final report

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Pelletizing Plant Cost Benefit Analysis

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Executive Summary

This report summarizes the findings of a cost-benefit analysis (CBA) for a project to generate a coal replacement fuel via the pelletization of organic waste that is otherwise being landfilled (i.e. paunch, aerobic sludge) at a meat processing facility.

A large number of scenarios were considered both in terms of technology and scale. The table below outlines the findings, with the most viable option for paunch being pelletization to create a fuel pellet and for sludge decanting to reduce landfilling tonnages. For paunch, a milling / drying stage via a Mahltechnik Gorgens GmbH TurboRotor was the most viable option, with the economics improving as the scale in increased (i.e. Stage 2 development). Thermal processing is one of the few options available to dry paunch to the low levels required (i.e. ~14%) to enable pelletizing. Non-contact drying utilizing steam as the source of heat in a rotating system is not viable with a payback over 10 years due to the high steam requirements and associated costs. The TurboRotor creates very small particles hence has the capability of drying the paunch via the use of waste heat rather than steam. The TurboRotor is not suitable for processing the high moisture content sludge, however decanting the sludge in order to target 80% moisture rather than 87.5% moisture appears to be highly economically viable due to the relatively low capital cost but high avoided landfilling costs. The key findings for four scenarios considered in detail are summarized in Table 1 below.

Table 1: Findings of paunch and sludge treatment cost-benefit scenarios considered in detail

Metric	**Stage 2 Paunch: Pretreatment then pelletization of 50% moisture Paunch**	**30% Growth Scenario: Sludge Decanting to 20% moisture (rather than 12.5% moisture)**	**30% Growth Scenario: Pretreatment then pelletization of 40% moisture Paunch**	**30% Growth Scenario: Pretreatment then pelletization of 77.5% moisture Paunch and Sludge**
Scale – Fuel pellet produced in tones per annum dry weight (tpa dw)	3630 tpa dw (4221 tpa pellets at 14% moisture)	1,737 tpa dw	2,538 tpa dw	4275 tpa dw
Total Capital Investment (TCI): supply, delivery, full installation, plant tie-ins.	$1.7 mil	$0.55 mil	$1.4 mil	$3.1 mil
EBITDA (yr 1)	$0.23 mil	$0.14 mil	$0.11 mil	$0.20 mil
Discounted Payback period (DPP)	8.3 yrs (7.2 yrs simple payback)	4.2 yrs (3.9 yrs simple payback)	NA (not in life of plant; 12.4 yrs simple payback)	NA (not in life of plant; 16 yrs simple payback)
Simple Present Value $ / head[1]	0.22	0.35	NA (not in life of plant)	NA (not in life of plant)
Net Present Value (NPV) $ / head	0.06	0.21	NA (not in life of plant)	NA (not in life of plant)
Net Present Value (NPV)	$ 288,729	$590,795	NA (not in life of plant)	NA (not in life of plant)

1 Total non-discounted present value of project assuming 10 year lifespan divided by number of head of cattle

The key parameters impacting the economics of the project, in order of relative impact, are coal price, pellet lower heating value, landfilling costs (these three of similar level of importance) followed by Total Capital Investment (TCI). The lower heating value of the pellet (GJ / t) is multiplied by the coal energy price ($ / GJ), hence the same percentage change in either variable results in the same impact on discounted payback period (DPP). However, due to the coal price being affected by external market, the coal price is anticipated to result in greater variability of the project economics. It is noted that Newcastle coal for March 2015 is currently at $AUS 93.3, which is a 16% increase compared to the assumed $80.79 / t, hence the DPP based on March 2015 coal prices is 7.4 years as opposed to the 8.3 years presented above. Sensitivity analyses were run to determine the impact of various parameters on the economic viability of the project. Figure 1 below displays how the discounted payback period (DPP) changes accursing to the coal value ($ / tonne). A DPP of five (5) years is achieved for a coal value of $133 / tonne with a three (3) year DPP achieved for a landfilling cost of $212 / tonne.

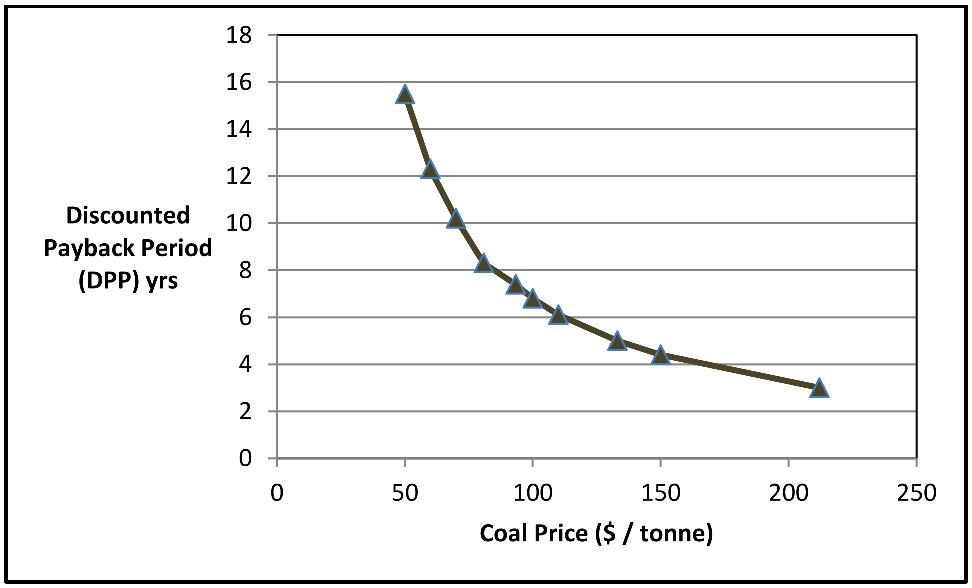

Figure 1: Sensitivity analysis for change in discounted payback period (DPP) as a function of the change in coal price ($ / tonne) for Stage 2 paunch to fuel pellets.

The figure below displays how the discounted payback period (DPP) reduces as the landfilling cost per tonne increases towards $100 / tonne. A DPP of five (5) years is achieved for a landfilling cost of $45 / tonne with a three (3) year DPP achieved for a landfilling cost of $75 / tonne.

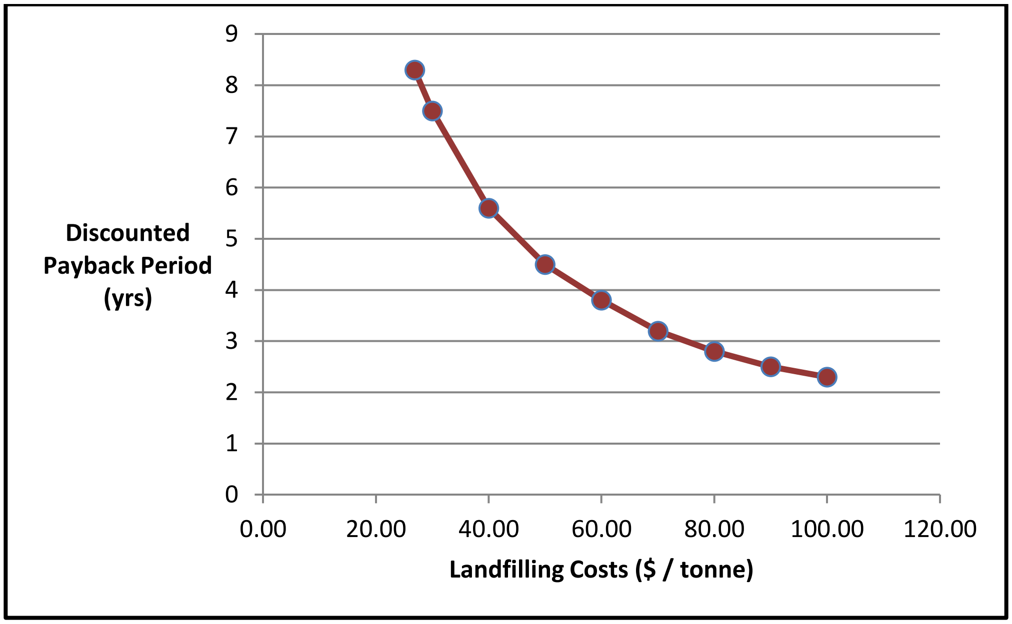

Figure 2: Sensitivity analysis for change in discounted payback period (DPP) as a function of the change in landfilling cost ($ / tonne) for Stage 2 paunch to fuel pellets.

Table of Contents

1 Background

A meat processing facility is currently undertaking a review of energy expenditure at the Canon Hill facility. The paunch and sludge is currently sent for off-site landfill disposal while coal is purchased to fuel the on-site boilers, with both contributing to rising operating costs for the facility and have significant greenhouse gas emissions.

The review includes evaluating alternatives to current fossil fuel sources, particularly coal. Technical solutions exist for converting paunch waste, aerobic and manure into a fuel to off-set coal consumed as boiler fuel. The key savings are reduced coal costs and reduced waste management costs. The challenge is to implement a process that has an acceptable capital cost and an operating cost lower than the savings that are made. A key consideration is the mass-energy balance for each processing option in order to minimize the on-going energy requirements for processing the organic wastes.

1.1 Scope of Works

This project involves a pre-feasibility study into the value adding options for paunch waste and aerobic sludge from processing facility. This project will be a technical, desk top study making use of published MLA / AMPC research and vendor data to firstly determine the technical viability of value adding options then consider the economic feasibility, which will take into consideration capital costs, operating costs, and savings (i.e. waste management and fuel).

Processing options that have been previously considered by industry include pelletization, anaerobic digestion, heat treatment (i.e. torrefaction or pyrolysis), composting (e.g. enclosed, mechanical or engineered systems), dewatering and Savealls.

In addition to reducing paunch and sludge waste disposal fees and increasing end product value, the proposed Emissions Reduction Fund (ERF) will be investigated as a potential source of revenue. The ERF could provide a new revenue stream to businesses that run approved energy efficiency and emissions reduction projects such as: reduced use of fossil fuels, energy efficiency, and landfill avoidance.

2 Previous works

2.1 Pelletizing

A brief literature review was carried out and findings from industrial pelletizing operations were:

- Consistent and homogenous feed is critical for pelletization, in particular the moisture of material exiting the pre-dryer and entering the pelletizer (ideally <15 %, up to 18% has been acceptable, with 14% suggested by the vendor).
- Too low moisture content and it reduces pelletability i.e. the higher the heating value, the more difficult it is to make pellets.
- For heating values <23 GJ/t, binders are not routinely required, however lubricants may be required (especially for extrusion).
- Hotter compaction / processing temperatures (i.e. the use of steam >100 ^{o}C) generally results in better pelletization; with pelletizing temperatures above 82 ^{o}C recommended.
- Higher abrasion increases the difficulty of pelletization.
- Hydrophobicity (water resistance) assists with pellet storage and keeping moisture low
- Absence of O_2 improves safety within the pelletizing plant. An automatic fire system is recommended.
- High fat percentages lead to more fines / dust which in turn lead to lower production rates due to recycling and higher production energy consumption. Should target <1.5% fat [expected combined stream ~1.2 to 3.6% fat dw]
- Hot product must be cooled before storage or exposure to air.
- Dust generated by the process and pellets is an explosion hazard.
- Conditioning (e.g. with steam) activates the natural adhesives of the feedstocks (e.g. starch gelatinization), softens the feed to increase surface area for binding, increases lubrication and destroys micro-organisms. 4-5% moisture is recommended to be added as part of conditioning.
- The key pelletizing parameters are moisture content, composition, structure, compressive pressure and heat transfer. Utility heating requirements are shown in Figure 3 below.
- Belt dryers enable use of low grade heat for drying[2].

2 Tony Boyd, D. de Vries, H. Kempthorne, J. Wearing, I.Wolff, NORAM Engineering and Constructors Ltd., Vancouver, Canada, 2011

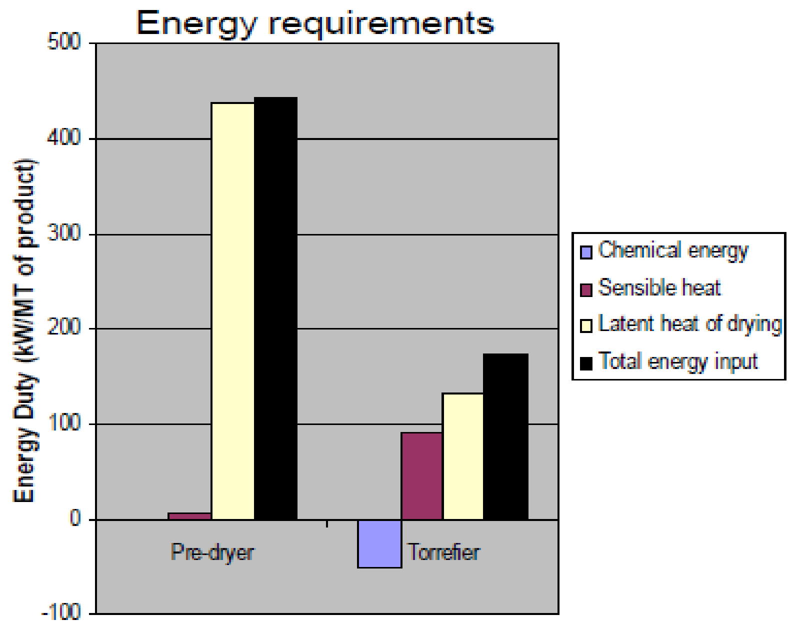

Figure 3: Heating requirement for feed pre-dryer to dry feed from 40% to 15% moisture content; 85% mass yield[1].

Jiang *et al*[3] found that high hardness pellets could be obtained at low pressure, temperature and biomass size for pelletizing sewerage sludge and biomass. The optimal moisture content for co-pelletization was 10–15%; the addition of sludge can reduce the diversity of pellet hardness caused by the heterogeneity of biomass. Increased sludge ratios also slow down the release of volatiles.

The feed stock for pelletizing systems is routinely received at 30% moisture before heating (direct or indirect) normally in a rotary drum dryer utilizing heat sources of 370 to 400 ^{o} C[4]. Use of indirect dryers tends to produce a less uniform and lower density pellet. There are three types of thermal dryers typically used in industry for pre-drying feed to pelletizer systems[5]:

[1] Direct dryers where the hot gases are mixed with the dewatered cake in the dryer and transport the sludge through the dryer evaporating the water off while in transit.

[2] Indirect dryers where heat transfer occurs through the barrier of the dryer. The heat carrying medium which can be hot gas or thermal oil is in a separate stream to the vapour. They fall into two types: single and multi-stage systems.

[3] A combination of both the above systems using both conduction and convection to evaporate water.

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3 Jianga, > et al "Co-pelletization of sewage sludge and biomass: The density and hardness of pellet", Bioresource Technology, Volume 166, August 2014, Pages 435–443.

4 Outwater, A. and Tansel B., *Reuse of Sludge and Minor Wastewater Residuals,* CRC Press, 1994.

5 http://www.esru.strath.ac.uk/EandE/Web_sites/97-8/energy_from_waste/page3.htm

The power draw for a pelletizer plant producing 11.6 tph is 11.0 – 11.9 kWh/t post steam conditioning. Where no steam conditioning is used, power consumption increases to 30.7 kWh/t[6]. Use of screw conveyors enables control of the rate of solids addition. The key control elements for a pelletizer plant are described in Figure 4 below.

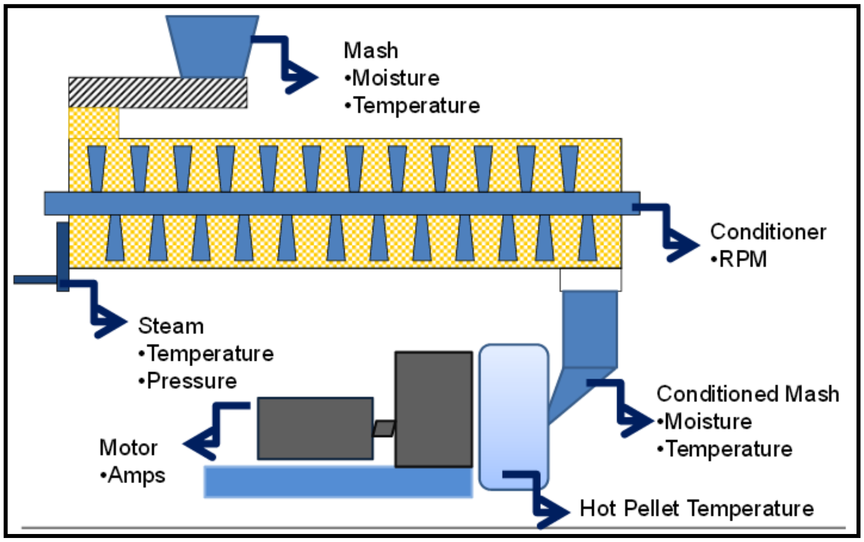


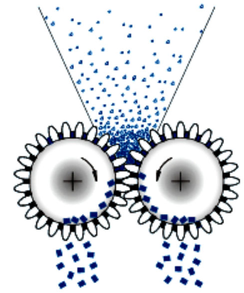
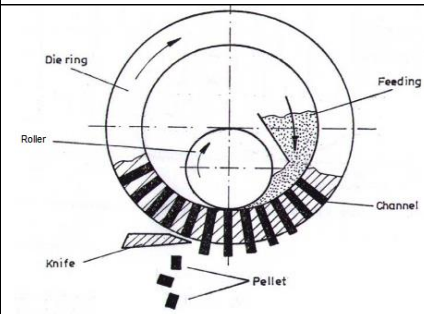
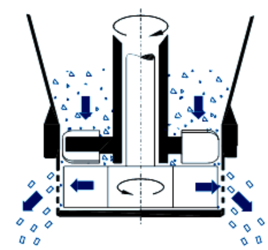
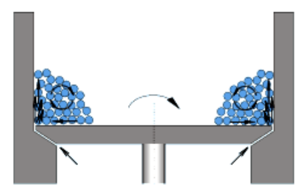
Figure 4: Key pellet plant parameters for monitoring and control[7].

6 Stark, C. and Ferket, P., *Conditioning, Pelleting, and Cooling,* College and Agriculture and Life sciences, NC State University, 2011

7 Stark, C. and Ferket, P., *Conditioning, Pelleting, and Cooling,* College and Agriculture and Life sciences, NC State University, 2011

Summarized in Table 2 below are the key pelletizing technology options.

Table 2: Principal pelletizing technologies[8,9]

Method	Product	Mechanical device	Image
Gear pelletizing	Cylindrical extruded pellet with even product integrity	Geared	
Roller (also called basket extruder)	Cylindrical extruded pellet	Roller die ring with channels. 80 – 100 kW per t/h.	
Extrusion	Cylindrical extruded pellet with comparatively loose structure and good solubility; low densification	Counter rotating rotors. Screen baskets enable different perforation sizes.	
Other: Granulation / agglomeration	Not considered due to low densification (<400 kg/m^3) and binding agent requirement. Ganules, Flakes, Briquettes.	Various	 Spinner to convert extruded pellet to spheres.

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8 Stark, C. and Ferket, P., *Conditioning, Pelleting, and Cooling,* College and Agriculture and Life sciences, NC State University, 2011.

9 Hosokawa Bepex GmbH, Germany, http://www.hmicronpowder.com/literature/PELLETIZING_TECHNOLOGY.pdf

2.2 Co-firing: Paunch and Sludge

A 2012 MLA report[10] found “significant economic advantages of dewatered paunch waste and DAF sludge co-combustion”. It recommended that “even if boilers suitable for biomass-firing need to be installed, the economics of such a retrofit looks attractive”. A key improvement was to identify suitable dewatering equipment for maximum water removal. Such improved dewatering operations will have a major positive impact on co-combustion economics. It also recommended exploring the concept of Build-Own-Operate (BOO) contracts at abattoirs for the supply of steam via privatised co-combustion systems, especially where retrofits for appropriate biomass-fired boilers are required.

There was no impact on the wood fired boiler combustion performance when co-fired with 7.5% of its energy input as dewatered PW+DAF (26% TS, firing rate 23% higher than the average waste generation rate at the abattoir). A FAN screw press can try the PW to 21 % TS. DAF sludge is dewatered via the centrifuge to 36% TS.

Abbas et al[11] confirmed the technical viability of co-firing sludge with coal: “A comparative analysis of the concentrations of selected metals (n, Cu, Cr, Mn, Ni, Cd, Pb) in various solid particle fractions collected near the furnace exit for the three flames shows that the metal enrichment on submicron ash particles was lowest for the sewage sludge flame and increased with the proportion of coal (fuel rank). From an operational view-point, the co-firing of dried, pulverized, sewage sludge (DPSS) slightly enhanced flame performance, while the metal emission values in the flue gas, as well as the metal leachability values, remained lower than recommended EU legislative limits. The 25% increase in NOx observed could in part be ameliorated through available NOx reduction techniques.”

A preliminary economic assessment of pyrolysis and gasification technologies for the processing of dried paunch waste and DAF sludge revealed that under certain conditions the process can be economically viable; whilst these economics are very preliminary in nature they indicated that gasification or pyrolysis of paunch waste and DAF sludge, with power generation, can provide positive returns for larger scale plants[12].

A 20 tpd gasifier, generating revenue from char and electricity resulted in a feedstock value of $40/t whilst the 5 tpd (-$212/t), and both pyrolysis systems (5 tpd at $-53 and 20 tpd at $-60/t) were not economically viable under the assumptions of 700 kW power generation, $0.12/kWh, 3 personnel to run the plant, 26.7% char yield, syngas yield of 8.9 GJ/t dry feed, char value of $100/t to off-set coal, emissions reduction value of $20/t, 5.34 tpd dry char, AUS2010 $7.66 mil (belt dryer plus ZWT system). Where the char is sold at $300 as a soil conditioner, the economics improves for the gasifier to $94 / t dry. Consideration was given to this technology however the scale (20 tpd) was too large for the operations and the capital outlay, carbon price and value of the char were not considered pertinent to the plant’s operations.

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10 “Use of dewatered paunch waste and DAF sludge as a boiler fuel”, MLA Report A.ENV.0106, 2012.

11 T. Abbas, P. Costen, G. De Soete, K. Glaser, S. Hassan, F.C. Lockwood, *The energy and environmental implications of using sewage sludge as a co-fired fuel applied to boilers,* Symposium (International) on Combustion, v*olume 26, Issue 2, 1996, pp 2487–2493.*

12 “Waste to energy: Alternative uses for paunch waste and DAF sludge; Waste pyrolysis review”, MLA Report A.ENV.0101, 2011.

Table 3 below outlines typical bituminous coal properties compared to paunch, sludge, the combined paunch/sludge stream, biomass pellets and the original coal specification as per the 1983 boiler documentation. The boiler plant flow diagram states “paunch” in the fuel hopper, hence the use of biomass based feedstock in the boiler is not expected to pose any specific limitation. Higher moisture content feed could increase the chance of corrosion, hence it is important to maintain a high operating and flue gas temperature.

Table 3: Key properties of current and potential boiler fuel and fuel feedstocks

Parameter	Aerobic Sludge	Paunch	Combined stream	Combined stream pellets	Biomass pellets	Bituminous Coal	boiler 1983 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)	15.6[13] – 18.74[14]	13.3 - 14	14.0	19	Assume 27.0 (23 – 32.54)	24.82
LHV (GJ/t) as delivered	~2 dw: 9.9–18.9[15]	~10 dw:14.4[16] – 17.1 Pellet: 13.6 – 16.7	~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%

13 “Use of paunch waste as a boiler fue”, 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

14 AMPC Presentation “Energy from Waste: DAF Sludge and PW”, Trevor Bridle, Bridle Consulting

15 Okazawa, K., Henmi, M., Sota, K., “Energy Saving in Sewerage Sludge Incineratnio with Indirect Heat Dryer”, Mitsubishi Heavy Industries Ltd, Japan, 1984

16 “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

2.2.1 Sludge Treatment and Drying

Aerobic sludge processing options include anaerobic stabilization, air drying, alkaline stabilization, incineration, cake landfilling, compost, heat drying and land application as a liquid. For this project, only dewatering and drying was determined to be within the scope due to surface area and land use limitations. To achieve sludge of up to 25% - 32% solids, industry typically uses decanters, centrifugation and/or filter belt presses.

To be pelletized, the biomass will need to be dried to 14% moisture. The main drying options are mechanical (e.g. vacuum drum, centrifugation, and filtration) and thermal (e.g. counter current rotating drum using air or flue gas; milling to a fine particle with hot air drying). High efficiency counter current biomass dryers claim energy consumption of ~760 kWh/ton evaporated and 40 - 60 kWh electrical energy.

When using a flue gas condensing heat exchanger, the estimated heat available in the flue gas from the fluidized bed coal fired boiler when operating at steady state is in the order of ~640 kW (250 kW from flue gas sensible heat when heat exchanged from 110 ^{o}C to 37 ^{o}C at 75% efficiency; 390 kW from latent heat of water if a flue gas condensing heat exchanger is used at 75% efficiency). This assumes the lower bound flue gas flow rate of 16,600 m3/h. Flue gas flow rate can be as high as 23,800 m3/h. Using a coal flue gas condensing heat exchanger increases the amount of fouling, water generation and acid concentration, hence appropriate flue gas handling, materials of construction and maintenance scheduling will be required.

Waste heat can also be recovered from the exhaust gas outlet of the pre-drying system (e.g. heating ambient air with 50 – 200 ^{o}C exhaust gas).

Direct contact flue gas drying has the disadvantages of product contamination, limited drying possibility due to limited energy in flue gases, limited drying due to the high moisture content of flue gas, fire and explosion risks and corrosion risks when operating at or below the dew-point leading to condensation.

3 Basis of Design and Assumptions

3.1 Basis of Design

The original basis of design was to pelletize paunch and sludge generated at a rate of 30% higher than 2013 production rates; this equates to 4,275 tpa dry weight of paunch and sludge to be pelletized. This original basis of design was directed by the plant to be the main scaling element for the proposed plant. That is, an increase from the current rate of 301,691 head per annum to 392,198 head per annum. Thermal systems were found to not be viable for processing the high moisture content sludge, hence a decenter was considered with separate processing of the paunch. A scenario was also considered for the future Stage 2. The key scenarios considered are outlined in Table 4.

Table 4: Key scenarios considered in the cost-benefit analysis pre-feasibility study

Metric	Stage 2 Paunch: Pretreatment then pelletization of 50% moisture Paunch	30% Growth Scenario: Pretreatment then pelletization of 40% moisture Paunch	30% Growth Scenario: Pretreatment then pelletization of 77.5% moisture Paunch and Sludge	30% Growth Scenario: Sludge Decanting to 20% moisture (rather than 12.5% moisture)
HSCW tpa	**123,428**	**86,284**	**86,284**	**86,284**
Scale – Fuel pellet produced in tones per annum dry weight (tpa dw)	3630 tpa dw (4221 tpa pellets at 14% moisture)	2,538 tpa dw	4275 tpa dw	1,737 tpa dw
Pelletization plant utilization (plant rated to 1.0 tph dw)	4377	2712	4800	NA

The full Basis of Design is presented in the Appendix. The feed preparation equipment presented in the concept design has been designed to be as close to full capacity as possible as type of heat treatment equipment is the more expensive element of the plant. The pelletizer, however, is a pre-designed plant and off the shelf item hence the scale selected was large enough to ensure sufficient capacity. Whilst not considered in this project, spare pelletizer capacity can be used to create a livestock feed. Summarized in Table 5 below are some key calculations extracted from a site-wide mass and energy blance model of the facility for the 30% growth basis of design .

The CBA was prepared in accordance with Meat and Livestock Australia's (MLA's) "Guide to Value Propositions and Cost/Benefit Analysis v1.0".

Table 5: Key Findings from Mass Balance for 30% increase in HSCW.

		Current	Basis of Design
Production rate	HSCW tpa		
Solid waste - wet weight			
Paunch generation rate	tpa		
Paunch landfilling cost	$ pa	☐*	☐*
Aerobic sludge	tpa		
Sludge landfilling cost	$ pa	☐*	☐*
Total landfill cost	$ pa	☐*	☐*
Total wet weight	tpa		
Solid waste - dry weight			
Paunch generation rate	tpa dw		
Aerobic sludge	tpa dw		
TOTAL	tpa dw		
TOTAL @ 10% moisture	tpa		
Minimum pelletizer size 8568 hpa	tph dry weight	**0.50**	
Minimum pelletizer size 4800 hpa	tph dry weight	**0.99**	

***** *information omitted due to confidential nature*

3.2 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.
- EBITDA increases at rate of 3.0% pa compound based on anticipated increases in landfill and coal costs due to CPI.
- All start-up costs are expended at the start of the first year of full scale operation.
- 30% increase in paunch and sludge generation from 2013 levels; or Stage 2 HSCW with paunch and sludge generation scaled accordingly to 2013 data.
- Paunch generated at 50% or 40% moisture, sludge generated at 12.5% moisture.
- Exchange rates: 1.00 EUR = 1.46 AUD[17]
- Plant to be located adjacent to truck unloading area, in proximity to the boiler house facility.

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

3.3 Battery Limits and Exclusions

Anaerobic digestion was excluded from detailed investigation as the existing WWTP is suitable for the current operations. Additionally, Covered Anaerobic Lagoons (CALs) have large footprint requirements and inherent risk associated with cover failures whist in vessel digestion is a comparatively high cap ex option compared to the invested WWTP capital. Anaerobic systems reduce sludge amounts by ~80%, however the energy content drops from as high as 23.24 GJ/t (ranges down to 11.16) to as low as 5.18 GJ/t (ranges up to 12.78).

Heat treatment (i.e. torrefaction or pyrolysis) was excluded as the aim of the process is not to generate a biochar / soil conditioner but rather to generate a fuel which can be utilized in the existing on-site boilers. Heat treatment is a comparatively high capex option which would still require densification (e.g. pelletization) to generate a biomass fuel plus requires a scale greater than the Stage 2 production rates (i.e. is not considered viable for the plant’s scale of operations).

[17] xe.com, essed 19 Dec 2014.

A DAF / Saveall system is currently not required due to the suitable performance of the existing WWTP. Such systems could be considered in the future should additional separation of solids and fats be required. The plant is undertaking works to separate process plant waste streams from black water, which in the future could further warrant a DAF / Saveall system.

Composting (e.g. enclosed, mechanical or engineered systems) on-site is not considered an option due to the geographic location of the facility.

3.4 Plant Technical Specification

Refer Appendix.

3.5 Fuel consumption: Current and Predicted

The fuel consumption was 5,166 t coal pa for a processing rate of 66,372 t HSCW pa. On a HSCW basis, energy consumption is 2016 MJ / t HSCW which is 10.04% more efficient than a "typical" plant even when the LHV of coal is taken into account.

For the mass and energy balance, the 2016 MJ / t HSCW energy consumption ratio was kept constant and the HSCW was increased with an associated increase in coal tonnage consumption.

The rate of ash generation will increase as the biomass pellets contain 41% of the heat of coal per tonne (10.5 for the paunch/sludge pellets and 16.7 for paunch pellets versus 25.9 GJ/t for coal) whilst also having over double the ash (14.3% dry weight for paunch/sludge, 9% for paunch versus 7% dry weight for coal). Table 6 shows the results for the scenario where HSCW increases by 30%.

Table 6: Key findings from mass and energy balance for 30% increase in HSCW pa.

<table>
<tr><th colspan="2">Feed stock</th><th colspan="2">Current</th><th colspan="2">Basis of Design</th></tr>
<tr><td colspan="2">Coal Only</td><td>5,166 tpa</td><td>133,799 GJ pa</td><td>6,716 tpa</td><td>173,939 GJ pa</td></tr>
<tr><td rowspan="3">Blended feed</td><td>Paunch and sludge pellets @ 10% moisture</td><td colspan="2" rowspan="3">NA</td><td>4,750 tpa</td><td>49,876 GJ pa
(29% total heat)</td></tr>
<tr><td>Coal</td><td>4,790 tpa</td><td>124,064 GJ pa
(71% total heat)</td></tr>
<tr><td>TOTAL</td><td>9,540 tpa</td><td>173,939 GJ pa</td></tr>
<tr><td colspan="2">Ash generation rate</td><td colspan="2">325 tpa
(coal only)</td><td colspan="2">913 tpa
(blended feed)</td></tr>
</table>

3.6 Boiler Modifications

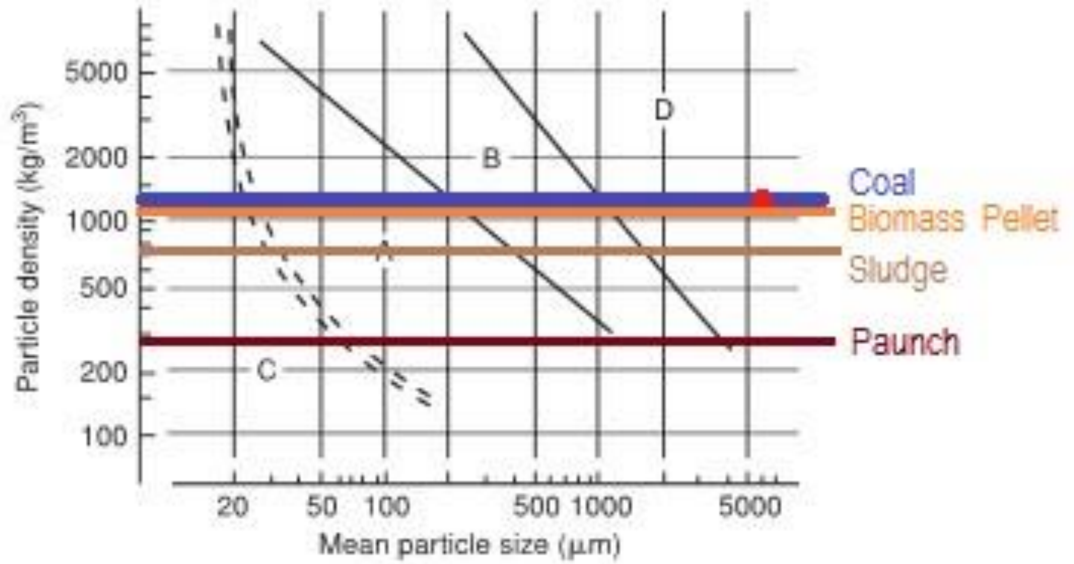
The detailed boiler modifications for coal/biomass pellet co-firing are outside of the scope of this project. Where the fuel is relatively high in density (e.g. > 500 kg/m^3 bulk density), hydrophobic, low dust, moisture ~10% and a 25 mm top size, then minimal works are expected to be required. The boiler plate states 8 – 10 tph steam at 9 Bar (approx. 188 ^{o}C) for an 8 MW boilers using paddle feeders with a capacity of 0.7 kg/sec (two off 0.35 to 0.09 kg/sec). The predicted current and instantaneous future rate of coal consumption is 0.347 kg/s. This equates closely with the estimated current paddle feed rate of 40% of the rated capacity (0.28 kg/s). The mass flow of the blended coal / pellet feed is predicted to be 0.471 kg/s which is 67.2% of the maximum feed rate. The pellet would need to have a 53% moisture content before the feed rate maximum is exceeded. The plant wishes to retain the duty / standby whereby only one boiler is in operation at any time. Under normal, steady-state operation the boiler delivers approximately 9 tph, with a peak of up to 11 tph. The plant directed that the biomass should be pelletized and not blended with coal as a powder due to fuel handling and particle residence time / combustion issues may occur with powdered fuel as opposed to a pellet.

An indicative quotation was received from Emerson that boiler review and biomass / coal co-firing optimization can be completed for approximately $15,000 by a global biomass co-firing expert. This includes a full review of a combustion trial with the biomass fuel, time on-site, control system tuning and travel costs. This excludes stack monitoring that may be required under EPA licensing modifications.

The original 2000 EPA agreement was for coal only. Additional operating costs for a mixed fuel will need to be considered. The measured discharge temperature was 102 – 114^{o}C at a volume range of 16,600m3/hr to 23,800m3/hr. An issue with the boiler is that the air to fuel ratio is locked in for a given operating scenario. Generally, air flow rates are at a minimum. Due to recent domestic coal availability limitations, only Run of Mine (ROM) coal is available hence the fuel specification was changed to 0 – 25mm, with no change in the operability of the boiler. The main feedstock challenge is if it is wet, resulting in bridging / blocking of the fuel feeding mechanism. The initial fuel specification was for 6 – 25mm (up until 5 to 6 yrs ago).

The incineration of dewatered sludge directly and after indirect heating is well documented, without the need for particularization or densification[14]. With further reduction in CH_4 and N_2O emission, the overall outcome of co-firing is a percentage reduction of global warming potential (CO2 equivalent) higher than the percentage of biomass in the blend.

Presented in Figure 5 below is a diagram showing how fluidizing properties changes with particle density and particle diameter. The red dot shows the minimum original particle size for the fluidized bed at the approximate density of bituminous coal. The blue line shows the current approximate specification for 0 – 25 mm bituminous coal, the orange line for biomass pellet, the brown line for sludge and the maroon line for paunch. Understanding the density and particle size of each feed will assist to determine the flowability / fluidization of the fuel. It would appear that, based on the original boiler specifications that fuel of group D and certainly A, B or D should be targeted.



Geldart's classification of fluidization behaviour for fluidization with ambient air.

The salient features of the four groups identified may be summarized as follows:

- *Group A*: Materials in this group show considerable expansion of the bed when fluidized. They also have good air retention properties, for when the air supply is cut off relatively slow settling of the bed results.
- *Group B*: Materials in this group fluidize very well and would typify the generally accepted model of fluidized bed behaviour. At air velocities above the minimum fluidizing velocity the expansion of the bed is small, and bubbling occurs at or just above this value. Collapse of the bed is rapid when the gas flow is shut off.
- *Group C*: This covers the cohesive materials. These are difficult to fluidize satisfactorily because of the high inter-particulate forces resulting from the very small particle size. Attempts to fluidize such materials usually results in the formation of stable channels or in the whole bed rising as a plug. Some success may be achieved, however, with the aid of mechanical vibrators or stirrers.
- *Group D*: This group includes materials having a large particle size and/or a high particle density. Fluidization behaviour is generally similar to Group B materials, but the quantity of air required trends to become rather high.

Figure 5: Geldart's classification of fluidization behaviour in ambient air[18].

18 Geldart, D. (1973). "Types of gas fluidization". *Powder technology* **7** (5): 285–292.

4 Capital Cost Estimate

4.1 Vendor Plant Submissions

Summarized below are the vendor submissions received in response to the technical specification for a plant to pre-treat and pelletize paunch and sludge.

Table 7: Summary of Vendor Submissions

Company	Contact	Summary
Palmer Milling Pty Ltd	pme@pme.net.au Michael Palmer 02 6962 7411 Griffith NSW Australia Phone: (02) 6962 7411 http://www.pme.net.au/pressp.html	1 tph Grinding system: $☐ 1 tph Pelletizer: $☐ Supply, transport, installation. Palmer Milling do not supply drying equipment.
Mahltechnik Gorgens GmbH	Ermano Gorgens Norfer Strasse 22, 41539 Dormagen, Germany. T: +49213324510; F+492133245144; M: +491737090991 ermano.goergens@mahltechnik-goergens.de Australian support: Chris Dahm M: 0409 559 915; E: chrisdahm@bigpond.com	Grinding and Drying: ☐ Euro (1650 kg/h moisture removal to dry feed from 77.5% to 14% moisture; 1185 kW heat; 250 kW power). Mahltechnik-Goergens do not supply pelletizing equipment.
		Grinding and Drying: ☐ Euro (380 kg/h moisture removal to dry feed from 50% to 14% moisture; 380 kW heat; 135 kW power).
		Grinding and Drying: ☐ Euro (170 kg/h moisture removal to dry feed from 60% to 14% moisture; 170 kW heat; 40 kW power).
Satake Australia Pty Ltd	Graham Podboj Feed Milling Technical Sales Representative E: gp@satake.com.au 15 Leland Street, Penrith NSW 2750 P: +61 2 4725 2600 M: 0487 001 350	2 tph pelletizer: $☐. Includes: pelletizer, cooling system, support structure and walkways, mechanical installation, commissioning, engineering and training. Satake Australia Pty Ltd do not supply drying equipment.
Keith Engineering (Australia) Pty Ltd	Anthony Boarer, Project Manager 20 Kellet Close, Erskine Park, NSW 2759. T +61 2 9852 1000 admin@keitheng.com.au	1.0 tph water removal: $☐. 0.5 tph water removal: $☐. Excludes: freight, installation, commissioning.
Flottweg Australia Pty Ltd	Stuart Paterson 90A Pacific Highway Roseville NSW 2069 Sydney Australia Telephone:+61 2 9410 2255 Facscimile:+61 2 9410 1466	C3E-4/454 skid mounted $☐ (able to process all sludge solids, with ideal solids inlet of 2%).

Company	Contact	Summary
	Mobile : 0410604391 E: stuartlpaterson@ozemail.com.au	
M&E Equipment Traders - SECOND HAND	Steven Baldini General Manager 4-8 Ferndell St. Sth Granville NSW 2142 P: +61 2 9725 6477 M: 0418 266 643 E: steven@equipmenttraders.com.au	Reconditioned centrifuge / decanter rated to 5tph with mono-pump: $56,000. Expected to take sludge from 78% to ~50% moisture. ($40k supply, $9k rebuild). Hammer mill: $18,000. Freight estimate: $7000. Estimated Total Capital Investment Installed: $148,000.
FEECO International Australasia	Barry Wilson Director/Operations Manger Feeco International Australia 0430 600575 E: Bwilson@feeco.com Factory 4, 4 Bormar Drive Pakenham, Victoria, 3810 Phone: 03 59404994	FEECO do not supply pelletizing equipment.
Macro Milling Pty Ltd / Andritz Pty Ltd	John Sich E: john.sich@macromilling.com.au Phone: +61 (0) 2 46 55 46 53, Mob +61 401 03 1144, E: Cameron.symons@andritz.com Phone +61 (3) 8773 4812 M: 0407 815 229	Systems of this scale not supplied.

4.2 Preliminary Design Considerations – Building

Capital cost has been allowed for an 18,500 mm by 16,000 mm building with two wide bay roller doors. The lump sum price includes slab/pier costs, construction, delivery, council application fee, engineering certification, minimum cladding requirements. Earth works, downpipes and completion of the development application are excluded. Figure 5.1 below provides an indication of the building size and layout. No site specific foundation requirements are expected for the slab or shed (e.g. micro-piling). It is likely that this building is oversized for the Stage 2 paunch process scenario.

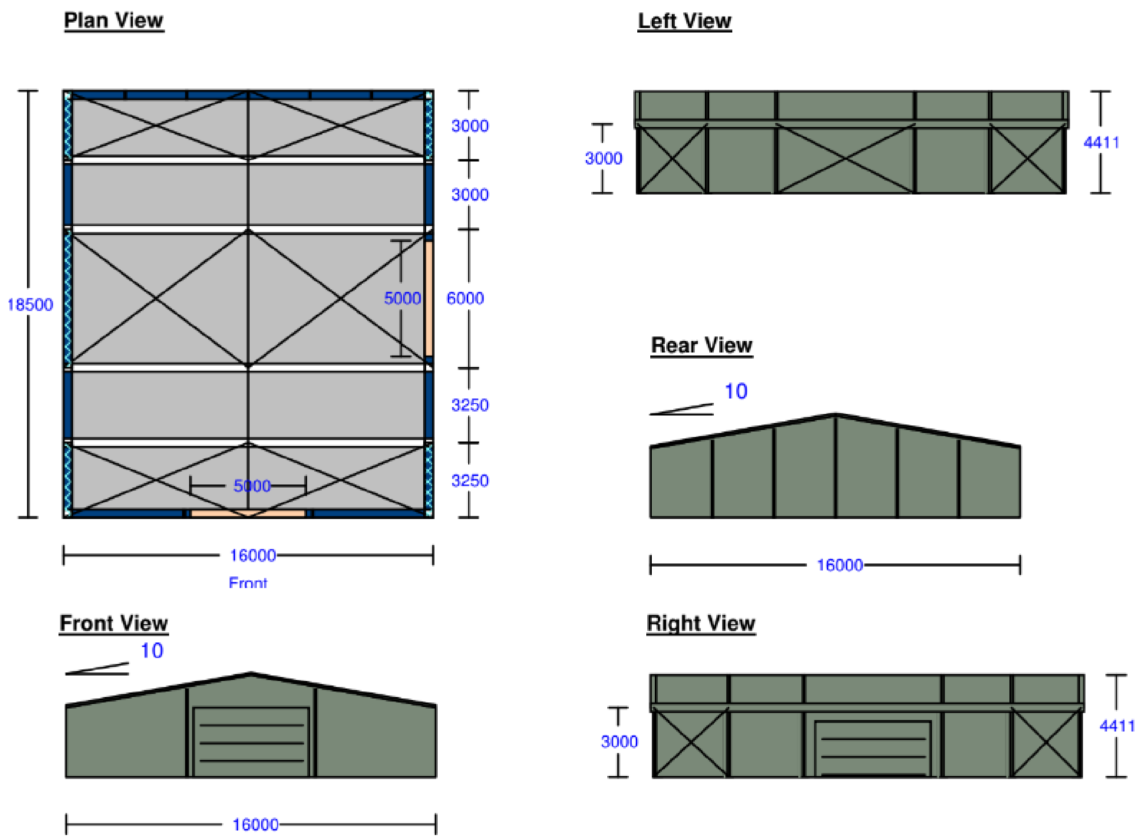


Figure 6: Indicative building layout for proposed facility.

4.3 Preliminary Design Considerations – Tie-ins

A key cost component is the tie-ins for the plant. The table below summarizes the preliminary plant requirements. It is likely that the flue gas ducting and off-gas ducting presented in this section is oversized for the Stage 2 paunch process scenario.

Table 8: Preliminary design details for plant tie-ins for a 30% HSCW increase and pelletizing of paunch and sludge

Item	Tie-in information
Steam	20 m lagged pipe to an existing steam header operating at ~9 Barg to a new pelletizer which requires 7 - 9 Barg. Steam requirement is ~50 kg/hour. Pipe diameter optimization recommend 20 NDmm pipe (~14 to 15 ID mm) required.
Flue gas ducting	20 m lagged ducting from an existing flue gas handling system. Flue gas at ~110 oC, 16,600 - 23,800 m^3/h. Assume 600 NDmm 304ss duct (e.g. spiral wound stainless steel) with one expansion joint. A knock out drum may be required for any condensing vapour, however this can be considered in the detailed design stage.
Off-gas ducting (to bio-scrubber)	60 m ducting to an existing bio-scrubber. Off-gas at ~40 oC and 57,492 m^3/h. Assume 1050 NDmm duct (e.g. spiral wound stainless steel) with one expansion joint. A knock out drum may be required for any condensing vapour, however this can be considered in the detailed design stage.
Compressed air supply line	10 m. Predominately for control system and cleaning. Assume 20 NDmm poly-pipe.
Drainage (storm water)	10 m. Assume 80 NDmm poly-pipe.
Waste water	15 m. Predominately for wash down and cleaning. Assume 25 NDmm poly-pipe.
Potable water	15 m. Assume 25 NDmm poly-pipe.Predominately for wash down and cleaning.
Power	30 m. Load estimate ~100 to 200 kW.
Communications	20 m.

4.3.1 STEAM LINE

For steam, the optimized pipe diameter was estimated at 20 NDmm. If steam is received at 9 barg, the discharge pressure will be approximately 8.7 barg. As the facility is able to accept down to, it is possible that a 15 NDmm steam line may suffice.

The additional capital equipment costed for as part of the steam line includes ball valves and a pressure reducing valve. FLUE GAS LINE

For the flue gas ducting, the optimized duct diameter was calculated at 800 ND mm for 23 800 m^3/h, which would result in a back pressure of 0.27 kPa, not including the heat exchanger. Where a backpressure of 1 kPa is acceptable then the ducting diameter could be reduced to 600 ND mm. At the lower flue gas flow rate of 16 600 m^3/h, the duct is calculated to be 650 ND mm with a pressure drop of 0.31 kPa, or for 600 ND mm ducting a pressure drop of 0.42 kPa.

4.3.2 OFF-GAS DUCTING

It is assumed that 14,102 tpa moisture is required to be removed. At an outlet temperature of 30 ^{o}C, the maximum water content is 30.4 g/m^3, at 40 ^{o}C it is 51.1 g/m^3 or at 60 ^{o}C it is 130 g/m^3. In the detailed design stage, consideration will need to be given to the optimal temperature to remove moisture but not to be so high as to impact the operation of the bio-scrubber. Assuming that the off-gas is at 40 ^{o}C, a gas flow rate of 57,492 m^3/h is required (in practice, the temperature will need to be higher to ensure that the water is not condensed before reaching the bio-scrubber).

For the off-gas gas ducting, the optimized duct diameter was calculated at 1227 ND mm, however the largest most common diameter is 1050 NDmm and this line will almost invariably require a fan blower either at the point of incoming air or to convey the moist air. For a 1050 ND mm duct with a fan blower operating at 70% efficiency, approximately 24 kW of power will be consumed (in the duct line only). Additional fan power will be required to overcome pressure drops in the inlet line and in the unit operations of drying and the bio-scrubber itself, hence a fan power load of 50 kW has been assumed.

4.4 Approximate Plant Equipment Area

The figure below provides a preliminary estimation of the surface area for the plant equipment only of approximately 8.5 m x 5.0 m. It is likely that this plant equipment area is oversized for the Stage 2 paunch process scenario.

Access of approximately 5 m has been allowed around the equipment, hence a slab size of 18.5 x 16 m has been allowed for. The approximate footprint is shown in the figure below with the tie-in to the pipe rack indicated by a red cross.

The capital cost estimate allows for a simple industrial shed to cover the slab and to a height of 4.0 m with two 5.0 m wide manual roller access doors.

4.5 Indicative Facility Footprint

Indicative site footprint: The cross below shows the tie-in point on the pipe rack to utilities. The proposed location is between the truck wash shed and the boiler, with the expectation that the plant can be manned 24 hrs per day, 5 days per week.

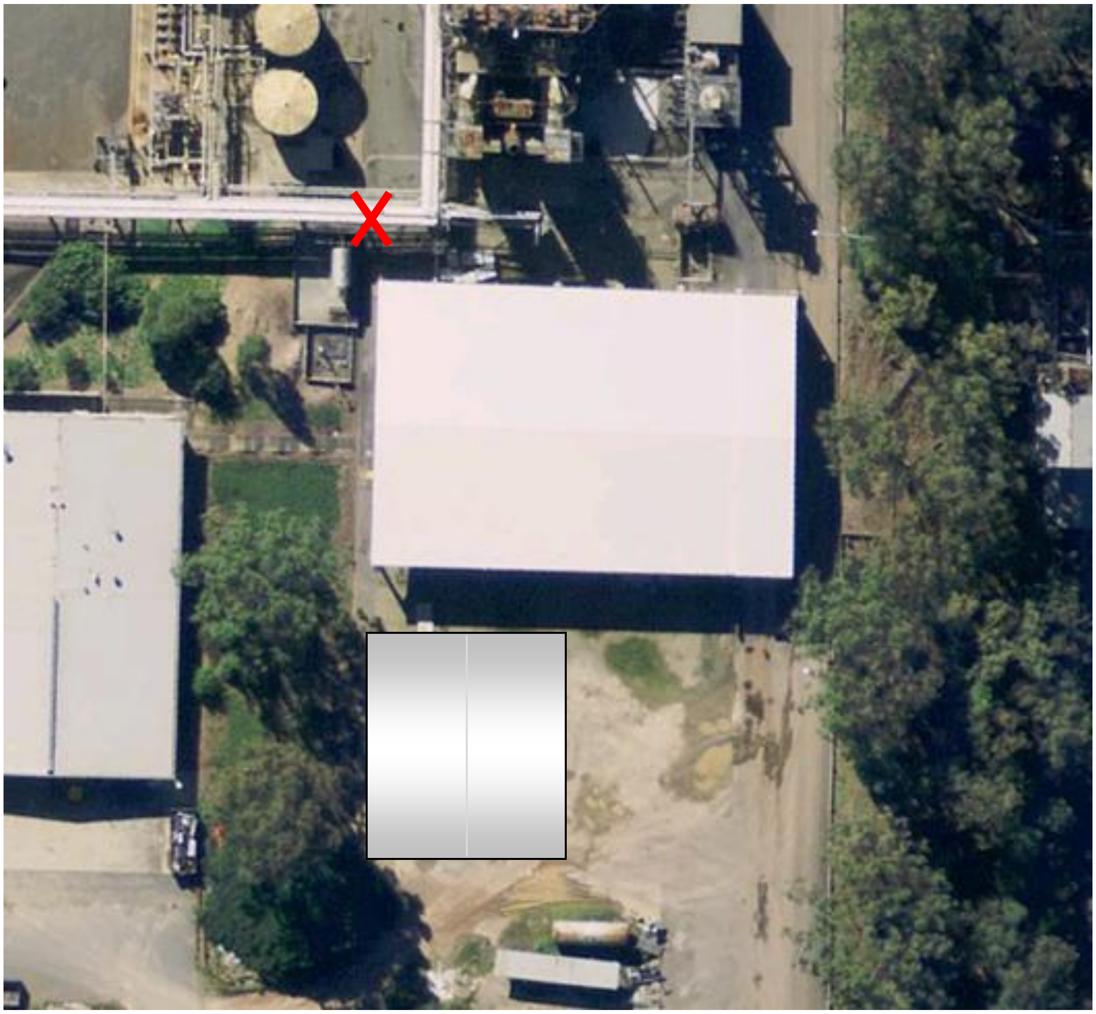


Figure 8: Indicative facility building footprint.

4.6 Labour Rates

Labour costs per hour for the various technical installation works were utilized.

Table 9: Technical labour rates for estimation of installation of plant equipment

Discipline
A - General
B - Earthworks
C - Concrete
D - Steelwork
E - Platework
F - Mechanical
G - Piping
H - Electrical
J - Instr & Control
M - Buildings & Architectural
N - Demolition, Relocation & Refurbishment
P - Indirects

4.7 Total Capital Investment – 30% HSCW Increase

A detailed cost estimate was developed for the scenario of “30% Growth Scenario: Pre-treatment then pelletization of 77.5% moisture Paunch and Sludge”. Similar cost estimation tables were generated for the other three scenarios presented in the executive summary.

4.8 Total Capital Investment – Stage 2 Paunch Treatment

A detailed capital cost estimate was generated to estimate the total capital investment to procure and install a pre-treatment and pelletizing plant for the Stage 2 paunch.

This scenario considered the pre-treatment then pelletization of 50% moisture Paunch to off-set coal (fuel pellets) at a rate of 3630 tpa dw (4221 tpa pellets). Some key assumptions were:

- Mahltechnik Goergens supplied heat exchanger is suitable for pre-heating air via the use of coal boiler flue gas and recycled exhaust air i.e. no additional heating costs.
- Mahltechnik Goergens vendor budget was modified to actual feedstock flow rate via a “capacity ratio exponents” method otherwise known as “Parametric cost estimation”.
- Mahltechnik Goergens vendor budget was modified to reduce budget associated with natural gas fired burner and burning chamber.
- Further capital cost savings could be achieved via:
    - The lower heat load will reduce the diameter of the flue gas and return gas ducting diameter hence reducing material, installation and lagging costs.
    - Foot print of the slab and building likely to be reduced.
    - Refinement of earth works and building supply scope of works.
    - Vendor supplied electrical equipment not to AS3000, hence can include all electrical works in lump sum pricing. Additionally, reduced scale of plant likely to reduce electrical requirements. Hence, high potential for net savings on electrical equipment supply / installed by removing electrical components from vendor scope and including in local contractor scope.
    - Utilization of mechanical / electrical subcontractors at preferential rates or personnel available on-site.
    - Where waste heat cannot provide suitable air temperature, use of a steam heat exchanger or CNG burner is reticulated natural gas is not available.
    - Reduce pelletizing plant or sections that can be scaled down to be rated to 0.5 tpa dw rather than 1.0 tpa dw.

5 Total Production Costs / Revenue / Savings

Current ash generation from the boiler is estimated at 325 tpa, with an ash generation rate for the coal / biomass blend estimated to be 913 tpa. Options for re-use include the cement industry, clay, ceramics, bricks, tiles, pipes, pottery and aggregate. It is anticipated that the existing hook bin system will be used to truck paunch to the pre-treatment plant with the sludge transported in a similar fashion or slurry pumped to the pre-treatment plant. Ideally, the new plant will be positioned as close as possible to the source of the biomass. It is estimated that 6 truck movements per day, each of 10 t will be required.

Current coal ash collection is Mon-Wed-Fri; it is anticipated that coal ash collection will increase to a daily collection Mon-Fri. It is to be determined as to whether the entire facility should be enclosed with a biofilter. A base line on the ODUs will be completed by the end of December 2015. In terms of this project, it is assumed that sufficient biofilter capacity is available. Sludge currently requires 4 x 10 t truck movements per day. This equates closely to the mass balance estimate of 44.0 t per day. The cost implication of the different production rate is to be considered (i.e. 0.5 or 1.0 tph).

Table 11: Estimate of Total Production Costs / Revenue / Savings for 30% HSCW increase; paunch and sludge pelletization.

		#	Rate	Value $ pa
Personnel - Pelletizer; 70k + 40% on-costs	pa	0.5		
Personnel - Milling and drying; 70k + 40% on-costs	pa	0.5		
Pelletizer plant Maintenance and repair @ 10% equipment cap ex	pa			
Pretreatment plant Maintenance and Repair				
Operating supplies and consumables @ 1% equipment cap ex	pa			
Ash haulage	tpa			
Process Steam			$/tonne or $ / GJ	
Saturated steam (700 - 900 kPa)	kg/h	45.45		
Saturated steam (700 - 900 kPa)	GJ pa	26006		
Electrical load (kW)		Power From Grid		
Bucket Elevator from pre-treatment to pelletizer	kW	0.75		
Pre-pellet Bin Discharge screw	kW	1.5		
Bin spreader screw	kW	0.75		
Conditioner screw	kW	3		

		#	Rate	Value $ pa
Stainless steel force feeder	kW	0.55		
PP300SW Pellet Press	kW	37		
Hot pellet screw conveyor	kW	0.55		
Hot pellet bucket elevator	kW	0.75		
Cooler discharge screw	kW	1.1		
Cooler fan	kW	7.5		
Cold pellet bucket elevator	kW	0.75		
Pre-treatment and drying plant	kW	250		
General power (inc lighting)	kW	2		
Instrument / compressed air	kW	0		
Control system kW	kW	0.5		
Sub-total Electricity		306.7		
Chemicals				
Cleaning				
Subtotal Chemicals				
Potable water			$/kL(estimate)	
Potable water for cleaning	kL pa	316		
Waste water				
Cleaning	kL pa	316		
DERM Environmental Fee	Excluded			
TOTAL ESTIMATED ANNUAL OPERATING EXPENSES/ P A	$ pa			560,320
Revenue			$ / GJ	
Coal off-set	GJ pa	49,876		
Paunch - Landfill cost reduction	tpa			
Sludge - Landfill cost reduction	tpa			
TOTAL ESTIMATED ANNUAL REVENUE Per Annum	$ pa			759,391

		#	Rate	Value $ pa
Net Revenue / Cost Savings	$ pa			199,071

6 RESULTS OF CBA EBITDA ANALYSIS

6.1 CBA Base Case Results

Similar CBA analyses to that presented below were completed for the scenarios resented in the executive summary.

Basis of Design: 30% growth from 2013 operations.

Days per annum	316
Head per day	1242
Total Capital Investment	$ 3,292,112

Table 12: Cost-benefit analysis for 30% HSCW increase; paunch and sludge pelletization.

Interest Rate	0.07									
Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Cash Flow	- 2,881,423	199,071	199,071	199,071	199,071	199,071	199,071	199,071	199,071	199,071
Discounted NCF	- 2,881,423	186047	173876	162501	151870	141935	132649	123971	115861	108281
Cumulative NCF	- 2,881,423	- 2,695,375	-2,521,499	-2,358,998	- 2,207,128	- 2,065,193	- 1,932,544	- 1,808,573	- 1,692,712	- 1,584,431
Discounted Payback Period Calculation	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NPV	- 1,393,376	$								
Discounted Payback period (yrs)	**N/A**	years								
IRR	-12	%								
ANB	- 139,338	Annual Net Benefit								
$ / head simple	- 0.20	$								
$ NPV / head simple	-0.36	$								
Simple payback (yrs)	15.5	Yrs								

7 Greenhouse Gas Emissions and Energy Considerations

7.1 Emissions Reduction Fund (ERF) – *INDICATIVE ANALYSIS*

The passage of the Direct Action legislation through the Senate means that the first ERF auction could be held as early as Q1 2015. Table 8.1 below and Appendix 1 provide an indicative summary of potential revenue from the proposed ERF. It must be noted that the methods are currently only in draft form and there could be changes to these methods before the auctions occur. The results in Table 8.1 are estimates only for the 30% HSCW increase based on the EXPOSURE DRAFT Carbon Credits (Carbon Farming Initiative) Methodology (Alternative Waste Treatment) Determination 2014. A conservative estimate is made that all of the organic waste is classified as “sludge rather than “food” waste.

It must be stressed that the ERF is currently not active and that the price per Australian Carbon Credit Unit (ACCU) is unknown and will be subject to market fluctuations.

Due to the market variability of the value of abatement credits under the ERF, it was decided to exclude ERF revenue. Additionally, due to the method for abatement associated with deferred landfill, annual revenue “accrues” and hence will have minimal impact on the discounted payback period (DPP), but will have a greater impact on the IRR. Refer to the Appendix for further information.

Table 13: Indicative estimate of total ACCU revenue – calculations based on a DRAFT method

Future value of ACCU under the proposed ERF	Indicative estimated revenue over 7 yr crediting period $
\$5 / t CO_2-e	131,083
\$6 / t CO_2-e	157,299
\$7 / t CO_2-e	183,516
\$8 / t CO_2-e	209,732
\$9 / t CO_2-e	235,949
\$10 / t CO_2-e	262,165
\$15 / t CO_2-e	393,248

7.2 Boiler Emissions – 30% HSCW Increase Paunch and Sludge

Not taking inefficiencies into account, when the paunch and sludge is co-fired, it is estimated that 49,876 GJ pa of heat is expected to be created from the biomass. The pre-treatment process calls upon approximately 36,688 GJ pa of steam with pelletizing requiring approximately 500 GJ pa of steam. Hence, the heat balance results in the creation of approximately 12,696. If it is assumed that the boiler and steam delivery system is 80% efficient, then the net heat drops to 3400 GJ pa. At 3400 GJ pa coal savings, Scope 1 emissions are reduced by approximately 301 t CO_2-e pa.

7.3 Boiler Emissions – Stage 2 Paunch

Not taking inefficiencies into account, when the paunch is co-fired, it is estimated that 70,491 GJ pa of heat is expected to be created from the biomass. The pre-treatment process calls upon approximately 380 kW for air heating, of which it is assumed that this heat can be obtained from boiler flue gas.

7.4 Net Emissions - 30% HSCW Increase Paunch and Sludge

The Scope 2 (mains electricity) emissions are calculated at 88 t CO_2-e pa. Avoided coal associated emissions are estimated at 2106 t CO_2-e pa. Due to avoided landfill emissions, over the first 7 years of operation, the facility is estimated to reduce emissions by 26,217 t CO2-e. Hence, over the first 7 years the average emissions reduction is estimated at 40,339 t CO2-e.

7.5 Net Emissions - Stage 2 Paunch

Where all air heating is achieved via coal boiler flue gas, the main additional emissions are the Scope 2 (mains electricity) emissions which are calculated at 48 t CO_2-e pa. Avoided coal associated emissions are estimated at 6219 t CO_2-e pa. Due to avoided landfill emissions, over the first 7 years of operation, the facility is estimated to reduce emissions by 31,968 t CO2-e (if paunch can be classified as “food” waste). Hence, over the first 7 years the average emissions reduction is estimated at 75,171 t CO2-e.

8 Alternative Processing Options

A number of alternative processing options exist for reducing costs associated with paunch and sludge outside of those presented in the executive summary. These are summarized in the table below.

Table 14: Alternative processing options that were briefly analysed

Option	Description	Indicative Cap ex	Opex / Revenue / Savings	Indicative Simple Payback
A	30% HSCW increase: Reconditioned used decanter to dewater sludge to ~20% moisture before landfilling. Additional advantage that some load will be taken off the existing WWTP / sludge treatment to dilute decanter feed to 2% solids. A key disadvantage is the return of waste water back to the WWTP.	$148,000	$140,165 tpa solid waste cost saving	1.1 yrs
B	30% HSCW increase: Drying and milling of paunch and sludge 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
C	Anaerobic digestion of aerobic sludge (5 batch high-rate AD vessels; MTU-DD biogas engine).	$2 mil + (testing required)	$0.8 mil power and waste cost savings	2.5 yrs+ (testing required)

Option	Description	Indicative Cap ex	Opex / Revenue / Savings	Indicative Simple Payback
D	Pre-treatment of paunch only followed by pelletizing. Note: long payback as due to low moisture landfill cost savings are low.	$1.93 mil	$0.27 mil	9.3 yrs
E	Stage 2 Paunch dried via steam rotating drum followed by pelletization	$2.2	$0.19 pa	12.3
F	Where sludge is to be pelletized, preliminary processing with reconditioned decanter to dewater sludge to ~20% moisture. Additional advantage and disadvantage as per A.	$148,000 (in addition to base case)	$ 56,959 tpa energy cost saving	2.6 yrs

9 Sensitivity Analysis

The key parameters impacting the economics of the project, in order of relative impact, are:

[1] Coal price
[=1] Pellet lower heating value
[3] Landfilling costs
[4] Capital cost

The lower heating value of the pellet (GJ / t) is multiplied by the coal energy price ($ / GJ), hence the same percentage change in either variable results in the same impact on discounted payback period (DPP). However, due to the coal price being affected by external market, the coal price is anticipated to result in greater variability of the project economics. It is noted that Newcastle coal for next month (Match 2015) is currently at $AUS 93.3, which is a 16% increase compared to the assumed $80.79 / t, hence the DPP based on March 2015 coal prices is 7.4 years.

Presented in Figure 10.1 below are the changes in the DPP due to changes in each parameter over the range of -50% to +100 %.

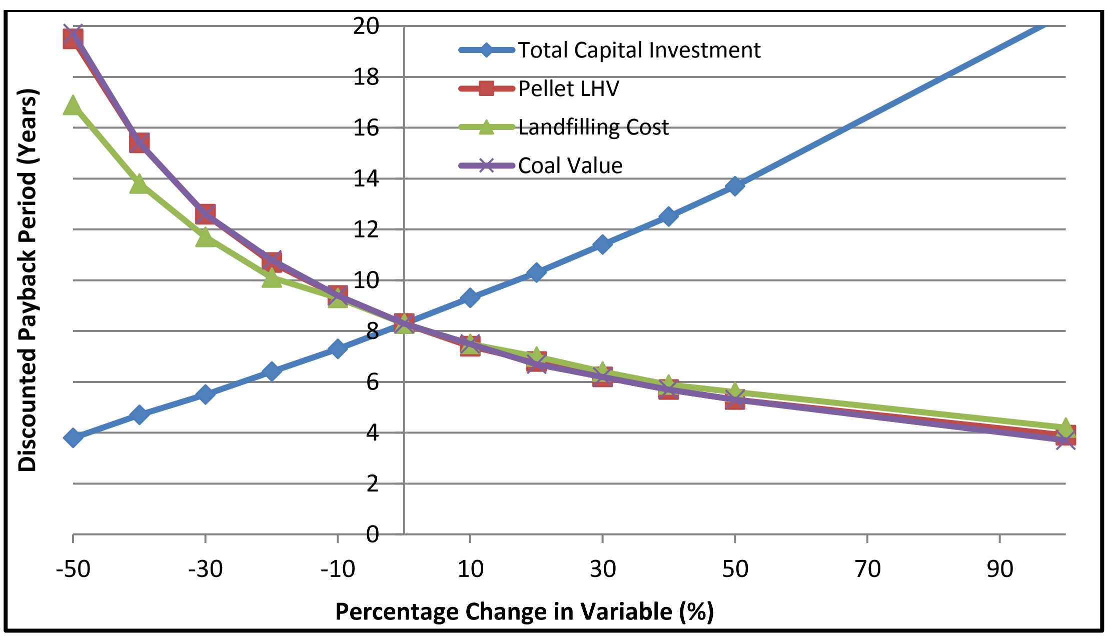


Figure 9: Sensitivity analysis for impact on discounted payback period (DPP) for variations in the Coal Energy Value ($/GJ), Pellet LHV (GJ / tonne), Landfilling Cost ($ / tonne) and Total Capital Investment (TCI) where the parameters are varied over the range from -50% to +100%.

10 Future Works

List below are the recommended stages of future work:

[1] Complete the Front End Engineering Design (FEED) with associated fixed and firm pricing for sludge decanting. The plant has access to a Flottweg unit, hence could achieve a rapid payback period (likely <1 year) by avoiding the initial capital outlay for a new decanter.

[2] Send paunch feed to Europe for drying testing. Ideally, a sufficient tonnage should be dried to enable pelletizing and co-firing trials.

[3] Where [2] above is not possible, milling and drying could be completed locally to enable a pelletizing and co-firing trial.

[4] Consider a biomass powder co-firing trial (i.e. un-pelletized paunch power).

[5] Determine the lower heating value (GJ / tonne) for the paunch powder and pellet.

[6] Depending upon results of stages [2] – [5] (i.e. technical viability of direct combustion of powdered biomass versus pellets), completion of Front End Engineering Design (FEED) and fixed and firm pricing for the chosen process.

[7] Project registration with the Emissions Reduction Fund (ERF). This can be completed at any time before the final investment decision.

[8] Project execution.

[9] Boiler optimization once sufficienct amounts of biomass fuel is available (e.g. consider control system, operating parameters and fuel feeding).

11 APPENDICES

11.1 Alternative Waste Treatment (Landfill avoidance) under the Emissions Reduction Fund

Source: EXPLANATORY STATEMENT Carbon Credits (Carbon Farming Initiative) Act 2011, Carbon Credits (Carbon Farming Initiative) Methodology (Alternative Waste Treatment) Determination 2014 - EXPOSURE DRAFT

Paunch and DAF Sludge included in analysis

Key issues: waste categorized as "food" or "sludge"

Reporting period	A0	A1	A2	A3	A4	A5	A6
1	936	936	936	936	936	936	936
2		936	936	936	936	936	936
3			936	936	936	936	936
4				936	936	936	936
5					936	936	936
6						936	936
7							936
Anet	936	1873	2809	3745	4682	5618	6554

TOTAL ABATEMENT OVER FIRST CREDITING PERIOD 26,217 t CO2-e

Equation 1

A_{net} = A0 - Aaccrued t CO2-e pa

Anet =		carbon dioxide equivalent net abatement amount, in tonnes CO2-e, f
A0 =		activity abatement portion A0, in tonnes CO2-e, for the reporting peri
Aaccrued =		amount, in tonnes CO2-e, that is the sum of: (a) each activity abater

Equation 2

Ay = (EB - EP)/7

Ay TOTAL		936.3			
	Paunch	Sludge			
Ay	607.857371	328.446615			activity abatement portion A0, A1, A2, A3, A4, A5
EB	4,347	2,362	t CO2-e pa		Baseline emissions using Equation 3
EP	92	63	t CO2-e pa		project emissions, in tonnes CO2-e, worked out us
	1.00	2.00	(assumed all biogas is eligible)		proportion of biogas that is generated by eligible w
$Mcom_{,h}$	-		-	m^3 pa	methane combusted by combustion device *h*, in c

Step 1.1	γ	0.014246	0.014246	factor to convert cubic metres of methane at stand

Equation 3

$$E_B = (1 - W_{LFG}) \times M_B \times (1 - OF_{LF}) \times GWP_{CH_4}$$

EB	4347	2362	t CO2-e pa	863 t CH4 as sludge	Baseline emissions using Equation 3
WLFG	30%	30%	QLD		average capture rate set out in the table in subsect
Mb	328.59	178.56	t CH4	65.1968 t CH4 as sludge	methane generation potential, in tonnes CH4, of th
OFLF	0.10	0.10	p 245 13/14 NGER determination		oxidation factor for near surface methane in landfill
GWPCH4	21.00	21.00			Global Warming Potential for methane in regulatior
WM	4640.625	10692	tpa	18.5625	WW tpd waste: DAF sludge plus digester sludge

Equation 4

$$M_B = \sum_w \left(WM_w \times DOC_w \times DOC_{F,w} \right) \times MCF \times W_{LFG,CH_4,def} \times F_{C \rightarrow CH_4}$$

WMW	3904	10692	tpa	quantity, in tonnes, of waste mix type w present ir
DOCW	0.15	0.05		degradable organic carbon value for waste mix typ
DOCF,w	0.84	0.50		degradable organic carbon dissimilated for waste
MCF		1		methane correction factor for aerobic decompositi
WLFG,CH4,def	0.5	0.5		fraction, by volume of methane generated in landfil
Fc->CH4	1.336	1.336		1.336, being the factor to convert a mass of carbo

Equation 5

$$WM_W = \left(\frac{Q_{MSW}}{TW} \times PW \times W_{MSW,w} \right) + \left(\frac{Q_{C\&D}}{TW} \times PW \times W_{C\&D,w} \right) + \left(\frac{Q_{C\&I}}{TW} \times PW \times W_{C\&I,w} \right)$$

QMSW	0			No municipal solid waste
QC&D	0			No construction and demolition waste
QC&I	3904	10692	tpa	
PW	TW			quantity, in tonnes, of putrescible eligible waste p
WC&I,w	Use 1.0 rather than default as C&I is assumed to be 100% food			proportion of waste mix type w in the eligible wast
TW	= QC&I			total quantity, in tonnes, of eligible waste received

Equation 6

Assume:

PW = TW

Equation 7 - 8 Assumed not applicable

Equation 9

$$E_p = \left(\frac{PW}{TW} \right) \times \left(E_{Fuel} + E_{Elec} \right) + E_{Waste}$$

Efuel	Assumed negligible			
Eelec	44.64	30.6	t CO2-e pa	
Ewaste	48	33	t CO2-e pa	emissions, in tonnes CO2-e, from the processi

Equation 10 - 11 Assumed negligible

Equation 12

$$E_{Waste} = E_{compost} + E_{AD} + E_{com}$$

					emissions, in tonnes CO2-e, from composting
Ecompost	0	0	t CO2-e pa	180	out in accordance with section 28 (Equation 13
EAD	0	0	t CO2-e pa		Assume emissions from anaerobic and combus
Ecom	47.6	32.6	t CO2-e pa		

11.2 Appendix 2: Full Basis of Design Calculations

11.3 Appendix 3: Vendor Submissions

Company
Mahltechnik Gorgens GmbH: three submissons.
Flottweg Australia Pty Ltd
Palmer Milling Pty Ltd
Satake Australia Pty Ltd
Keith Engineering (Australia) Pty Ltd
M&E Equipment Traders: Reconditioned decanter and hammer mill

11.4 Consumer Price Index (CPI)

CPI data for the appropriate period was accessed from the Australian Bureau of Statistics (ABS), http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/6401.0Sep%202014?OpenDocument, accessed 29th Dec 2014.	Index Numbers ; All groups CPI ; Brisbane ;
Unit	Index Numbers
Series Type	Original
Data Type	INDEX
Frequency	Quarter
Collection Month	3
Series Start	Sep-1948
Series End	Sep-2014
No. Obs	265
Series ID	A2325816R
Mar-2009	92.4
Jun-2009	92.9
Sep-2009	94.2
Dec-2009	94.5
Mar-2010	95.2
Jun-2010	95.9
Sep-2010	96.9
Dec-2010	97.4
Mar-2011	98.6
Jun-2011	99.6
Sep-2011	99.9
Dec-2011	99.7
Mar-2012	99.9
Jun-2012	100.5
Sep-2012	101.6
Dec-2012	101.9
Mar-2013	102.0

Jun-2013	102.5
Sep-2013	103.8
Dec-2013	104.6
Mar-2014	105.2
Jun-2014	105.8
Sep-2014	106.5

11.5 Technical Specification; Invitation for Budget Pricing

Email sent 1st Dec 2014:

Your company has been short listed to provide budget pricing for a pelletizer and feed pre-treatment plant as per the attached technical specification. Budget pricing is required for plants capable of producing:

[1] 0.50 metric tonnes per hour (dry weight equivalent) of pellets.

[2] 1.0 metric tonnes per hour (dry weight equivalent) of pellets.

Budget pricing is required by COB Mon 22nd Dec 2014. Email submissions to: gareth@allenergypl.com.au

Please confirm via email if you intend to provide budget pricing.

Feel free to email any questions that you may have,

Gareth.