A dual discharge system in with the lower density products separated via gravity separation and water discharged with a stationary impeller under pressure.

In the case of consistent feed quality processing for fat/oil separation with water the three stage decanter system can achieve comparable results to the two stage process with approximately two thirds of the capital outlay for equipment.[9] Single stage separation preferable in cases where composition and consistency are fairly constant where two stage separation is a more versatile method.

Depending on the immiscible liquids; increasing the temperature of the feed into the centrifuge can increase the efficiency of separation between oil and water.[11] Increasing the temperature has a number of effects on oil/water separation.[12] For thermal decanting the waste feed can be passed through an economiser absorbing what would be waste process heat and channelling that into a useful application to increase the separation efficiency and reduce waste treatment costs either by reduced capital or operating expenses. pH modification is also used when needing to create coagulation within a process feed.[11]

4.2 Decanter Total Capital Investment Estimate

Assumptions:

- Flows and cake tonnages extrapolated from July 2015 to a 10kpw scenario.
- Per hour (ph) volumes based on 24/7 operation of decanter.
- Contingency of approx. 1 day per week of additional dewatering capacity.

Table 5.1: Basis of pricing.

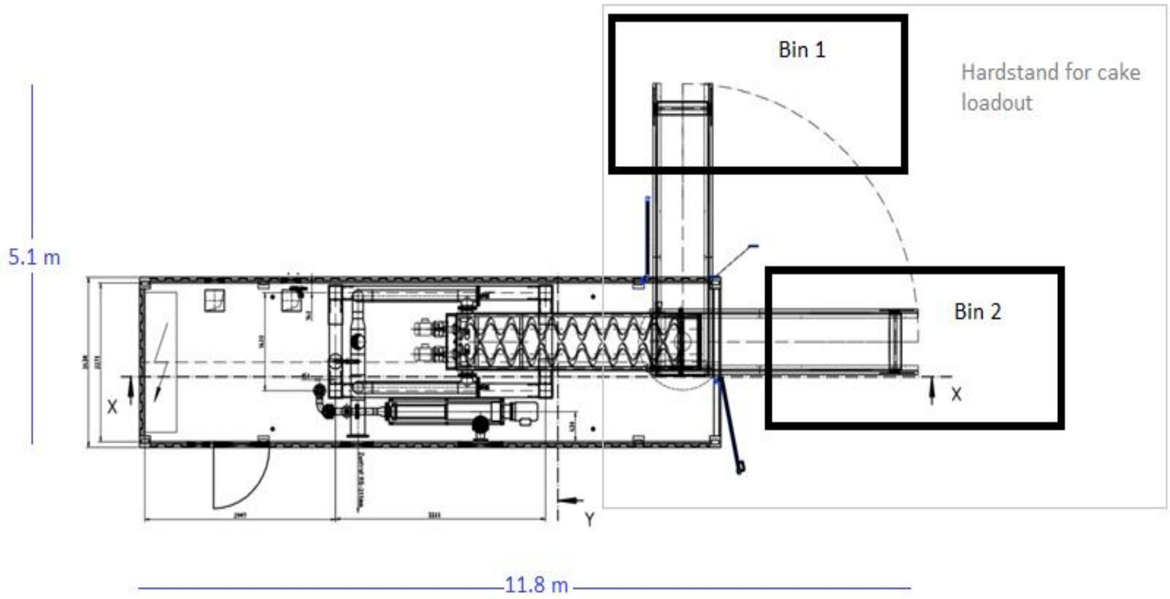
Scenario	STREAM	m3 pd	m3 ph	Solids %	Solids dry weight tpd	Solids dry weight tph	Information
H1 2015	To belt press	873	36.4	0.63%	5.53		15hrs of flow per production day
	Sludge cake (WAS)	42	1.75	12.50%	5.25		95% solids capture via belt press
							Normally 85-95%
	Centrate (Press filtrate)	831		0.03%	0.28		Joins influent flow to Pond 1
10kpw	To belt press	1538	64	0.63%	9.74		15hrs of flow per production day
	Sludge (WAS)	74		12.50%	9.25		95% solids capture via belt press
	Centrate (Press filtrate)	1464		0.03%	0.49		Joins influent flow to Pond 1

Table 5.2: Decanter vendor submissions.

	G-Tech	Alfa-Laval	GEA	Flottweg
Model	Haus DDE 4742	Aldec 75 Decanter	UCF 466	C4E
Inlet flow	35-40 m3/hr, maximum 1% solids.	to 40m3/hr of WAS at 1.8% of solids.	25-40 m3/hr, to 2.5% solids	10 - 45 m3/hr hydraulic capacity, feed slurry from 0.4% - 3.5% is acceptable (typically 1%).

Solids	1.96 tph @ 20%	3.6 tph @ 20%	4.8 tph @ 20%	6.7 tph @ 20%
Power draw	Start Amps = 106A Start (with large motors on VFD) = 76kVA Running = 83kVA Total estimated recommended = 100kVA	150 Amps, 415V, 3 phase ~40 kW.	Full load current: 90A KW ~ 45 kW Pre-fuse: 125A	Standard container 60kW max. (equals 98 Amps on 415v supply). 2.2kW Macerator 4 kW feed pump 4 kW polymer station 2 x 4 kW screw conveyors
Container	20’	40’	30’	23’
Lead	6 – 7 months.	8-9 months	~8 months (6 months + ~2 months shipping)	~7 months (5 months + ~2 months shipping)

4.3 Decanter Layout Examples



Flottweg decanter installation option: Containerised decanter (C7E) , switch board and screw loadout on structural steel platform, conveying cake via swinging arm into a 2 bin arrangement.

Flottweg containerised Medium to Large Unit: 40 – 60 m3/h, e.g. C5E.

Alfa-Laval Containerized System

4.4 Decanter Op Ex

Decanters are designed to be "set and forget", with dewatering and polymer systems able to be automated / semi-automated. Due to the lower personnel hours, the operating cost for a decanter compared to the current belt press is expected to be approximately similar.

If a polymer emulsification is used (due to the success of the trial) the personnel hour requirement is estimated at approximately 1 hr per day. Some increase is expected in power consumption and maintenance costs for the decanter, which are ameliorated by lower personnel hours.

		#	Rate	Value $ pa
Personnel	pa			
Plant Maintenance &repair @ 10% equipment cap ex	pa			
Consumables @ 1% equipment cap ex	pa			
Electrical load (kW)		Power From Grid		
Main motor	kW	27.6		
2nd motor	kW	8.2		
Screw	kW	0.7		
Poly pump	kW	0.4		
General power (inc lighting)	kW	0.4		
Control system kW	kW	0.1		
Sub-total Electricity		37.4		
Chemicals				
Polymer (conservative – at higher end)	kg			
Cleaning				
Subtotal Chemicals				
Potable water				
Potable water for cleaning	kL pa	4,338.72	1.2	5,206
DERM Environmental Fee	Excluded			
TOTAL ESTIMATED ANNUAL OP EX	$ pa			327,095
Revenue		tpa		
Reduced landfill at 20% solids				
Reduced landfill at 22% solids				

Decanter Timing

The long lead item is the decanter itself. Suggested timing for each stage is as follows:

Trenching: 1 week

Cables and piping: 2 weeks

Civils: 2 weeks

Road: 1 week

Ex-works / FOB from payment of invoice: 6 months

Shipping / customs: 3 months (for foreign suppliers)

5 Dissolved Air Floatation (DAF) Considerations

In the AMPC report “Cost Benefit Analysis of Dewatering Abattoir Sludge Using Three-way Decanters” (Lycopodium Process Industries, 2015) it was reported that Bird Environmental estimated the DAF sludge, on average, would be broken into the following constituent parts: 90% water, 7% solids and 3% oil. A “typical” 625 head per day facility is estimated to create 8.1 tpd of DAF sludge.

The oil and solid streams are not pure, however, and each is partially contaminated by components from the other two. Studies conducted by Bird Environmental found that, depending on specific facility drivers and process conditions, the solids stream contained approximately 5.5-12 wt% oil and 55-70% water (39.5 – 18% solids), the oil stream contained 0.04-0.26 wt% water and 0.06-0.2 wt% solids, while the water stream contained 0.04-1.0 wt% solids and 0.0-0.4 wt% oil. Although Bird Environmental no longer appears to be in business, a number of other major equipment vendors such as Alfa Laval, GEA Westfalia, Flottweg, Hiller Separation & Process, and Huading Separator, provide three-phase centrifuges to the food processing industry. The mode of operation recommended by centrifuge equipment manufacturers today is the same as proposed by Bird Environmental 20 years ago; heat the DAF sludge to 85-95°C and then process the DAF sludge with the three-phase centrifuge. Up to 5-6% by volume oil recovery was stated for polymer flocculants and 3-4% for inorganic metal salts.

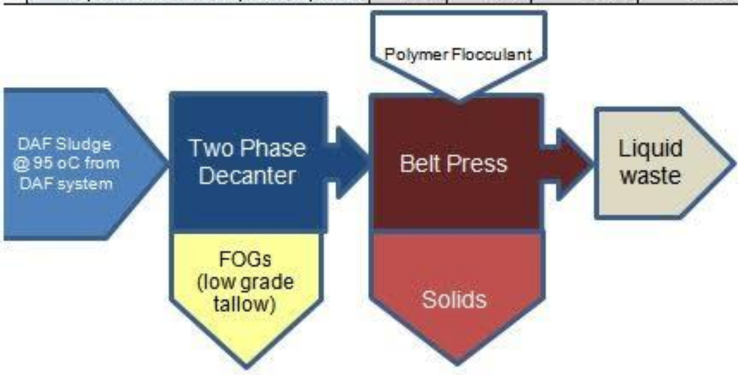
DAF MEB for 10 khpw, 48 weeks per annum.

Heurstic Estimate Using Published Industry Data - High FOGs

#	Stream	% FOGs	FOGs tpa	% solids w/w	solids tpa	% water	water tpa	Annual tonnage as delivered (wet weight tpa)
1	DAF Sludge	6.00%	576.00	7.0%	672	87%	8,352	9,600
2	FOGs (low grade tallow)	99.6%	467.72	0.2%	94.0%	0.25%	1.17	470
3	DAF Sludge minus decanted FOGs	1.2%	108	7.3%	671	91.5%	8,351	9,130
4	Solids from belt press (pet food?)	5.5%	108	28.8%	566.00	65.8%	1,294	1,969
5	Liquid waste from belt press (to pond?)	0.00	0.00	0.07%	5.01	99.93%	7,156.46	7,161

Heurstic Estimate Using Published Industry Data - Low FOGs

#	Stream	% FOGs	FOGs tpa	% solids w/w	solids tpa	% water	water tpa	Annual tonnage as delivered (wet weight tpa)
1	DAF Sludge	3.00%	186.81	7.0%	436	90%	5,604	6,227
2	FOGs (low grade tallow)	99.6%	78.53	0.2%	15.8%	0.25%	0.20	79
3	DAF Sludge minus decanted FOGs	1.2%	108	4.8%	436	61.4%	5,604	6,148
4	Solids from belt press (pet food?)	5.5%	108	28.8%	566.00	65.8%	1,294	1,969
5	Liquid waste from belt press (to pond?)	0.00	0.00	0.07%	2.93	99.93%	4,176.52	4,179



Dinmore	1500	hrs pa
	8	m^3 / hr
	12000	m^3 pa
	3700	head per day beef
	0.01297297	m^3 per head
	6227	tpa
AMPC Report: Energy from Waste: DAF Sludge and PW		
	3.700	kg/head
	2	kg/head dw
	20	kg/head ww
	9600	tpa
Mid-range		
	8087.04	tpa

6 WWTP DCS

6.1 Summary

A high level estimate for motor status on all motors, monitoring and control of the DAF and decanter sections, monitoring on ponds, COD on the stream influent and an associated DCS that can link into the site-wide web based SCADA is approximately $ 370k fully installed. The supply and installation of 8 key flow metering devices is estimated at a further $152k, hence monitoring of the WWTP and control of the main plants is estimated at $522k. Control of the motors not part of the DAF or decanter plants is estimated at a further $160k.

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Polymer Selection

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