final report

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Reduction in fossil fuel derived energy demand in 5 years at Australia Meat Holdings Pty Ltd Dinmore food processing facility

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Abbreviations

AD	Anaerobic Digestion
AMH	Australia Meat Holdings Pty Ltd
BOD5	Biological Oxygen Demand (5 day)
BP	Belt Press
CCS	Centrifuge Clarifier Separator
COD	Chemical Oxygen Demand
CWT	Changing World Technologies
DAF	Dissolved Air Flotation
EPA	Queensland Environmental Protection Agency
EPCM	Engineering, Procurement and Construction Management
EPI's	Energy Products of Idaho
ESI	Environmental Solutions International
FBC	Fluidised Bed Combustion
FBG	Fluidised Bed Gasification
GHG	Green House Gas
GJ	Giga-joules
HDP	Hydrothermal Depolymerisation
hr	Hour
HRT	Hydraulic Retention Time
HVC	Hot Vapour Combustion
kPa	Kilo-pascals
MEB	Mass and Energy Balance
MLA	Meat and Livestock Australia
MSW	Municipal Solid Waste
MW	Megawatt
MW_e	Megawatt electrical
MWth	Megawatt thermal

MWh	Megawatt hour
NG	Natural Gas
NGAC	New South Wales Greenhouse Abatement Certificates
PE	Polyethylene
PFD	Process Flow Diagram
PSS	Press Screw Separator
RES	Renewable Environmental Solutions
RTP	Rapid Thermal Pyrolysis
SBR	Sequencing Batch Reactor
SPC	Screw Press Compactor
STC	Sun Thermal and Combustion
STP	Standard Temperature and Pressure
t	Tonnes
TCP	Thermal Conversion Process
TKN	Total Kjeldahl Nitrogen
TP	Total Phosphorous
TSS	Total Suspended Solids
VGF	Vegetable, Garden and Fruit Waste
WID	Waste Incineration Directive

Executive summary

Background

Australia Meat Holdings Pty Ltd (AMH) is recognised as one of the nation's 250 largest energy users. To reduce their reliance on imported energy, AMH have established a corporate target of achieving a 10% reduction in fossil fuel demand at their Dinmore food processing facility within a 5 year period. One potential method of achieving this goal is to recover energy, in form of electricity, steam and/or hot water from the solid waste streams currently generated at the site.

Energy could potentially be recovered or saved by:

- Collecting and combusting the biogas generated by the existing anaerobic ponds
- Dewatering the organic solid waste streams to reduce the energy used to transport the solids off-site for disposal; and/or
- Using thermal methods to recover energy from the dewatered organic solid wastes.

To further explore these possibilities, AMH entered into a project to conduct a Feasibility Study to assess the technical and financial risks associated with these opportunities for energy recovery. In particular, the study focused on developing an integrated process solution for waste management and energy recovery at the Dinmore site, utilising mechanical dewatering of the waste streams prior to energy recovery using thermal technologies.

The design basis for the study was the current operating format of 11 shifts per week. Comparison was made with a 14 shifts per week alternative, which is a potential future operating scenario for the Dinmore facility.

Study Format

The Feasibility Study was completed in a number of phases. These were:

- Phase 1 – Collation and review of background information;
- Phase 2 – Development of design criteria;
- Phase 3 – Technical review of process options;
- Phase 4 – Financial review of process options; and
- Phase 5 – Reporting.

In addition to the above phases, on-site mechanical dewatering test work was planned to allow evaluation of the performance of the FAN Separator GmbH (FAN) screw press technology. The ability to demonstrate the reduction in moisture levels in the feed material to an acceptable level for energy recovery was considered a key technical hurdle for the integrated "Waste to Energy" opportunity.

Formulation of a concept design

Initial data collection and collation efforts focused on establishing baseline waste production rates and physico-chemical data for the waste streams generated on the site. This information was the basis for establishing design criteria for the study. The streams considered and the associated production rates are shown in Table E1.

Table E1. Generation rate of solids waste streams

Solid Waste Stream	11 shifts per week		14 Shifts per week[1]	
	Average t/wk (wet)	Peak t/d (wet)	Average t/wk (wet)	Peak t/d (wet)
Paunch Grass	358	73	456	73
Saveall 2 Solids	143	42	182	42
DAF Float[2]	385	93	490	93
Truckwash Solids	34	34	43	43
BP Cake	312	71	396	71
Subtotal	**1232**	**313**	**1567**	**322**
Miscellaneous[3]	23.9	-	28.6	-

Based on the data collected, a concept Process Flow Diagram (PFD) and associated mass and energy balance (MEB) was developed, which included the following processing steps for an integrated waste to energy solution:

- Solids collection and conveying to a central point for dewatering;
- Mechanical dewatering of solids in a one stage or serial two stage process using screw presses, with thermal drying also considered as an alternative;
- Collection of biogas generated from existing anaerobic lagoons; and
- Combustion of dewatered solids (and biogas) in a thermal energy recovery system.

The concept designs were further developed (and associated costs estimated) based on the ability to stage the works as separate stand-alone packages or as a fully integrated single scope of work. The packages considered are as follows:

- Biogas recovery system designed as either a stand-alone option or fully integrated with the energy recovery unit associated with the solid wastes;
- Stage 1 mechanical dewatering using FAN Separator PSS technology coupled with FAN Separator CCS technology. The design allows for automation of the solids collection process such that trailers are no longer required for moving solids around the site; and
- Conveying and blending of Stage 1 dewatered cake with the BP cake. The blended cake may then either be:
    - Further dewatered in a Stage 2 dewatering unit;
    - Further dewatered in a thermal dryer; or
- Fed as a wet feed to the thermal energy recovery unit.
-

Biogas recovery

The biogas generation rate for the four existing anaerobic lagoons on the Dinmore site was estimated based on COD removal performance for each of the lagoons. It is estimated that the

[1] Predicted generation rate based on multiplying current flows by 127 %. The peak daily flow is not expected to increase

[2] Based on unflocked material at 15% TS. Currently, this material is flocked producing about 45% TS (129 t/w).

[3] Miscellaneous streams made up of cardboard (waste and recycled), plastics and hay bales

lagoons emit approximately 14,500 m^3/d of biogas[4], which contains the equivalent of 3.5 $_{MWth}$ of available energy and is equivalent to the release of about 50,000 t/y of CO_{2-e} (in the form of methane). Combustion of this biogas would reduce the CO_{2-e} emissions from the site by approximately 43,000 t/y (excluding any credits for energy generation from the biogas replacing fossil fuel derived energy).

As a stand-alone case, the covering of the anaerobic lagoons for biogas recovery and associated combustion in existing natural gas fired boilers for steam raising, has a capital cost of $1.95M (± 25%) and an associated payback period of approximately 5.8 years. Integration of the biogas recovery system with the solid waste to energy facility (see below) was considered a superior alternative, as this approach would maximise electricity generation and hence the subsidies attributable to “green” energy e.g. RECs, and would also help to stabilise the operation of the solid waste combustion unit.

Mechanical Dewatering

The approximate moisture content of the combined waste streams presented in Table E1 (excluding the miscellaneous streams) is in the order of 83%. This is higher than acceptable for all thermal processing options that target a net recovery of energy. It was therefore essential to demonstrate that the moisture content of the feed could be reduced to an acceptable level.

During the study, two separate mechanical dewatering trials were completed:

- A single stage trial using FAN Separator Press Screw Separator (PSS) technology; and
- A two-stage trial using two FAN Separator PSS units operated in series, with the second stage unit being a new and previously untested design[5].

Based on these trials, it was demonstrated that a moisture content of about 65 % could be achieved in the blended waste materials (excluding the BP cake) fed to the single stage FAN Separator PSS unit, with about 57 % moisture achieved in the two stage trial. Blending the BP Cake in with the other solid waste materials led to a reduction in mechanical dewatering performance and an increase in the solids load to the filtrate. Moisture content in the order of 65 to 75% was achieved with the BP Cake-containing blends.

The performance of the mechanical dewatering alternatives considered in this study was insufficient to achieve a moisture content of <50%, which is desirable for processes using thermal equipment for energy recovery. As such, mechanical dewatering remains unproven as the sole dewatering step. Other mechanical dewatering alternatives, such as the Screw Press Compactor (SPC) technology, require further evaluation and testing before mechanical dewatering is eliminated as a process solution. The current study also investigated thermal dewatering alternatives, although suppliers were generally cautious about the expected performance of these units on AMH-type feed and either would not offer process guarantees without further testing or declined to quote.

The cost of implementing a single stage mechanical dewatering process at the AMH site was evaluated. The capital cost was estimated at $1.1M with a pay back period of 3.7 years. Cash flow was generated primarily by a reduction of the amount of solid waste trucked off site,

[4] This estimate assume a 15 % reduction in biogas generation rate once the hydrocyclones are commissioned in the abattoir

[5] When the current study was initiated, it was believed that application of the Fan Separator Screw Press Compactor (SPC) (coupled with the first Stage FAN Separator PSS) had the potential to achieve < 30 % moisture in the dewatered solids. It became apparent during the study, however, that FAN Separator had withdrawn their support for this product due to the inherent unreliability of these units

although no financial consideration was made for potential additional costs associated with treating the screw press filtrate on site using existing wastewater treatment infrastructure.

Energy Recovery

Assessment of the current technologies for converting abattoir solid waste to energy (in the form of electricity, hot water and/or steam) was undertaken for this study in three stages:

- Background review of relevant thermal (and biological) technologies for energy recovery;
- A workshop involving key AMH internal stakeholders to shortlist the preferred options; and
- Further development of the preferred option(s) to identify technical/operating constraints and risks, capital costs and overall financial viability compared with AMH project assessment criteria (2 years payback).

The options considered include:

- Gasification;
- Combustion/Incineration;
- Pyrolysis;
- Thermal Depolymerisation;
- Hydrolytic processing with digestion; and
- Anaerobic ‘dry’ digestion (for comparative purposes).

Based on the three stage assessment process employed in this study, Fluidised Bed Combustion (FBC) was identified as the preferred waste to energy technology for solid wastes (and biogas) generated on the Dinmore site.

Three possible overall plant configurations have been considered:

1. Base Case - FBC operating on a feed moisture content of ~50 %, achieved using a two-stage mechanical dewatering process (not yet demonstrated);
2. Case 1 – FBC operating on a feed moisture content of ~30 %, achieved using an thermal belt dryer (Andritz); and
3. Case 2 – FBC operating on a feed moisture content of ~70 %, achieved using a one-stage FAN mechanical dewatering process.

It was necessary to consider a number of alternative cases, as the moisture content target of the base case (~50 % moisture using a two-stage dewatering process) is yet to be successfully demonstrated. Further mechanical dewatering test work is planned, although this will be completed after submission of the current Feasibility Study.

A comparison of these alternative cases is presented in Table E2.

Table E2. Waste to energy economics (11 shift/week operation)

Variable	**Base case:** FBC 50% moisture + Biogas	**Case 1:** FBC 30% moisture (dryer) + Biogas	**Case 2:** FBC 70% moisture+ Biogas	**Comments**
Waste Feedstock MWth	6.0	6.0	6.0	
Biogas MWth	3.5	3.5	3.5	
Capital estimate	$17	$20	$17.5	A$m, 2005
Output				
Power MW_e	2.6	2.8	1.8	Before internal consumption
Hot water MWth	4.3	4.6	3.2	Assume all used
Soil enhancer/ash	1021	1021	1021	tpa estimate
Income $m/a				
Power - internal	$0.93	$1.01	$0.66	A$m at $47/MWh$_e$
Power- RECs	$0.79	$0.86	$0.56	$40/MWh
Power - NGACs	-	-	-	No credit included
Hot water	$0.47	$0.51	$0.35	Steam etc at $4/GJ
Soil enhancer	$0.03	$0.03	$0.03	$30/t ex-gate
Reduction in GHG	-	-	-	No credit included
Waste disposal reduction	$0.59	$0.59	$0.59	70% moisture basis, $20/t
Total	**$2.81**	**$2.99**	**$2.19**	
Operating cost				
Variable costs	$0.20	$0.60	$0.22	Mainly energy inputs
Fixed costs	$0.85	$1.00	$0.87	Integrate with existing operations
Total	**$1.05**	**$1.60**	**$1.09**	
Net Cash flow $m/a	**$1.76**	**$1.40**	**$1.09**	
ROI%	**10.4%**	**7.0%**	**6.3%**	
Payback (years)	**8.2**	**11.8**	**12.6**	

Overall Conclusions

The corporate target of reducing fossil fuel usage at the Dinmore site by 10 % can be achieved with the implementation of a waste to energy program. Depending on the configuration adopted, 25 to 35% of the electrical needs and 15 to 25% of the steam/hot water needs of the site can meet through recovery of energy from solid waste and biogas generated on the site. This conclusion is premised on the ability to demonstrate that 50 % moisture can be achieved in the dewatered solid waste using mechanical dewatering technology

Contents

1 Introduction

1.1 Background

Australia Meat Holdings Pty Ltd (AMH) is recognised as one of the nation's 250 largest energy users. To reduce their reliance on imported energy, AMH have established a corporate target of achieving a 10% reduction in fossil fuel demand at their Dinmore food processing facility within a 5 year period. One potential method of achieving this goal is to recover energy, in the form of electricity, steam and/or hot water, from the solid waste streams currently generated at the site. Energy could potentially be recovered or saved by:

- collecting and combusting the bio-gas emitted from the existing anaerobic ponds;
- dewatering the organic solid waste streams to reduce the energy used to transport the solids off-site for disposal; and/or
- using thermal methods to recover energy from the dewatered organic solid wastes.

To further explore these possibilities, AMH entered into a "Partnership in Innovation" project grant with Meat and Livestock Australia (MLA) to conduct a Feasibility Study to assess the technical and financial risks associated with these opportunities for energy recovery.

1.2 Methodology

The Feasibility Study was completed in a number of phases, as follows:

- Phase 1 – Collation and review of background information;
- Phase 2 – Development of design criteria;
- Phase 3 – Technical review of process options;
- Phase 4 – Financial review of process options; and
- Phase 5 – Reporting.

In addition to the above phases, on-site mechanical dewatering test work was planned to allow evaluation of the performance of the FAN Separator GmbH (FAN) screw press technology.

1.3 Issues to be addressed

A number of key focusing questions were used to drive the direction of the study, such that the technical and economic feasibility of the proposed scope of work would be clearly delineated. These questions were:

1. Can the mechanical solids dewatering process (FAN Separator GmbH technology) remove sufficient amounts of water to allow combustion of the solids in their own right?
2. Are there alternative mechanical dewatering processes available in the marketplace?
3. Can the solids dewatering process be carried out successfully without adversely affecting the overall performance of the existing wastewater treatment system?
4. What thermal energy recovery technology is most appropriate for the waste solids generated at the AMH Dinmore site?
5. Can the proposed waste to energy project(s) meet AMH internal financial hurdle rates of a 2 year pay back period?
6. Are there any technical issues/risks that make the waste to energy concept non-viable i.e. are there any "show-stoppers"?

2 Design Basis

2.1 Operational times

The AMH Dinmore abattoir currently operates 11 shifts per week, with 2 shifts each day between Monday and Thursday and a single day shift on Friday to Sunday. Each shift is of approximately 10 hrs duration. There is a 4 hour sanitation/hygiene shift each day. Between Monday and Thursday, the sanitation/ hygiene shift runs between about 1 am to 5 am, while on single shift days, this shift runs immediately after the completion of the one shift for that day.

Depending on future market conditions, AMH may consider expanding their operations to 14 shifts per week. As a result, it is expected that there will be a linear increase in the amount of solid wastes that are generated.

For the purposes of this study, an assessment of the financial and operational consequences of both 11 and 14 shift per week operation have been considered. Broadly speaking, there is not a significant capital cost difference for the dewatering and energy recovery systems that would be required for an 11 or 14 shift week. The abattoir currently operates 2 shifts per day for 4 days of the week; hence equipment needs to be sized for this peak production rate. The inability to store waste solid materials on site for more than 24 hrs (a current EPA Licence condition) also limits the ability to normalise the flows over a one week period.
The 11 shift per week operational format is considered as the Base Case for this study.

2.2 Solid waste materials

A range of solid waste material is generated on the Dinmore site. Those relevant to the current study (as agreed with AMH) are described in Table 1. The naming system adopted in this table will be used throughout the report.

As part of this study, AMH undertook a 2 week audit to obtain a better understanding of the production rate of the waste solids identified in Table 1. The results of the audit are attached as Appendix A. This audit was used as the primary basis for establishing the design criteria for solid waste generation rates on the site. The production rates established from the audit are shown in Table 2.

During this audit period, representative samples of each of the waste streams (two of each stream) were collected for physico-chemical analysis. The raw data from these assays is attached as Appendix B. The data was used to develop a mass and energy balance (MEB) for the waste streams (see Section 2.4.1).

Table 1 Solid waste streams considered

Solid Waste Stream	Description
Paunch Grass	The paunch grass stream is currently collected from the kill floor and screw conveyed (some dewatering occurs in this step) to a truck trailer in the abattoir building. The material is trucked off site for disposal. It is currently not conveyed to the savealls.
Saveall 2 Solids	The saveall 2 solids are made up of a combination of the saveall 2 contra-shear and saveall 2 bottoms materials. These waste streams are collected in two separate trailers. This material is blended and trucked off site for disposal.
DAF Float	The DAF float is actually a mixture of the float product from the DAF unit combined with the saveall 1 and 2 top float. These materials are collected in a hopper associated with the DAF and then pumped to a trailer. Polymer is added during pumping to facilitate dewatering of the solids as they are held in the trailer (this practice will not be continued if mechanical dewatering is established). This material is blended with other waste solids and trucked off site for disposal.
Truckwash Solids	The truckwash solids are collected in a large sump associated with the truckwash area. The solids settle in the sump and the partially clarified wastewater overflows into a separate sump from which it is pumped to the cattle yard dam. The solids accumulate in the sump for 5 to 10 days before being removed by a front-end loader and disposed off site.
BP Cake	The Belt Press (BP) Cake is the dewatered biosolids originating from the two on-site SBRs. The material is collected in a trailer and disposed off-site with the other waste solids.
Plastics	A range of waste plastics is generated on the site. It is estimated that this is made up of (MLA, 1996 and empirical data supplied by AMH): P 67 % vacuum pack bag off-cuts P 25 % - stretch plastic pallet wrap waste P 7.9 % - PE plastic film P 0.1 % -plastic strapping
Cardboard – Recycled	Clean cardboard that has not been contaminated during the slaughtering process is collected and recycled.
Cardboard – Waste	Waste cardboard it considered any material that is potentially contaminated. A contractor removes this material from site.
Hay Bales	Irrigation is used for disposal of some of the treated wastewater generated on the site. The resulting grass is harvested and dried. Currently, this material is stored on site (due to restriction for sale associated with potential fire ant infestation).

Table 2 Generation rate of waste solids based on AMH 2 week audit

Solid Waste Stream	11 shifts per week		14 Shifts per week[6]	
	Average t/wk (wet)	Peak t/d (wet)	Average t/wk (wet)	Peak t/d (wet)
Paunch Grass	358	73	456	73
Saveall 2 Solids	143	42	182	42
DAF Float[7]	385	93	490	93
Truckwash Solids[8]	34	34	43	43
BP Cake	312	71	396	71
Subtotal	**1232**	**313**	**1567**	**322**
Plastics	2.9	-	3.7	-
Cardboard – Recycled	5.7	-	7.3	-
Cardboard – Waste	8.3	-	10.6	-
Hay Bales[9]	7	-	7	-

2.3 Process Flow Diagram

The basis of this study was to develop a process, which included the following significant processing steps:

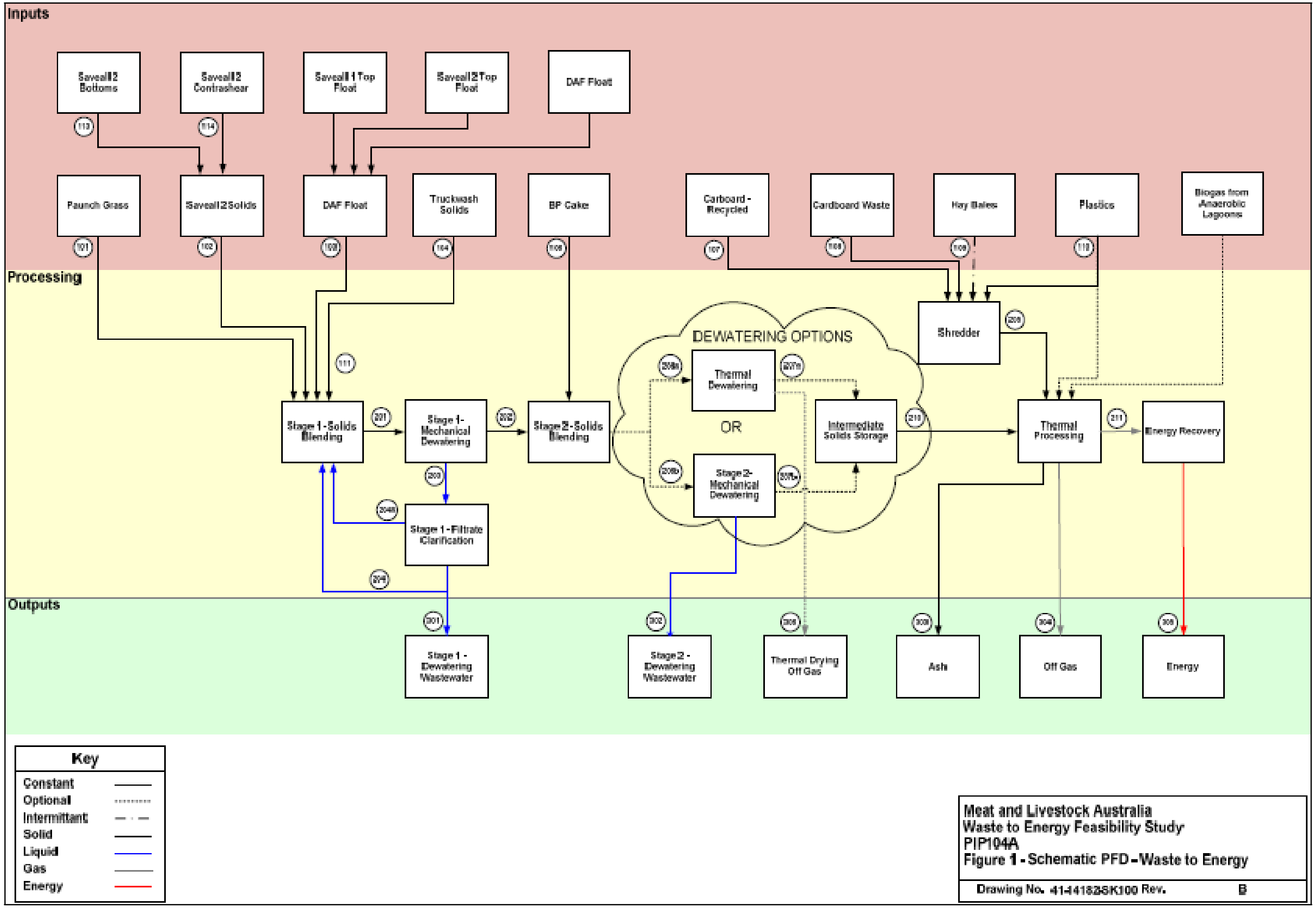
- Automate the collection of the various waste streams to a central point for dewatering. (Currently, waste solids are collected in trailers from various points around the site, before they are blended and trucked off site for disposal);
- Blend the collected waste solids prior to dewatering in a two-stage mechanical dewatering step;
- Convey the dewatered solids to the energy recovery unit (to be identified as part of this study); and
- Pump the wastewater generated during dewatering to the existing anaerobic lagoons for further treatment.

A schematic Process Flow Diagram (PFD) was developed to identify these key processing steps, as well as identify the streams to be included on a mass and energy balance for the process (Section 2.4). The schematic PFD is attached as Figure 1.

[6] Predicted generation rate based on multiplying current flows by 127 %. The peak daily flow is not expected to increase.
[7] Based on unflocked material at 15% TS. Currently, this material is flocked producing about 45% TS (129 t/w).
[8] Truckwash material is currently collected in a sump and emptied every 5 to 10 days following dewatering in the sump. It is proposed that this flow would be normalised by continuous pumping to the Stage 1 dewatering unit rather than allowing the solids to accumulate.
[9] Hay production rate is limited by available irrigation area

The key features of the PFD are as follows:

- The PFD is divided into three sections; Inputs, Processing and Outputs;
- The organic solid waste material (excluding the BP Cake [Stream 106]) will be collected and blended;
- The blended organic solid waste material [Stream 201] will be dewatered through a Stage 1 screw press arrangement (FAN Separator PSS);
- The filtrate [Stream 203] from the Stage 1 dewatering step will be clarified to recover solids. The solids (and any associated water) [Stream 204a] will be returned to the Stage 1 blending process. The clarified filtrate [Stream 301] will be pumped to the anaerobic lagoons. A portion of the clarified filtrate [Stream 204] will be recycled to the Stage 1 blending (if required) to control solids percentage;
- The cake from the Stage 1 dewatering step [Stream 202] will be conveyed to an area adjacent to the belt press for blending with the BP cake [Stream 106];
- There are three options considered for the blended solids resulting from the above processing steps;
    - The solids are further dewatered in a second stage of mechanical dewatering [Stream 206b]
    - The solids are further dewatered in a thermal dryer [Stream 206a]
    - The solids are fed directly to the energy recovery unit
- The other solid waste streams generated on the site (cardboard, hay bales and plastic) are shredded and feed to the energy recovery unit [Stream 205]; and
- Biogas is shown entering the Thermal Processing unit operation. It is also possible that the biogas recovery option will be considered as a stand-alone project, in which case the biogas would be combusted in existing NG-fired boilers.



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2.4 Mass and Energy Balances

A mass and energy balance (MEB) was developed in Microsoft Excel to allow:

- Assessment of mass an energy flows of the proposed energy recovery process; P Development of process design criteria;
- Sizing of the process units; and
- Supply of information to assess (by others) the potential impacts of the dewatering circuit on the current on-site wastewater treatment system.

The MEB for the management of the solid waste streams is discussed in Section 2.4.1. The process calculations associated with the generation of biogas on the site are discussed in Section 2.4.2.

2.4.1 Waste solid materials

The detailed MEB is attached as Appendix C. Stream numbers are labelled as per the PFD (Figure 1) and the MEB has been split into three sections as per the PFD i.e. Inputs, Processing and Outputs.

The mass balance was built up based on data supplied by AMH (Section 2.2), as well as information obtained during the Stage 1 FAN Separator PSS trial (Section 3.2.1).

2.4.2 Biogas

AMH supplied performance data for the existing anaerobic lagoons. The data covered the 2004 calendar year. Based on this data, the rate of biogas generation was estimated. Information on actual biogas composition was not available; hence generation rate was estimated based on the following assumptions:

- A methane generation rate of 0.35 m^3/kg COD removed;
- Methane represented 60 % vol/vol of the biogas;
- The biogas energy value was 21 MJ/m^3;
- The H_2S content of the biogas would be in the range of 0.05 to 0.5 % (vol/vol); and
- Peak gas flows (for equipment design purposes) were based on 95th percentile values calculated from the supplied data.

A summary of the biogas mass balance is attached as Appendix D.

The amount of methane released to atmosphere from the lagoons was also estimated based on the available data. Methane is a relatively potent green house gas (GHG), with a global warming potential of 21 kg CO_{2-e}/kg CH_4 (based on a 100 year time horizon). Capturing and combusting the biogas will reduce the GHG emissions from the site by approximately 50,000 tonnes CO_{2-e} per annum. A typical coal-fired power station emits about 1 t CO_2 per MW_h electricity generated. Therefore, from an emissions perspective, capturing and combusting the biogas is nominally equivalent to reducing coal-fired electricity usage by about 50,000 MW_h/annum (5.7 MW_e equivalent).

2.5 Design Criteria

Design criteria were established on the basis of the information collated and evaluated in Sections 2.1 to 2.4. The design cases for both 11 and 14 shifts per week were considered, as any projects resulting from this study would be evaluated financially under the two operating scenarios. In other words, for a project to be considered at this time, it would need to be financially viable under current operating conditions.

2.5.1 Waste solids materials

The key design criteria for the waste solid materials are outlined in Table 3

Criterion	**Units**	**Shift Number**		**Comments**
		11 shifts/week	**14 shifts per week**	
General				
Kill rate	head/d	1600 to 3300	3263	
Shifts –Current	Shifts/w	11	14	10 hr/shifts, with 1 x 4 hr hygiene shift per day
Major shut downs	days (Christmas) days (Easter) miscellaneous	35 5 5	35 5 5	
Operating time	d/y	321	321	
Average site energy use ○ electricity ○ coal ○ gas ○ steam (shift) ○ steam (off-shift) ○ hot water	MWh/w t/w GJ/w t/hr t/hr m^3/d	1256 255 2373 22.1 7.1 1493	1600 325 3020 22.1 7.1 1900	Use for both steam raising and direct drying. 1000 kPa steam. Based on 1 week of data. For 14 shift week, this will only be 4 hr/day max. Assume all at 87°C from ambient (single use).
Solid waste streams				
Paunch Grass	t/w (dry)	59	75	Continuous production

Criterion	Units	Shift Number		Comments
		11 shifts/week	14 shifts per week	
	t/w (wet)	358	456	At 16.5 % TS.
Gross calorific value	GJ/w	718	914	
Saveall 2 solids	t/w (dry)	37	47	Intermittent to continuous production
	t/w (wet)	143	182	At 26 % TS
Gross calorific value	GJ/w	526	669	
DAF float solids – Design	t/w (dry)	58	73	Intermittent to continuous production
	t/w (wet)	385	490	At 15 % TS (unflocced)
Gross calorific value	GJ/week	1195	1521	
Truckwash solids – Design	t/w (dry)	6	8	Intermittent (potentially continuous)
	t/w (wet)	340	433	At 1.8 % solids (currently about 36 % TS)
Gross calorific value	GJ/w	73	93	
BP Cake solids – Design	t/w (dry)	47	59	Continuous production (but variable)
	t/w (wet)	311	396	At 15 % TS
Gross calorific value	GJ/w	663	844	
Cardboard - Recycled	t/w	5.8	7.3	Continuous production
Gross calorific value	GJ/w	104	132	
Cardboard - Waste	t/w	8.3	10.6	Continuous production
Gross calorific value	GJ/w	150	191	

Criterion	Units	Shift Number		Comments
		11 shifts/week	14 shifts per week	
Hay Bales	t/w	7	7	Intermittent production
Gross calorific value	GJ/w	70	70	
Plastics	t/w	2.9	3.7	Continuous production
Gross calorific value	GJ/w	122	156	
Summary				
Total available solid waste	t/w (dry)	231	291	
	t/y (dry)	10,600	13,400	Based on 321 days per year operation
Gross calorific value	GJ/w	3621	4590	
Stage 1 dewatering (FAN Separator PSS)				
Feed rate	t/d (wet)	175	223	Based on 2 shifts per day
	t/d (dry)	23	29	Based on 2 shifts per day
Feed rate – Peak	t/d (wet)	268	268	Add 20 % peaking factor to 2 day shift
	t/d (dry)	38	38	
Cake moisture	% w/w	65	65	Better than achieved in trial
Solids recovery	%	98	98	
Filtrate – production	t/d	89	113	Some recycle to feed mixing tank may be required.
-- suspended solids	% w/w	0.4	0.4	Assume 80 % recovery with FAN CCS

Criterion	Units	Shift Number		Comments
		11 shifts/week	14 shifts per week	
Streams included in feed to FAN Separator PSS units		Paunch Saveall 2 DAF float Truckwash		Option to take current feed to savealls directly to battery of PSS machines (decommission savealls). Potentially higher capital cost. FAN CSS solids and some clarified filtrate potentially returned to mix tank.
Stage 2 mechanical dewatering (to be confirmed)				
Streams included		Cake from Stage 1 dewatering BP Cake		Possibility to add cardboard/hay bales streams if this improves dewatering of material
Cake moisture target	% moisture w/w	<50	<50	Noted that FAN Separator no longer supply SPC technology. Trial with new FAN technology pending.
Cake produced - average	t/d (wet) t/d (dry)	57 29	73 37	Estimate assuming 50 % cake moisture achieved and 100 % recovery of solids.
Filtrate produced - average	t/d	50	64	Estimate assuming 50 % cake moisture achieved
Energy Recovery				
Streams included		Cake from Stage 2 dewatering Cardboards Plastic BP Cake (dried) Hay bales		

Criterion	Units	Shift Number		Comments
		11 shifts/week	14 shifts per week	
Solids feed	t/w (dry)	227	288	
Moisture content	% w/w	<50	<50	Will depend on dewatering approach adopted – screw press, thermal drying or neither
Available energy in solids	GJ/w	3460	4400	Assumes overall 95 % solids recovery through dewatering

2.5.2 Biogas

The key design criteria for the lagoon biogas are outlined in Table 4.

Table 4 Key design criteria for biogas

Criterion	Units	Shift Number		Comment
		11 shifts/week	14 shifts/week	
Methane content	% v/v	60	60	Assumption
Biogas generation rate	m^3 CH_4/kg COD removed	0.35	0.35	Assumption
Biogas generation rate – average[5]				
Lagoon 1	m^3/d	3,290	4,200	
Lagoon 2A	(at STP)	3,590	4,600	
Lagoon 2B		5,020	6,400	
Lagoon 3		2,580	3,300	
Biogas generation rate – 95th percentile				
Lagoon 1	m^3/day	6,200	7,900	Used to size blower
Lagoon 2A	(at STP)	7,900	10,100	
Lagoon 2B		8,800	11,200	
Lagoon 3		4,400	5,600	
Biogas generation rate - specific				
Specific generation rate	m^3 biogas/m^3.d	0.43	-	Calculated from available data
		0.47	-	Based on current performance
		0.66	-	
		0.34	-	
Energy				
Available energy	MW_{th}	3.5	4.5	Assumes 85 % of current[10]

[10] Assumes a 15 % reduction will occur once the hydrocyclones are operational i.e. improved fat recovery. This assumption should be revisited once actual operating performance becomes available. In addition, the contribution of COD from the mechanical dewatering stage(s) should also be included in this reassessment

3 Concept Design and Cost Estimation

Concept designs were developed based on the specified criteria for the project. The designs have been developed (and associated costs estimated) based on the ability to stage the works as separate standalone packages or as a fully integrated single scope of work. The packages considered are as follows:

- Biogas recovery system designed as either a stand-alone option (see Section 6.2) or fully integrated with the energy recovery unit associated with the solid wastes (see Section 6.1);
- Stage 1 mechanical dewatering using FAN Separator PSS technology coupled with FAN Separator CCS technology. The design allows for automation of the solids collection process such that trailers are no longer required for moving solids around the site; and
- Conveying and blending of Stage 1 dewatered cake with the BP cake. The blended cake may then either be:
    - Further dewatered in a second stage dewatering unit;
    - Further dewatered in a thermal dryer; or
    - Fed as a wet feed to the thermal energy recovery unit.

This section presents information on the concept designs that were developed during this study, along with associated cost estimates and design notes. Capital cost estimates for the energy recovery circuit are presented in Section 6.

The installed cost estimates presented in this section were developed based on extrapolation of recent similar project pricing, budget quotes for some major equipment items, industry unit rates and GHD experience. The accuracy of these estimates is not expected to be better than about 25% for the scope of work described in this report. A detailed design is recommended if a more reliable estimate is required. It is also noted that the contracting strategy used to deliver the projects may also have a significant bearing on the overall cost. For this study, it was assumed that the project would be delivered under and EPCM arrangement[11].

3.1 Biogas collection and transfer

3.1.1 Design Basis

Lagoon Covers

The design basis for the lagoon covers for capturing biogas is based on the dimensions of each lagoon. Table 5 summarises the volume and dimensions for each lagoon.
The depth of the lagoon has been taken into account when calculating the total surface area of cover required. This allowance is made so that when the lagoons are empty, the cover will lay on the lagoon bottom. This will prevent the covers from being under tension and avoid the risk of tearing.

Lagoon covers would be complete with a concrete ring wall battening system and rainwater sump pumps.

[11] EPCM – Engineering, Procurement and Construction Management. For this style of project delivery, AMH (or it's project management representative) would manage the engineering design and delivery of the project. Other project delivery methods could be considered, although the overall projects costs and ownership of risk will vary depending on the model selected

Table 5 Summary of Lagoon Dimensions

Criteria	Lagoon 1	Lagoon 2A	Lagoon 2B	Lagoon 3
Length x Width x Depth (in metres)	65 x 50 x 5	75 x 50 x 5	115 x 45 x 7	50 x 50 x 5
Volume (ML)	9	15	18	9

Desludging lagoons

An allowance has been made for desludging of the lagoons, which includes removal of both the floating sludge crust and settled sludge. A contractor will desludge the lagoons as required to protect the lagoon covers from the floating sludge crust, and to maintain the capacity of the lagoons.

A preliminary estimate of desludging frequency is every 5 years. Desludging is anticipated to be completed by pulling back a corner of the lagoon cover and inserting a mixer to homogenise lagoon contents. Homogenised sludge contents would then be pumped to a mobile centrifuge or belt press for dewatering and off site disposal (or potential energy recovery on site).

The need and frequency for ongoing decrusting of the lagoons is not well defined. AMH are currently commissioning hydro-cyclones within the abattoir to improve fat recovery. In addition, the use of screw presses for dewatering may improve the efficiency of fat removal from the wastewater stream. These two activities are expected to reduce the fat load reporting to the lagoons, and hence reduce the rate at which the crust layer builds up on the lagoons.

Biogas recovery

The biogas recovery system was designed based on the calculated volume of biogas generated from the lagoons each day. The generation of methane is based on the assumption of 0.35 m3 methane/kg COD (at STP). The generation of biogas was calculated by assuming 60 % v/v methane in biogas. The remaining gas components in the biogas are carbon dioxide (CO_2) at 39.9% v/v and hydrogen sulfide (H_2S) at 0.1 % v/v.

The biogas design criteria are outlined in Table 4 above.

The biogas recovery system includes a gas blower, a chiller for gas drying, and a gas flare. Refrigerative drying with the chiller will satisfy the requirements of the combustion boiler. A gas flare will be provided for combustion purposes in the event the boiler is out of operation.

Process specification.

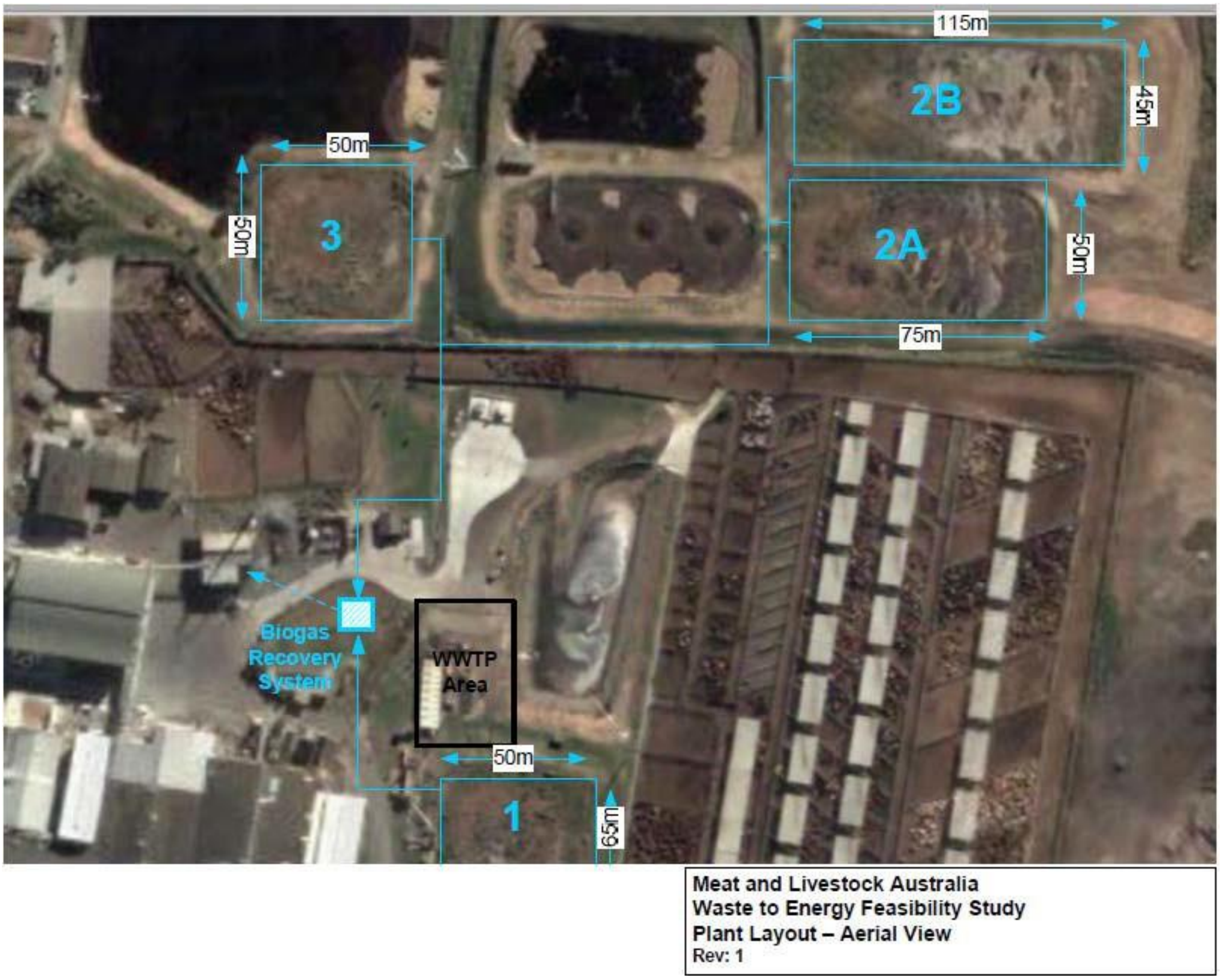
The process specifications for the lagoon lining and biogas collection system are shown in Table 6.

Layout

A proposed layout for the anaerobic lagoons is attached as Figure 2.

Table 6 Process Specification for biogas collection

Process Unit	Description	Design Criteria	No. & Capacity of Units	Notes
Lagoon Covers	Plastic (PP) cover to capture biogas from anaerobic lagoons	Lagoon 1: 65m x 50m Lagoon 2A: 75m x 50m Lagoon 2B: 115m x 45m Lagoon 3: 50m x 50m	Lagoon 1: 9 ML Lagoon 2A: 15 ML Lagoon 2B: 18 ML Lagoon 3: 9 ML	Covers suitable for gas collection
Sump Pump	Pump located in sump of lagoon covers to remove rainwater from surface of covers	1 m^3/hr	Four (4) in total – one (1) for each lagoon cover	Submersible pump can be supplied by lagoon cover vendor
Biogas Blower	Extract biogas from covered lagoons.	Biogas flowrate (ave): 17,000 m^3/d	One (1) 833 m^3/hr	
Biogas chiller	Chiller to dry gas suitable for combustion	Biogas flowrate (ave): 17,000m^3/d, dry to 10^{o}C dewpoint	One (1) air cooled chiller	Air cooled chilling suitable for drying biogas for boiler combustion
Flare	Combustion of biogas.	Biogas flowrate (ave): 17,000m^3/d	One (1) 833 m^3/hr	



3.1.2 Cost estimate

Capital and operating cost estimates were established for the biogas recovery system. Capital costs were itemised per lagoon and for the biogas collection system. A summary of these estimates is shown in Table 7. Detailed cost estimates are attached as Appendix E.

Table 7 Capital cost estimate for biogas collection

Description	Cost
Lagoon Covers	$ 647,000
Civil / Site Works	$ 244,000
Mechanical	$ 441,000
Electrical	$ 90,000
Installation[12]	$ 150,000
Subtotal	$ 1,572,000
Contingencies	$ 216,000
Engineering	$ 150.000
Total	**$ 1,950,000**

12 Installation costs were included in some of the capital costs provided. Therefore, installation was estimated only for those items that did not have an installation allocation.

Table 8 Annual operating cost estimate for biogas collection[13]

Description	Cost
Power	$ 6,000
Maintenance	$ 100,000
Total	$ 106,000

3.2 Stage 1 mechanical dewatering

One of the key drivers for the current study was to further explore the use of FAN Separator GmbH screw press dewatering equipment and it application in energy recovery from abattoir solid waste. AMH have conducted previous trials with FAN Separator technology. This study extends this work and puts it into a project context.

To complement this study, a GHD representative visited the FAN Separator factory in Germany. The notes from this visit are attached as part of Appendix F. Two process configurations were developed from this visit:

- Option 1 – A configuration that was designed to replace the existing saveall units; and
- Option 2 – A configuration integrated with the existing saveall unit.

Based on the outcomes of the Technical Risk Workshop (see Section 5), it was agreed to develop only Option 2 in more detail. The workshop perception was that the capital cost of Option 2 would be lower than that of Option 1, although it was recognised that Option 1 would supply an overall more streamlined and “operator friendly” solution.

3.2.1 Test work program

Stage 1 dewatering
As part of this study, a one day test work program was completed to assess the performance of the FAN Separator GmbH press screw separator (PSS). This piece of dewatering equipment has been identified as a potential candidate for the partial dewatering of solid wastes generated at the AMH Dinmore.

A previous trial completed at the Dinmore site on the 6 February 2004 indicated that a moisture content in the range of 51 to 62 % w/w could be achieved after processing through the FAN PSS unit. The trial completed during this study was used to confirm these results, as well as compare performance for a range of waste solid feed blends.
The trial was completed on the 15 March 2005 using a pilot-scale, trailer mounted FAN PSS unit supplied by Australian Waste Engineering. The model used was a PSS 1.2-520, which is a 4 kW unit using the long screw auger and a screen basket with a slot size of 0.75 mm.

A detailed overview of the results of the trial is attached as Appendix F. The key observations from the trial were:

- The feed material was difficult to pump, even with the addition of dilution water. Pumping was discontinued after the first trial, with the material blended manually then fed to the unit via gravity (see Appendix F for photographs);
- It was difficult to control the feed flow to the screw press and it is believed that the feed rate exceeded the design solids feed rate for the unit throughout the trial. This at least partly explains why moisture content in the range of only 70 to 75 % was achieved;

[13] No additional allowance has been made for labour. It is assumed that the existing site labour is able to manage the new plant

- Additional weights to hold the solids plug in the screw press may have improved dewatering performance;
- Attempts to feed the screw press with a blend containing BP cake were unsuccessful. The bulk of the BP material was not retained with the cake but left the unit with the filtrate; and
- Significant additional nutrient load will be added to the site wastewater system, through the collection and treatment of the filtrate.

Stage 2 dewatering
In late August 2005, a further trial using FAN PSS technology was conducted to assess the performance of a two stage process i.e. two FAN PSS units operating in series. The first stage unit for the trial was identical that used in the Stage 1 trial (above), while the second stage machine was a FAN PSS3.2-1040. The second stage unit consists of an auger of varying pitch that is approximately twice as long as the stage 1 unit.

The details of the Stage 2 dewatering trial are attached as Appendix L. The key observations from the trial were:

- The Stage 1 unit delivered a cake moisture (excluding BP cake) in the order of 70 to 75%, which was consistent with the earlier Stage 1 trial (above);
- The 70 to 75 % moisture content from the Stage 1 unit was achieved using either a wet feed (a feed blend produced using paunch grass mixed with material pumped directly from the Saveall 2 pit) or partially dewatered feed (a feed blend produced using paunch grass mixed with Saveall 2 solids). This suggests that Option 1 and 2 Stage 1 FAN dewatering configurations (see Section 3.2 above) will deliver similar moisture content in the Stage 1 dewatered material;
- Serial two-stage dewatering of waste solids (in the absence of BP Cake) delivered a cake moisture of 55 to 60 %. On the addition of BP Cake material at an appropriate ratio, the final cake moisture increase to 65 to 75 %;
- Total solids in the filtrate from the Stage 2 PSS unit were in the order of 6 to 9 % w/w, confirming the need for solids recovery from the screw press filtrate stream to minimise organic load reporting to the existing wastewater treatment plant;

As with the Stage 1 trial, significant additional nutrient load will be added to the site wastewater system through the collection and treatment of the filtrate. Analysis of this impact of the filtrate quality and quantity on the existing wastewater treatment plant was beyond the scope of the current study and will be performed independent to the Feasibility Study.

Further dewatering test work
To date, the mechanical dewatering trials completed using AMH Dinmore waste material as feed have not been able to achieve the target of <50% moisture. This moisture level is necessary to achieve optimal energy recovery from the solids. At the time of issuing this report, further trials using SPC technology (sourced directly from German manufacturer rather than through FAN Separator GmbH) were being planned for January 2006. The success of these trials will be critical for the overall waste to energy project.

3.2.2 Design Basis

Screw conveyors from savealls to mix tank
One (1) inclined stainless steel screw conveyor with capacity 0.5 t/hr is proposed to be provided from the Saveall 1 contra-shear to the Mix Tank and one (1) inclined stainless steel screw conveyor with capacity 1.5 t/hr is proposed to be provided from the Saveall 2 bottoms to the Mix Tank. A duty standby screw should also be considered, but has not been included in the current design.

The intent of all system screw conveyors and equipment is to eliminate truck transportation of sludge and automate all sludge handling processes (excluding the handling of Saveall 1 bottoms, which is a small flow that is assumed to remain manually conveyed).

Paunch grass conveying system

For the purposes of this report, a solid handling chopper pump, sump, mixer and discharge piping have been preliminarily proposed to be the components of the Paunch Grass handling system. The contents of the paunch grass handling system are discharged to the Mix Tank.

It should be noted that GHD has contacted Food Pro Systems (Australian contact Brian Kerry at Food Processing Equipment - FPE), who was identified by AMH as the preferred equipment supplier for a paunch grass vacuum system. At the time of writing this report, FPE were unable to provide a budget estimate due to time constraints.

Mix tank

One (1) painted mild steel mix tank (12 m³ capacity) with mechanical mixing is proposed to be provided. The tank has been designed on a flowrate of 12 t/hr with an HRT of 1 hour. The design flowrate is based on waste streams from the abattoir, and recycled screw filtrate water to achieve approximately 10% w/w dry solids. Air mixing was also considered for this duty, but is considered a higher capital cost alternative.

Screw press feed pumps

The Screw Press Feed Pumps will be progressive cavity solid handling pumps with the capability to pump 10% w/w (nominal) and 15% w/w (maximum) dry solid sludge from the Mix Tank to the Fan screw presses. The pumps are needed to deliver sludge to the screw presses, located on an elevated operating platform. One (1) duty pump and one (1) standby pump are proposed to be provided. Capacity of 23 m³/hr is based on a peak solids flowrate of 15 m³/hr at 10% w/w sludge, with a 50% safety factor on the pump sizing.

FAN Separator Press Screw Separator (PSS)

The FAN Separator GmbH Press Screw Separators (PSS) were identified by AMH as the preferred dewatering technology manufacturer. The PSS's have been sized to each take half of the flowrate from the mix tank (6 t/hr), for a combined capacity of 12 t/hr. The screw presses will be elevated above the ground on a platform and the dewatered solids will be discharged to a chute feeding a hopper and screw conveyors. The elevated platform is proposed to allow gravity feed to the CCS, or in abnormal operating conditions, to a truck for disposal.

FAN Separator Centrifuge Clarifier Separator (CCS)

The CCS's have been sized on the basis that the cake produced from the PSS contains 35% w/w dry solids (65% w/w moisture) and a solids recovery to cake of 97%. Based on this, screw press filtrate flow rates are calculated to be 8.7 m3/hr, suitable for the CCS. It is proposed that the CCS will be a stainless steel hydrocyclone, with a high-speed impeller. The CCS is proposed as the preferred solids separation device for the PSS filtrate, since it is also manufactured by FAN Separator.

Alternative clarification units may also be considered e.g. DAF or Baleen Filter and are likely to be less capital intensive. However, the CCS units have been selected for this study on the basis of integrating the FAN Separator PSS and CCS technology.

Clarified filtrate storage tank and pump

The 5 m³ Clarified filtrate (from the CSS) provides 40 minutes of storage, so that the blending rate of filtrate can be varied to maintain 10% w/w solid in the mix tank. The filtrate pump capacity of 11 m³/hr is pumped to the either the mix tank or the anaerobic ponds for disposal. The pump capacity of 11 m³/hr is based on a peak flow rate of 7.2 m³/hr plus 50% safety factor on this small centrifugal pump.

Screw conveyors from screw presses to continuous solids mixer
The proposed stainless screw conveyors have been sized based on a peak design dewatered solids flowrate of 4.2 t/hr. This flowrate has been calculated based on PSS cake containing 35% w/w dry solids (65% w/w moisture) and solids recovery to the of 97% from the PSS's. A total of 3 screw conveyors (in series) are anticipated with total length of approximately 45 metres, which are elevated over the access road. No allowance has been made a duty/standby screw configuration, although this should be considered.

Continuous solids mixer
The Continuous Solids Mixer blends abattoir waste, and sludge cake from the belt filter press (wastewater treatment plant biological sludge). The capacity of 7 t/hr includes an allowance of 4 t/hr of dewatered abattoir waste from the PSS's and 3 t/hr of belt filter cake. The actual capacity of the unit is in the range of 10 to 20 m^3/hr. The continuous solids mixer feeds an existing 50 m^3 storage bin.

Storage bin
The Storage Bin capacity of 50 m^3 is based on 6 hour storage of 7 t/hr of combined sludge cake. A requirement of 6 hours storage allows downstream energy recovery systems to continue to operate in the event of a temporary process upset in the sludge dewatering systems, and during hygiene/sanitation shifts.

Process specification
The process specifications for the Stage 1 dewatering system are shown in Table 9. The process specifications for the conveying, blending (BP cake and Stage 1 dewatered cake) and storage of dewatered solids are shown in Table 10.

Table 9 Process Specification for the Stage 1 dewatering circuit

Process Unit	Description	Design Criteria	No. & Capacity of Units	Notes
Screw conveyors	Saveall 2 contrashear to mix tank.	0.5 t/hr	One (1)	inclined
	Saveall bottoms to mix tank	1.5 t/hr	One (1)	inclined
Mix Tank	Mix tank for wastewater streams (Paunch, kill floor, Boning, DCB, by-products, truck wash)	1 hr HRT	One (1) 12 m^3	
Screw Press Feed Pumps	Pumps to feed FAN Screw presses from Mix Tank via a screw pump feedbox	15 m^3/hr each	Two (2) 23 m^3/hr each, one duty, one standby	Positive displacement pump for high solids
FAN Screw Press (PSS)	Dewatering process to remove water.	12 t/hr	Two (2) 6 t/hr, both required to normally operate	
FAN Centrifuge Clarifier Separator (CSS)	Removal of solids by centrifugal motion	8.7 m^3/hr	One (1) 9 m^3/hr	Provided by FAN as part of PSS system package
Clarified Filtrate Pump	Clarified Filtrated from CSS pumped to anaerobic ponds and recycled back to Mix Tank	7.2 m^3/hr	One (1) 11 m^3/hr	
Clarified Filtrate Storage Tank	Downstream of CSS	40 minutes storage	One (1) 5 m^3 tank	

Table 10 Process Specification for conveying, blending and storing of dewatered solids

Process Unit	Description	Design Criteria	No. & Capacity of Units	Notes
Screw conveyors	From Dewatering Plant to Blending Plant.	4.2 t/hr	One (1) inclined unit Two (2) units	Total length of 45 metres length to convey solids over road on elevated platforms
	From continuous solids mixer to storage bin	7 t/hr	One (1)	inclined
Continuous Solids Mixer	Mix/Blend belt filter cake with dewatered abattoir solid waste	4 t/hr of dewater abattoir waste 3 t/hr of belt filter cake	No. 7 t/hr	BHS Twin shaft mixer used, type DKX 2500
Blended Solids Storage Bin	Storage bin for blended solids.	6 hours storage.	No. 1 50 m^3	

3.2.3 Impact of filtrate on the existing wastewater nutrient load

Mechanical dewatering of the solids will generate an additional wastewater load that will require treatment. Based on the results of the Stage 1 dewatering trial, estimates were made of the additional nutrient and hydraulic load that will be generated.

It was beyond the scope of the current study to determine the potential impacts of this additional load on the existing wastewater treatment infrastructure at the Dinmore site. As such, no allowance has been made in the capital and operating cost estimates for any augmentation that would be required as a result of this additional load.

Additional load will also be generated if a second stage mechanical dewatering unit is included in the final design. Currently, there is limited data available to predict the quality of this filtrate, as a successful Stage 2 filtration trial is yet to be completed. If the following assumptions are made:

- Stage 1 dewatering can achieve 65 % moisture; and
- Stage 2 dewatering can achieve 50 % moisture (using a blend of Stage 1 cake and the BP cake as feed.)

The additional hydraulic load to day will be approximately 64 kL per day for a 14 shift week and 32 to 64 kL per day for an 11 shift week. The quality of this water cannot be defined at this stage; hence the nutrient loadings are not presented. This information will need to be established once a successful second stage dewatering trial is completed.

The above assessment is based on using a FAN CCS unit to recover suspended solids in the filtrate prior to pumping the filtrate to the anaerobic lagoons. If this clarification step were omitted, further organic and nutrient load would report to the anaerobic lagoons. This optimisation should be considered when evaluating the impact of the filtrate on the existing wastewater treatment systems at Dinmore.

Table 11 Estimated hydraulic and nutrient loads associated with the Stage 1 dewatering filtrate

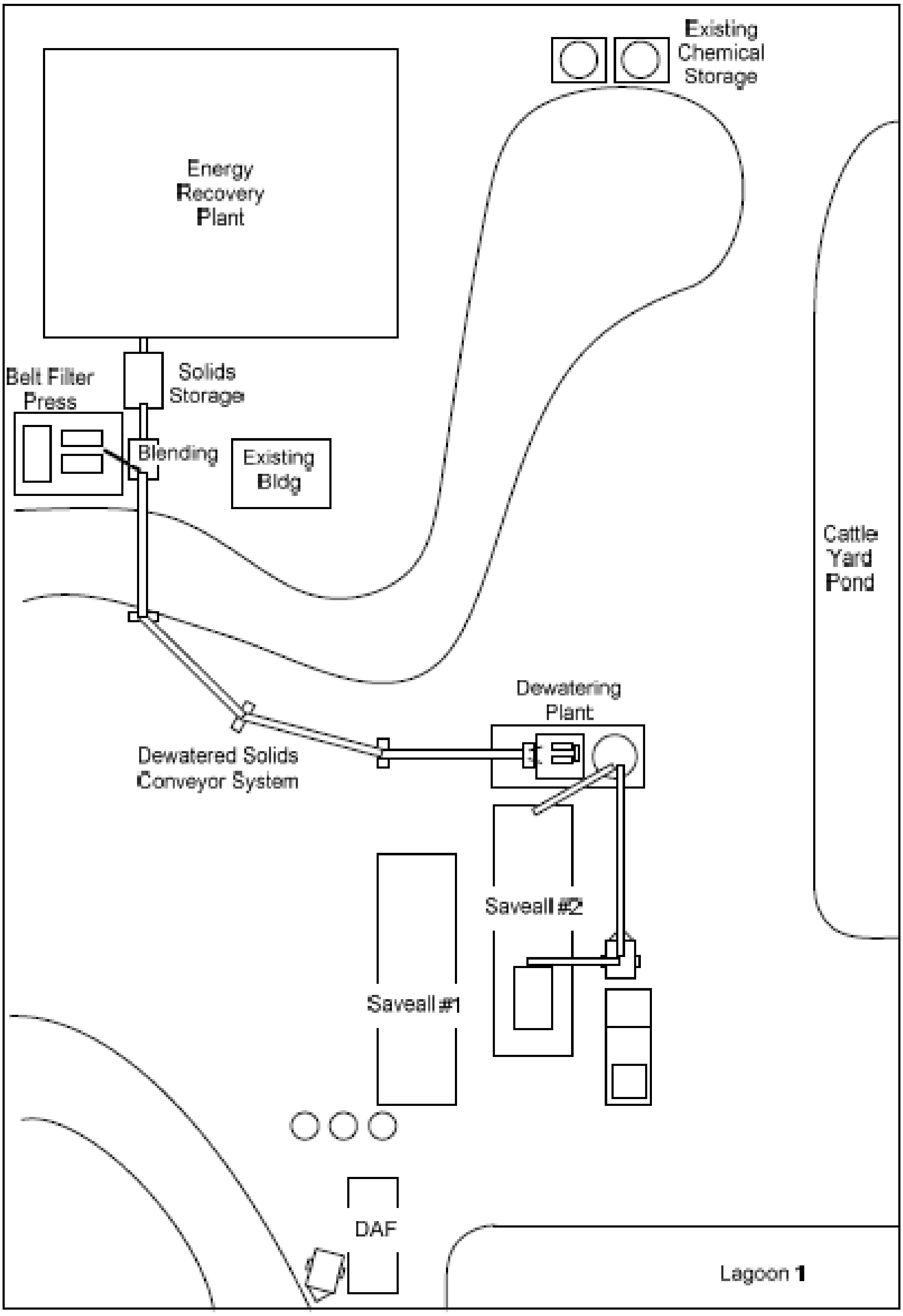
Parameter	Units	Shift No.	
		11 shifts per week[14]	14 shifts per week
Average flow	m^3/day	71 to 142[15]	142
CODt[16]	kg/day	1060[17]	1350
CODs	kg/day	700	900
BOD^5	kg/day	630	800
TKN	kg/day	70	60
TP	kg/day	44	56
Oil and Grease	kg/day	270	340

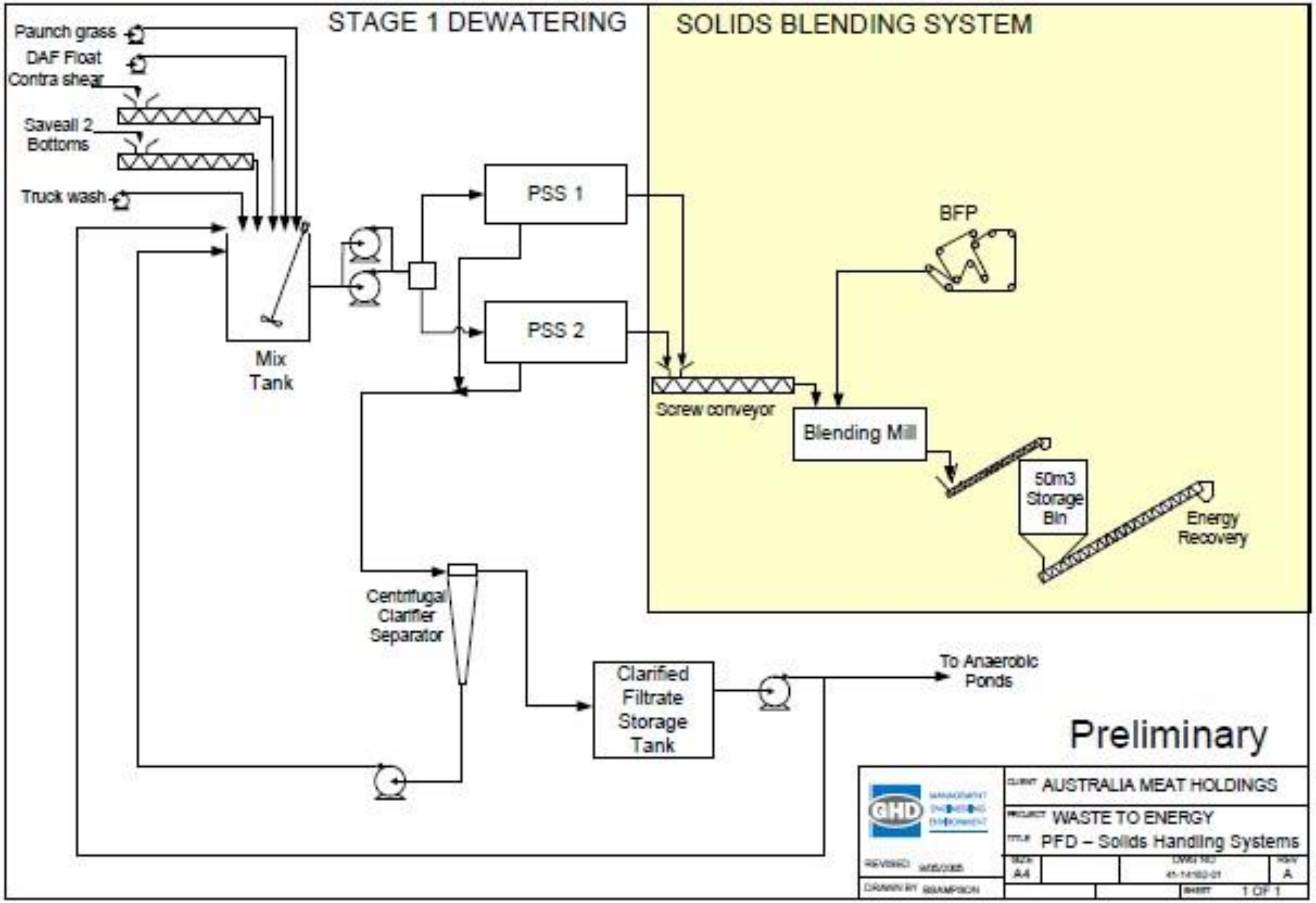
[14] Loadings are the average for a week, but there will be daily variations associated with either 1 or 2 shift operation
[15] Flow will depend on 1 or 2 shift day
[16] Assumes filtrate quality of 0.1 % TSS can be achieved
[17] The anaerobic lagoons currently remove about 29,200 kg COD/day (see Section 2.4.4)

3.2.4 Conceptual Layout and PFD

A conceptual layout was developed to assist in the development of a capital cost estimate. The layout is shown in Figure 3.

A more detailed schematic PFD was also developed for this area of the plant and is attached as Figure 4.




STAGE 1 DEWATERING
SOLIDS BLENDING SYSTEM
Paunch grass
DAF Float
Contra shear
Saveall 2 Bottoms
Truck wash
Mix Tank
PSS 1
PSS 2
BFP
Screw conveyor
Blending Mill
50m3 Storage Bin
Energy Recovery
Centrifugal Clarifier Separator
Clarified Filtrate Storage Tank
To Anaerobic Ponds
Preliminary
AUSTRALIA MEAT HOLDINGS
WASTE TO ENERGY
PFD – Solids Handling Systems
A4
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1 OF 1

3.2.5 Cost estimate

Capital and operating cost estimates were developed for the implementation of Stage 1 solids dewatering infrastructure (refer Appendix G for detailed estimates). To facilitate the economic evaluation of the Stage 1 dewatering system as a stand-alone project, the cost estimate was split into two segments:

- Waste solids collection, conveying to the Stage 1 dewatering plant, mixing and dewatering (Table 12); and
- Conveying, blending and storage of the Stage 1 dewatered cake and BP cake (Table 13)

Table 12 Capital and operating cost estimates for Stage 1 dewatering Capital Cost Summary

Description	Cost	
Civil / Site Works	$	32,000
Mechanical	$	460,000
Electrical	$	59,000
Installation	$	266,000
Subtotal	**$**	**817,000**
Contingencies	$	163,000
Engineering	$	123,000
Total	**$**	**1,103,000**

Annual Operating Cost Summary[18]

Description	Cost	
Power	$	13,000
Maintenance	$	40,000
Total	**$**	**53,000**

Table 13 Capital and operating cost estimates for blending post Stage 1 dewatering Capital Cost Summary

Description	Cost	
Civil / Site	$	79,000
Mechanical	$	304,000
Electrical	$	54,000
Installation	$	193,000
Subtotal	**$**	**630,000**
Contingencies	$	126,000
Engineering	$	95,000
Total	**$**	**851,000**

Annual Operating Cost Summary[19]

Description	Cost	
Power	$	11,000
Maintenance	$	29,000
Total	**$**	**40,000**

[18] No additional allowance has been made for labour
[19] No additional allowance has been made for labour

3.2.6 Financial assessment of implementing Stage 1 dewatering

It is possible that the Stage 1 dewatering circuit could be implemented as a stand-alone project. Dewatering of the waste solids will reduce the mass and volume of the waste and hence reduce trucking costs from the site. Currently, up to six trucks a day are required to remove solid organic waste from the site.

Based on the mass balance presented in Section 2.4.1, about 975 tonnes per week of organic waste solids is currently trucked off site. With the implementation of the Stage 1 dewatering system, this will reduce to about 755 tonnes per week, a reduction of 220 tonnes per week or about 22%[20].

A simple financial model was developed to assess the payback for implementation of the Stage 1 dewatering circuit. The model assumed:

- Operating cost credits for reduced trucking and disposal costs of $20/tonne;
- Removal of poly dosing to DAF float hopper pump ($80k/annum);
- Reduction in manpower from 2 per shift to 1 per shift; and
- Maintenance and electricity costs increase by about $43K/annum.

Based on these assumptions and the capital estimate presented in Section 3.2.5, the payback period is 3.7 years, which is outside the AMH hurdle of a 2 year payback.

3.3 Stage 2 mechanical dewatering

AMH are exploring use of advanced screw-press dewatering supplied by the German company, FAN Separator GmbH. When this study was initiated, it was believed that application of the Fan Separator Screw Press Compactor (SPC) (coupled with the first Stage FAN Separator PSS) had the potential to achieve < 30 % moisture in the dewatered solids. It became apparent during the study, however, that FAN Separator had withdrawn their support for this product due to unreliability of these units.

Subsequent to this finding, FAN Separator (through their Australian agent Australian Waste Engineering [AWE]) indicated that they have developed a new generation FAN Separator PSS unit that has the potential to dewater the solids to achieve <50 % moisture. Towards the end of this study, a trial was held with this new unit (see Section 3.2.1 above). Results indicate that a moisture content of approximately 60 to 65 % could be achieved, although this is higher than the target 50 % moisture target preferred by suppliers of energy recovery equipment (see Section 6).

Some preliminary data on the new FAN units has been received from AWE:

- The units are similar to the Stage 1 PSS units, except that the screw auger is about twice as long, the auger changes pitch down its length and the gearbox and auger are strengthened compared with other PSS units;
- The size of unit that would be recommended will only be known after the trial is completed. The possibilities are:
    - A single FAN PSS8-1200 30 kW unit ($240K); or
    - Multiple FAN PSS3.2-1040 units ($85K).

[20] The BP cake is included in this assessment, although it is not dewatered in the Stage 1 dewatering circuit

- The configuration of the units would be similar to that proposed in the Stage 1 concept design; and
- A moisture content of 50 % or less is possible, but remains unproven following testing.

Based on the available information on power draw and cost, it is expected that a Stage 2 mechanical dewatering system will be significantly cheaper and more energy efficient than a thermal dryer. A preliminary cost estimate for installing a Stage 2 dewatering unit using the proposed FAN technology is in the order of $1M (based on using 3 x FAN PSS3.2-1040 units), although the concept design for this system was not developed in detail as part of this study.

With the exception of Electro-dewatering, there is no other mechanical dewatering system which is likely to achieve the required level of cake TS. Electro-dewatering could potentially achieve a cake TS of 50%, but based on prior experience, the electrical power requirements exceed those of thermal dryers and thus this type of mechanical dewatering is not considered cost effective (Trevor Bridle, personal communication).

Kilia Wertstoff-Technik GmbH[21], an alternative supplier of screw press technology, were approach to supply details of their KompriHydro screw press units. One of the authors of this study, Chris Hertle, was able to view this unit at a trade show in Germany in April 2005. The unit looked robust and marketing information suggested the unit may be applicable to AMH feed. Repeated attempts to get further information on this unit have been unsuccessful, through either direct contact with Kilia in Germany (Christoph Schurmann – christoph.schuermann@kilia.com) or their Australian agent Global Machinery and Supplies (Mike Jackson –jacko globalms@bigpond.com). At the time of writing this report, information on cost and specific experience had been pending for more than 3 months. Additional information on the Kilia KompriHydro screw press is attached as Appendix H.

Fournier Industries Inc.[22] of Canada was also approached regarding their Rotary Press technology. They declined to offer a bid for this application, as their past experience suggested that the Rotary Press was not a good option for abattoir solid waste. The presses use friction between the sludge cake and the internal components to effect dewatering. The supplier indicated that the high fat content of the abattoir waste does not allow enhanced dewatering performance.

Based on the above, proving the success of the Stage 2 dewatering is still critical to achieve a superior financial outcome for the waste to energy concept. It is recommended that additional mechanical test work be completed as an alternative to thermal drying or feeding the energy recovery unit with a wetter feed.

3.4 Thermal drying

The residues from the AMH Dinmore facility are to be used for energy (electricity and steam) production, most probably using an FBC/boiler/steam turbine system (Section 6). Presently, it is assumed that without secondary dewatering, a cake moisture content of approximately 73% can be achieved. This level of moisture is too high to maximise energy recovery and two options are being evaluated to reduce cake moisture, namely enhanced (secondary) mechanical dewatering (Section 3.3) and thermal drying.

The residues from the abattoir are greasy and thus flash dryers or thin-film dryers are not considered appropriate since the potential for fires and explosions is too great. Low temperature

[21] www.kilia.com
[22] www.rotary-press.com or www.fournierindustries.com

belt dryers are considered the best drying option, although indirectly heated rotary-drum and tower dryers are possibly acceptable. Based on information from FBC/powergen suppliers, it has been assumed that power generation would be maximised at a cake moisture content of approximately 35%. Consequently, thermal dryers are typically designed to produce a product moisture content of 35%.

For the AMH situation, a thermal dryer would be designed to process about 37 t/d of feed (dry), at a nominal moisture content of 73% and dry the material to 35% moisture[23]. The evaporation load is thus 3.3 t/h of water. A quote for this drying duty was received from one belt dryer supplier (Andritz) (attached as Appendix I). In addition, quotes received in 2001, from a rotary drum dyer supplier (Andritz) and a tower dryer supplier (Seghers), to dry sewage sludge has been used to provide comparative costs to the belt dryer quote. These dryers were quoted with an evaporation rate of 3 tph of water and have been scaled up to the required 3.3 t/h using the 2/3 power-law. Prices have been escalated by 5% per annum. Data on these three drying systems are provided in Table 14.

As can be seen, the belt dryer has the lowest capital cost and also the lowest thermal energy demand, but the highest electrical energy demand. It is thus recommended that this dryer be used when evaluating the various energy recovery options for AMH Dinmore.

Huber, an alternative supplier of belt dryer technology (the Kult belt dryer), were also asked to supply budget quotations but declined. This supplier was concerned with belt blinding issues with this application due to the high levels of oils, fats and grease in the feed. In addition, Huber have no prior experience with this feed type, with the Kult units only every having been used on primary and activated biosludges and drinking water sludges.

Based on the mixed response from suppliers, thermal drying is considered a significant risk for the project, with test work of dryer technology recommended prior to accepting this as a preferred dewater approach.

Table 14 Comparison of thermal drying technologies to remove 3.3 tonnes water/hr

Criteria	Andritz Belt Dryer	Andritz Drum Dryer	Seghers Tower Dryer
Capital Cost (A$M)	4.4	6.2	7.5
Electrical power draw (MW_e)	0.33	0.30	0.15
Thermal energy demand (MW_{th})	3.1	4.3	3.1

As an alternative to the above approach, it is possible that only selected streams could be dried in a thermal dryer rather than blending all streams together. The BP Cake could be targeted for drying as a separate stream. This approach has a number of advantages, including:

- Reduced technical risk, as there is significant world-wide experience with thermal drying of municipal and industrial biosolids;
- Blending prior to drying will not be required; and

[23] It is noted that the dryer is sized to dry only part of the total solids flow i.e. a side stream. The blended stream will have a moisture content of 35%. See Appendix I for details

- Overall reduction in capital cost by combining thermal and mechanical dewatering processes (particularly due to the poor mechanical dewatering performance of the mechanical methods trialled to date.)

It is recommended that options for thermal dewatering of the BP cake be further explored.

3.5 Energy transformation and recovery

Detailed discussion of energy transformation and recovery can be found in the subsequent Sections 4 and 6.

4 Recovery of Energy from Solid Waste – A Review

Assessment of the current technologies for converting abattoir solid waste to energy (in the form of electricity, hot water and/or) was undertaken for this study in three stages:

- Background review of relevant thermal (and biological) technologies for energy recovery (Section 4);
- A workshop involving key AMH internal stakeholders to shortlist the preferred options (Section 5); and
- Further compare and develop the preferred option(s) to identify technical/operating constraints and risks, capital costs and overall financial viability compared with AMH project assessment criteria (2 years payback) – Sections 6.

GHD have recently completed a broad assessment of the energy recovery technologies potentially applicable to the red meat processing industry (MLA, 2003). The initial background review for this study extended this assessment, with particular reference to the Dinmore site.

It is noted that the review presented in this section was completed prior to verified information being available regarding the amount and quality of the solid waste streams generated on site. Therefore, references to mass flows and waste characteristics are based on preliminary information. The more detailed assessment of technology options presented in Section 4.3 was prepared with the benefit of more detailed information.

4.1 Context

The context of this background review is processing the (mainly) wet waste streams from the AMH red meat processing facility at Dinmore, with an indicative 15,000 dry tonnes per annum[24]. AMH's target is to maximise energy recovery (for internal use) and to minimise disposal costs of solid residues.

The mixed feed moisture content is anticipated to be reduced to <50 % (weight basis), from an initial value of 80-90% using FAN Separator dewatering technology.
The feed is highly variable in terms of both composition and availability. Site conditions limit storage to a maximum of 24 h (in an unprocessed form).
Considering the waste is of animal origin, any disposal option needs to consider health aspects of possible air emissions and effluent disposal.

[24] Annual tonnage is based on a predicted future operation of 14 shifts per week. The current operating format of 11 shifts per week generates approximately 10,500 dry tonnes per annum (assuming 46 weeks per year operation). This equivalent to a weekly production rate (during plant operation) of approximately 230 dry tonnes per week or 33 dry tonnes per day

4.2 Options Considered

The options considered include:

- Gasification;
- Combustion/Incineration;
- Pyrolysis;
- Thermal Depolymerisation;
- Hydrolytic processing with digestion; and
- Anaerobic ‘dry’ digestion (for comparative purposes).

It is noted that many of the technologies above lack a commercial track record; specifically for the AMH type feed components.

4.2.1 Gasification

Gasification involves partial thermal combustion of carbonaceous feedstock to produce syngas, which is typically a mixture of CO, H_2 and CO_2. Other components (technology dependent) include N_2 (particularly if air-blown), methane and some H_2S/NH_3 impurities. For high proteinaceous wastes, such as those generated by AMH, ammonia production could be significant and the syngas thus requires extensive gas clean up before combustion.

Gasification can give a high thermal recovery, with ~80% for a dry (less than 15% moisture) feed. Gasification has traditionally been suited to large-scale plants (e.g. The Sasol Lurgi gasifier processes 1000 tpd of coal), but in the past 15 years various variants have been developed to process biomass on considerably more modest scales.

The challenge has been to generate a ‘clean’ syngas (with minimal tars and other contaminants) with minimal processing steps and equipment to keep cost down for small-scale operations. This generally limits the choice to steam and air gasification, rather than the more thermally efficient oxygen blown process.

While the syngas can be converted to power (via a gas engine), a more valuable application is to use the syngas as a NG supplement or as a boiler fuel.

Gasification efficiency is sensitive to feedstock variation and operator experience.
Stable feed composition/ feed rate provide stable syngas operation. Turndown is generally slow, and instable combustion leads to process unreliability and low availability.

For process critical output, two gasifier trains are generally specified (even with a standby gasifier). For small applications, a back-up fuel such as pipeline NG provides standby fuel should there be operational upsets.

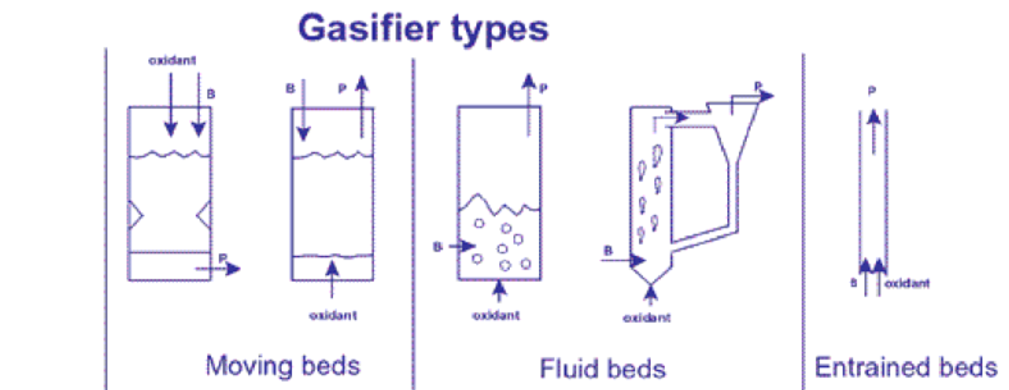
Biomass experience
Biomass gasifiers have been operated with a wide range of feedstock. As indicated, dry feeds work best, which implies pre-drying most biomass feeds. Biomass differs from coal in having considerably higher oxygen, with a lower fixed carbon content.

Biomass ash tends to have a low slagging (melting) point, resulting in sticky ash removal. It is also more corrosive than coal, with formation of various short chain organic acids such as acetic. Feed handling is more complex than coal, requiring modifications to avoid bridging and blockages.

Operational data has varied from 98% availability to unsuccessful technology variations of 20-30%. Over 80% availability is feasible with an appropriate choice of technology and feed management.

Types of gasifiers

There are essentially three different types of gasifiers as shown in Figure 5 below.



	Co-current	Counter current	dense	circulating	
T°C	700-1200	700-900	< 900	< 900	>1500
tars	low	very high	intermediate	intermediate	absent
control	easy	very easy	intermediate	intermediate	very complex
scale	< 5 MW_t	< 20 M_t	10<MW_t<100	20<MW_t<?	> 100 MW_t
feedstock	very critical	critical	less critical	less critical	very fine particles

Figure 5 Varieties of gasifiers

Fixed (moving) Bed – The different fixed-bed reactor types are characterised by the direction of the gas flow through the reactor (upward, downward or horizontal) or by the direction of respectively the solid flow and the gas stream (co-current, counter-current or cross-current). For specific feedstock a co-current gasifier is used with the advantage that the tar content in the producer gas is low. Additional gas cleaning is avoided. This reduces the investment and operational costs.

Fluidised Bed - In a fluidised bed gasifier air and biomass are mixed in a hot bed of solid material sand). Due to the intense mixing the different zones -drying, pyrolysis, oxidation, reduction - cannot be distinguished; the temperature is uniform throughout the bed. Contrary to fixed bed gasifiers the air-biomass ratio can be changed, and as a result the bed temperature can be controlled. The producer gas will always contain certain amounts of tar, which need to be removed.

Examples of gasifier technologies include:

HoST Fixed Bed
The HoSt downdraft fixed bed wood gasifier proved to be a suitable technology for gasification of waste wood to a capacity of 2 MW_{th}. The gasifier of HoSt is specially designed to gasify

shredded or chipped waste wood. The feeding system and the gasifier have been successfully modified to prevent arching and blocking. These systems consist of the following components:

- Wood storage and feeding system
- Gasifier and ash removal system
- Gas cleaning: Cyclones, gas filters
- Water treatment
- Engine combined heat and power

Fuel specifications are as follows:

- Particle size 10 up to 150 mm
- Free of metal pieces.
- Moisture content preferably below 25%

The range of standard size units are shown in Table 15.

Table 15 Standard HoST gasifier units

TYPE	HFIG-100	HFIG-200	HFIG-400
Electrical output	100 kW_e	200 kW_e	410 kW_e
Heat output (40-70°C)	200 kW_{th}	430 kW_{th}	860 kW_{th}
Wood consumption	110 kg/hour	200 kg/hour	400 kg/hour
Wood storage for one day	17 m3	30 m3	60 m3
Height of the gasifier	6 m	6 m	6 m

Segher's Fluidised Bed Gasifier

Seghers Keppel's offer a combination of Fluidised Bed Technology Gasification followed by combustion for sludge waste reduction. The flue gas is scrubbed to minimise emissions.

This low temperature gasification is typical for most fluidised bed gasification processes. The lower temperature requires gas processing to remove tars (which are usually recycled back to the reactor) and ash. Biomass ash tends to have a low ash melting point (~950ºC), which forces the choice to operate below this regime, or add additional processing complexity.

The syngas produced is typically a low calorific fuel (Approximately 15-20% of NG), which is typically co-fired with NG in a gas engine or boiler.

4.2.2 Combustion

Combustors coupled to steam boilers are commonly used by various industries to generate steam, electricity and process heat. The most commonly used fuels are coal, fuel oil, gas or waste material such as wood waste and MSW. Combustors are typically of the grate type (fixed or moving) as used for MSW and more recently the use of Fluid Bed Combustors (FBCs); either once-through or recirculating types are rapidly gaining prominence.

Most combustion treatment typically includes fly ash and sulphur removal. Scrubbing of sulphur with lime to produce calcium sulphate is generally only practised for large-scale (eg. >40 MW_{th}) facilities or as dictated by local environmental regulations.
The combustion parameters (temperature, excess air, burner flame design) influence the formation of particulate and other emissions such as dioxins.

For processing of wastes containing significant quantities of chlorides and heavy metals, use of the fluidised bed combustors is recommended.

An example of a FBC is EPI's (Energy Products of Idaho) Fluidised Bed Boiler. As indicated, conventional grate boilers have not operated satisfactorily for waste and biomass firing, requiring modification to optimise reliability and emissions. The lower heating value, variability and fouling on tubes/blockage of conventional grates have limited biomass addition as a 10-15% co-firing option.

EPI has designed fluidised biomass and waste combustor/boilers for over 15 years. The fluidised bed approach incorporates a sand bed that provides advantages of:

- Thermal inertia to feed fluctuations;
- Feed flexibility and robustness;
- Rapid mixing provides cleaner combustion;
- Ability to add limestone to control sulphur emissions; and
- Good turndown and rapid start-up.

EPI have had experience with various waste streams including paunch, manure, straw and cardboard sludge.

The boiler emissions are 'reasonable', with choice of operating parameters and additional processing equipment to minimise dioxin and other listed emissions. A preferred scale appears >15 MW_e.

4.2.3 High temperature combustion

Incineration is the term usually associated with the disposal of waste and incorporates high temperature combustion (> 850ºC) to minimise release of hazardous chemicals usually associated with such waste streams. The European Union Waste Incineration Directive (WID) requires that all waste incinerators operate at above 850ºC for a 2 second gas retention time (after the last waste injection point).

Incineration has been the preferred technology for MSW disposal in various countries such as Japan (~75%), Singapore (>80%) and Denmark (52%), where landfill is at a premium. Early technology variants (i.e. the old moving grate incinerators) have been under environmental scrutiny, following awareness of incineration contributing a significant source of dioxins and release of other heavy metals. Modern incinerators have improved combustion design with significantly lower dioxin emissions (see Figure 6 for UK data).

The historical track record has cast a question in the public's mind on the safety of incineration technology, and various countries have opted for non-thermal waste disposal technologies.
Typical incinerator thermal recovery can be ~25% (electricity, on MSW), with the moisture content of the feed affecting the yield. This equates to a thermal recovery of ~55%. Value to steam is thus higher than 45% (as steam). This recovery is affected by scale, with smaller scale ~~units allowing a lower degree~~ of (cost effective) thermal recovery. For a feed moisture content

exceeding about 40%, an incinerator requires additional external energy input to ensure stable combustion.
Incineration is not a low cost solution for waste management, with Singapore reporting A$800 of capital per 1000 tonnes per annum for large scale energy recovering plants.

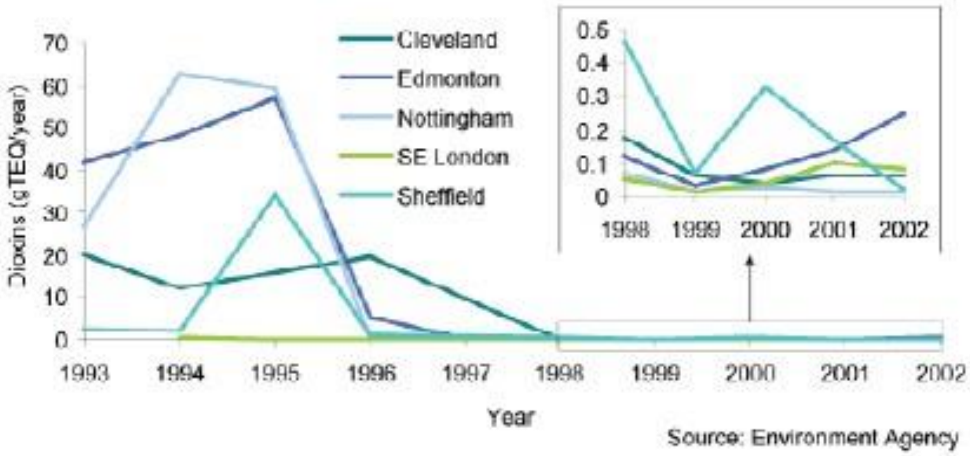


Figure 6 Dioxin emissions from UK incinerators

4.2.4 Pyrolysis

Pyrolysis is an 'old' technology used for converting solid fuels (typically wood biomass) with thermal exposure without air addition, at 400-500ºC, to liquid fuels to enhance thermal properties and transportability.
Examples of pyrolysis are outlined below.

Ensyn (Wood waste only)

Over the past decade much research has focused on rapid thermal pyrolysis (RTP) – as coined by the Canadian company Ensyn. By introducing precision to pyrolysis, a much greater liquid (bio-oil) product yield is obtained, with increased thermal efficiency. The bio-oil (described as the colour and consistency of cappuccino) has a thermal value of ~65% of fuel oil, a specific density of ~1.2 and consists of 'solubilised lignins'.

The bio-oil comprises highly oxygenated compounds including organic acids and thus has a low pH (acidic) and is best used as a fuel oil supplement.

Ensyn has striven to increase product value by marketing co-products such as resins, extracted from the bio-oil. Ensyn reports ~75% mass yield conversion to bio-oil, with ~80% thermal efficiency. The balance is gas and char, which are used to provide energy to the process. A process requirement is a feed moisture content of below 15%.

Ensyn currently has four commercial RTP™ facilities in operation; three in Wisconsin and one in Ottawa, Ontario. These are currently the only commercial fast pyrolysis plants in the world. The largest of these processes 75 green tons per day of mixed hardwood wastes (i.e., equivalent to around 40 tons of dried wood going to the RTP™ unit). This RTP™ facility was built in Wisconsin by Ensyn in 1996, and has operated with a commercial availability of over 94%. Ensyn produces ~~more than 800 tons of bio-oil~~ per month in Wisconsin.

Ensyn recently constructed a second 40 dry ton per day RTP™ unit.

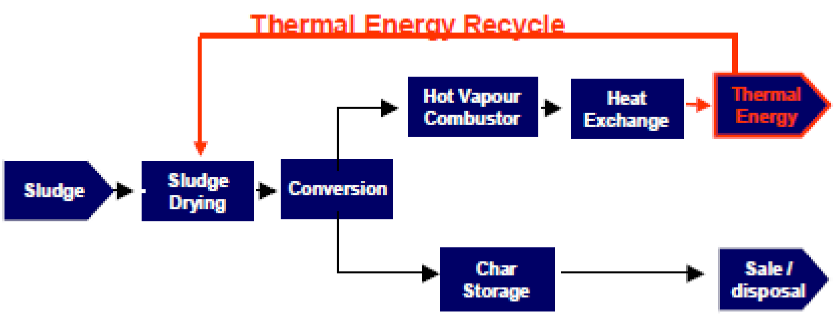
Figure 7 Ensyn RTP plant

ESI (Environmental Solutions International)
In 1999/2000, ESI commissioned the first commercial, oil-from-sludge, or Enersludge™ plant at the Subiaco wastewater treatment facility in Perth, Western Australia, to process sewage sludge.

The technology involves pyrolysis of dried sewage sludge to recover bio-oil, which can be used to generate power. Dried sludge is heated to 450°C in a dual reactor system in the complete absence of oxygen. The process is enhanced by vapour phase catalytic reactions in the second reactor that removes most of the oxygen from the oil, producing a higher energy density product than with wood pyrolysis. The oil contains mainly hydrocarbons and is not miscible with water, as is the oil from wood pyrolysis.

Indicative yields from the Subiaco sludge processing facility are: ~30% oil, 46% char, 12% gas and 12% water. This $A23 million facility was designed to process up to 25 dry tonnes per day of sewage sludge, producing approximately 800 kWh of electricity for sale from each tonne of sludge processed. In this facility the char, gas and water were combusted in a FBC to provide the energy for sludge drying.

The technology has been simplified and made more robust since start up of the Subiaco plant. Three process options are now offered, including the simple Hot Vapour Combustion (HVC) option, as shown in Figure 8 below.
ESI went into receivership in November 2004 and the Enersludge™ technology is now for sale.



~~Figure 8 Enersludge process~~ flow sheet for Hot Vapour Combustion.

SWERF (Solid Waste and Energy Recycling Facility)

The SWERF Wollongong demonstration plant converted sorted MSW to fuel, gas, and power. The process employed an air free pyrolysis 'gasifier' reactor, followed by gas cleaning and combustion of the syngas generated to generate power (Figure 9). The solid/char residue is considered for compost use (thermally sterilised).

The syngas was reported as having a thermal value of ~17 MJ/m³, which is ~50% of NG. The process did not meet its design objectives, and encountered various operational problems. Environmental groups successfully managed to dissuade the public from supporting additional plants, and this culminated with Energy Developments Limited withdrawing from the SWERF project at the end of 2003.

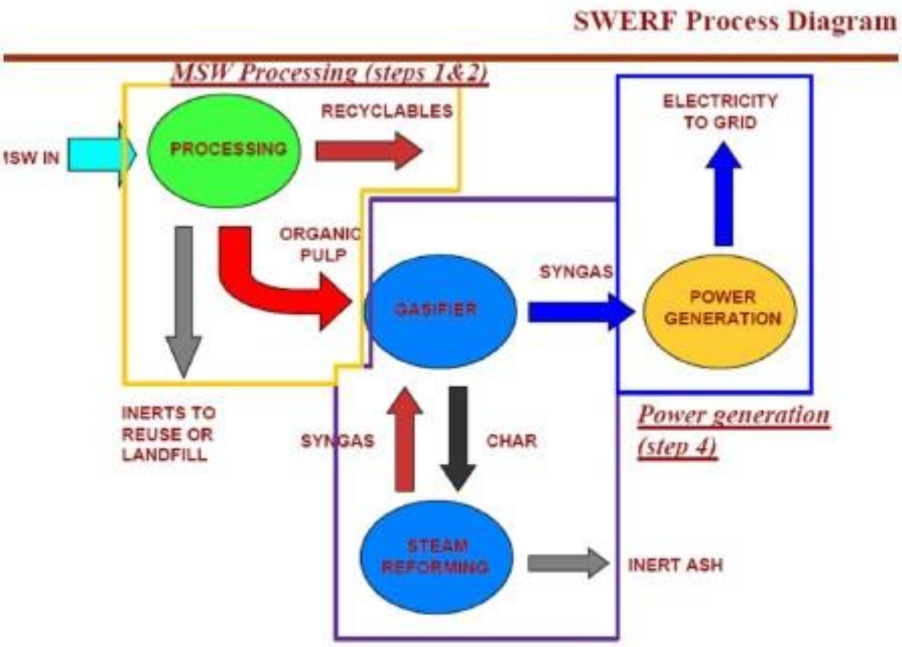


Figure 9 SWERF process flow sheet

4.2.5 Hydrothermal Depolymerisation (HDP)

The attraction of hydrothermal depolymerisation is to use a 'wet' (up to 50% moisture) waste feed, and process thermally efficiently to a user-friendly fuel.

The most advanced facility is the 200 wet tonne per day[25] demonstration plant processing turkey waste, in Carthage, Missouri, USA (Adams et al., 2004 and Roberts et al., 2004). The proponents are Changing World Technologies (CWT) and Conagra, who together have formed Renewable Environmental Solutions (RES) to develop the Thermal Conversion Process (TCP).

Steps of the TCP process include:

1. Pulping and slurrying the organic feed with water;
2. Heating the slurry under pressure to the desired temperature;

[25] The dry tonne per day feed rate is not known, but is likely to be in the order of 40 to 60 dry tonne per day, which is higher than the AMH case

3. Flashing the slurry into a lower pressure to separate the mixture (steam, organic and solids);
4. Heating the slurry again (coking) to drive off water and produce light hydrocarbons; and
5. Separating the products.

The process is not simple, and as such suited to large-scale facilities (e.g. 1,000 t/d target)[26].

As with all thermal processes, the TCP process is thought to destroy the BSE prion and can potentially be used for disposal of specified risk materials or other BSE-related material.

The claims for the process have moderated with the demonstration plant experience. The plant currently appears to be operating at 20-40%[27] of design, and undergoing 'optimisation'. The history of the performance of this plant is summarised in Table 16.

Table 16 Genesis of the RES plant in Carthage, Missouri.

Parameter (200 tpd feed)	Before built	Commissioning	DOE EIA submission
Capital	A$27m	A$40m	A$41m
Production bbl/d	600	500	400-500
Efficiency	>85%	85%	Over 80%
Product	No. 2 fuel oil	No. 4 fuel oil	

Other similar processes include Ozmotech's Thermofuel process, which converts waste plastic to 'diesel' fuel, via a mixture of liquefaction, pyrolysis and catalysis.

Modular units of 10 t/d are targeted, which are claimed to produce ~60 bbl/d of diesel (noting that the thermal value of plastic is considerably higher than that of organic waste).

This process is suited to processing unsorted, unwashed plastic waste, assuming that this waste is largely polyethylene, polypropylene, polystyrene and ABS. This allows processing of multiplayer laminates and other printed films.

PVC and PET plastic are not suitable feedstocks and most of AMH's waste stream would not be suitable for processing in the Thermofuel system.

4.2.6 Hydrolytic Processing with Digestion

The hydrolytic processes use mechanical pressure, shear forces and/or elevated temperatures with water and or chemical additives. The aim is to break up the sludge (waste) particles to allow better dewatering and removal of non-combustible components.

The techniques can thus be seen as a pre-process to enhance thermal recovery and mass reduction of waste streams.

[26] CWT / RES FAQs
[27] CWT RES technology news 19/5/2004

Examples of hydrolytic processes are as follows:

Krepro Process *(Kemira / Alfa Laval)*
This process has been demonstrated with a pilot plant and a (~70 000 tonne per annum) commercial plant on municipal sewage sludge from Helsingborg in Sweden. The process acidifies sludge to a pH of ~1.5, which is then boiled at 140°C. This is followed by removal of insoluble organic matter in a decanter centrifuge.

The reject water is pH adjusted, which causes the inorganic fraction to precipitate. This is then again centrifuged. The liquid (water) portion is recycled.

The organic sludge has a TS of ~45-50%, with a thermal value comparable to woodchips, making it a suitable biofuel for either combustion or biotreatment. The inorganic fraction has suitable fertiliser characteristics and is free of most heavy metals.

It has been reported that the product sales value is marginally less than operating costs i.e. the impact of the waste is reduced at near zero cost.

Cambi Process

The Cambi process was developed in Norway and involves thermal hydrolysis. This involves dewatering the solids to ~10-15% solids, followed by pulping with steam, which provides both sterilisation to Class A standards and solubilisation of organics. After 20 minutes, the reactor pressure is released, flashing off the steam/water to recycle to the pulper. The flash ruptures cells and makes the residual organic pulp easier to transport to simple anaerobic digestion. The digestion yield is higher from this pre-processing, and the final product is easier to dewater.

Brisbane Water is currently constructing a Cambi hydrolysis plant at the Oxley Creek WTP to precondition extended aeration biosludge (collected from various Brisbane STPs). The unit will be able to treat more than 10,000 dry tonne per annum.

Wet Air oxidation

This involves sub-critical water oxidation operating at 150-350°C and pressures of 10-100 bar for periods of 15-120 minutes. The process energy requirements are low, but the capital cost is considered high. The overall TS reduction is modest, but the remaining sludge is easier to dewater.

Supercritical water oxidation

Also known as hydrothermal oxidation, this process uses water at > 374°C and 220 bar.

The reaction time is accelerated to a few minutes. The process is capable of a high degree of TS reduction (60-80%), produces a high quality effluent, and minimal emissions. Issues include complex control, exotic materials of construction and complexity.

Currently the process is classed as ‘innovative’ status, with mainly pilot plant work.

4.2.7 Anaerobic ‘dry’ Digestion

While anaerobic digestion is not strictly a thermal process, it has found broad application for biowastes, such as those produced at AMH Dinmore.

Waste reduction is achieved by producing marketable compost, together with some energy (biogas).

There are many process variants including ‘wet’ (the classical anaerobic lagoon), ‘dry’ (40-50% TS), 1-2 stage and continuous/batch.

The dry system is potentially of most interest for the AMH waste. This system can use mesophilic (~35°C) or thermophilic (45-55°C) micro-organisms to accelerate digestion. This differs from the classic lagoon system (which was derived from wastewater processing) in processing mixed sludge slurry.

The net energy output is dependent on the feed composition. Biologically ‘clean’ feeds (i.e. minimal glass, metals, plastic etc) have higher conversion rates as shown in Table 17 below.

Table 17 Net energy production from anaerobic digestion for a range of feed types

Material	Biogas produced L/kg TS@	% methane in biogas	Suitable RT**
Banana (fruit and stem)	940	53	15
Potato (tuber)	880	54	15
Sugarbeet (root)	620	65	15
Meat waste (paunch, offal)	600	59	25
Lucerne	450-600	56-64	20
Kale	440-560	47-58	20
Grass	450-530	55-57	20
Maize (whole plant)	350-500	50	20
Oats (whole plant)	450-480	51-55	20
Hay	350-460	54-65	20
Straw (ground)	350-450	54-58	25
Poultry manure (fresh)	300-450	57-70	20
Pig manure (fresh)	170-450	55-65	20
Sugarbeet (leaves)	380	66	20
Garbage (organic fraction)	380	48	25
Lakeweed (Lagarosiphon)	380	56	20
Straw (chopped)	250-350	58	30
Newspaper	240	52	30
Cattle manure	190-220	68	20
Sheep manure	180-220	56	20

TS@ = total solids or dry matter
RT** = retention time in days

The net energy produced is ~20% compared to thermal (incineration) processes.

The process is robust, and importantly, is potentially a relatively low cost option compared to thermal systems. An indicative cost is ~60% of an energy recovering incinerator system.

A concern with animal derived waste is the transmission of disease, pathogens or even the BSE prion. EU standards have determined class ‘A’ parameters for digestion plants, which requires certified exposure (residence) time at specified temperatures. Pasteurisation (at 70°C) is often employed.

Examples are as follows

Biocel, Lelystad, Netherlands

This anaerobic dry batch process takes ~38% TS VGF (vegetable, garden and fruit waste) and achieves ~1.65 GJ/t of feed, biogas. The technology uses batch reactors to achieve digestion, recovers water, compost and biogas. The biogas has a calorific value of ~20 MJ/m^3.
A batch approach allows flexible adjustment to varying feed composition and rates. The digestion treatment requires 15 days to complete.

A 13,300 dry tonne per annum demonstration plant has been upgraded to 19,000 dry tonne per annum.

ORT Dicom Process

This technology developed in Perth, involves a batch multi-step reactor, which anaerobically extracts energy from screened MSW (municipal waste). MSW contains a mix of organic waste including food scraps, garden cuttings and paper (newsprint, cardboard), producing quality compost.

Potential advantages of this process are a small footprint; low capital and ability to scale down to modest feed rates (30,000 to 50,000 wet tonne per annum).

4.3 Processing Constraints

4.3.1 Fluctuating Feed rate and composition

Varying Feed rate
AMH currently operates with two 10 h shifts between Monday and Thursday, with only single shifts each day between Friday and Sunday. With higher demand, two 12 h shifts may potentially operate daily.

Much of the waste generation is proportional to activity, but some elements (e.g. DAF float) operate on a continuous basis, with regular removal of solids. A 24 h site storage capacity limits the ability to average out of feed flow-rate.

Turndown for thermal processes is typically ~50%, with lower turndown typically requiring the use of smaller multiple units.

Varying Feed composition
Thermal processes operate stably with a consistent feed composition. Stable operation minimises emissions and process upsets. The nature of the AMH streams requires intimate mixing to achieve consistency.

Screening for metal recovery should be considered.

Segregating feed components
Most of the waste streams contain fat and other organics, with a high degree of moisture.

The cardboard and plastic wastes are fairly homogenous streams, and may benefit from separate processing of the other waste.

4.3.2 Moisture Content in Feed

The moisture content of the feedstock strongly impacts thermal processing performance and reduces energy efficiency, with much of the energy consumed internally to ‘dry’ a wet feed.

Hydrothermal depolymerisation (commercially immature) and anaerobic digestion have a highest flexibility to high moisture (~65% moisture). Gasification, combustion and pyrolysis all benefit from additional drying to lower moisture levels.

4.3.3 Inorganics and salts

Inorganics typically include salts, ash and sand. These non-combustible fractions have to be removed from site, and contain residual carbon (char).

Alkali metals in the biomass, such as potassium and magnesium, lower the ash melting point, which complicates operation with sticky ash. This may lead to possible corrosion issues with construction materials. Chloride carry over can result in corrosion issues downstream of a gasifier.

AMH preliminary sample analysis suggests moderately high ash content, implying care will be required with high temperature thermal processing (see Section 6.1.6 Ash).
Following high temperature thermal treatment (sterilisation), the residues may be suitable as a fertiliser.

4.3.4 Dioxin formation

Thermal processes open to atmosphere result in dioxin and other toxic emissions. Dioxin formation is linked to presence of chlorine, carbon and oxygen.

One of the main mechanisms is attributed to residual carbon in fly ash during cooling of the off-gases (de novo synthesis). By optimising combustion parameters (to minimise unburnt carbon), dioxin formation can be minimised to acceptable levels.

Fluidised bed technology provides superior performance to fixed bed options.

4.3.5 Residual Waste Disposal

All the processes will have some residual solid waste, requiring off site disposal. This ranges from the ash portion of the feed (inorganic, with residual unburnt char [carbon]), to heat-treated organic compost.
The solid waste volume reduction, with thermal processing is:

- Removal of the waste moisture (~70%) – preferably recycled;
- Removal of the organic fraction (20-25%); and
- Residual ash (5-10%).

The ash could have a fertiliser value, this being dependent on the level of heavy metals in the ash. Once data is available, this should be compared with the values identified in the MLA report on Assessment of Contaminants in Waste Solids from Meat Processing Wastewater Streams (MLA, 2002).

The alternative remains disposal to landfill.

4.3.6 Preliminary Ranking of Technologies

Table 18 below ranks the various technology options against likely AMH constraints, using a fatal flaw (0), poor (1), medium (2), high / favourable (3) differentiation. This ranking was done prior to the workshop (Section 5) to obtain a 'subjective feel' of the technologies that would be most suited to the AMH Dinmore situation. In effect, this preliminary ranking allowed the workshop to focus on the most appropriate technologies for AMH Dinmore.

Table 18 AMH Dinmore preliminary technology comparison

Technology	Robust (feed)	Moisture tolerance	Inorganic tolerance	Commercial experience	Effluent / emissions	Energy recovery	Cost/ Pay-back	Total[28]
Gasification Fixed Bed	0	2	2	1	1	2	2	**10**
Gasification Fluidised	3	2	2	2	3	2	1	**15**
Steam Boiler grate	2	2	1	3	1	2	2	**13**
Boiler Fluidised	3	2	2	2	3	2	2	**16**
Pyrolysis	2	1	2	1	2	2	1	**11**
Thermal depolymerisation	2	3	2	0	1	2	0	**10**
Hydrolytic	3	3	2	0	2	0	1	**11**
Anaerobic (dry) digestion	3	3	2	1	3	1	1	**14**

Fixed bed gasification, Thermal depolymerisation and hydrolytic processes suffer from a fatal flaw for the AMH Dinmore feed.

The preferred options appear to be:

- fluidised boiler;
- fluidised gasifier; and
- anaerobic digestion.

In terms of feed experience, all three of these technologies have been demonstrated experience with most of the feed elements in the Dinmore feed (paunch contents, manure, cardboard and organic fats). While anaerobic systems handle high moisture content (50-70%), the fluidised options benefit from feed drying, preferably integrated and using waste heat.

Site Energy supply options

AMH Dinmore uses a mixture of coal and NG for steam raising, hot water production and direct thermal drying. Electricity, mainly used for refrigeration, is purchased off the grid. Based on a review of the energy usage on the Dinmore site, broad energy requirements for the site were defined (Table 19).

[28] A higher score is indicative of a preferred technology for the AMH Dinmore situation

Table 19 Indicative site Energy demand, unit cost and annual cost[29]

Energy Source	Usage (average)	Energy unit cost	Annual cost
Electricity[30]	7.5 MW_e	$47/MWh	-$2.6m/a
Natural Gas	3.9 MW_{th}	$6.3/GJ	-$0.68m/a
Coal[31]	11.4 MW_{th}	$1.6/GJ	-$0.51m/a

Based on this high-level energy balance for the Dinmore site, the following generalisations can be made for the three preferred technologies identified in Section 4.3.6.

- A fluidised boiler could substitute site steam derived from NG (estimated to be up to -3 MW), with excess production (if any) substituting coal-derived steam, although this has a lower economic return.
- A fluidised gasifier producing syngas would target NG substitution, with power generation as a secondary option. The low calorific value syngas (-5 MJ/m³) is preferably used for fired heating rather than power generation. Potential tar carry over confirms this view.
- Anaerobic digestion produces biogas (-60% methane, -21 MJ/m³), which could either be used for fired heating or power generation (with a gas engine). Gas cleaning may be required.

The figure below (Figure 10) from Jenbacher highlights the respective thermal content of various feed types. Syngas typically has the thermal value of ‘wood gas or pyrolysis gas’.

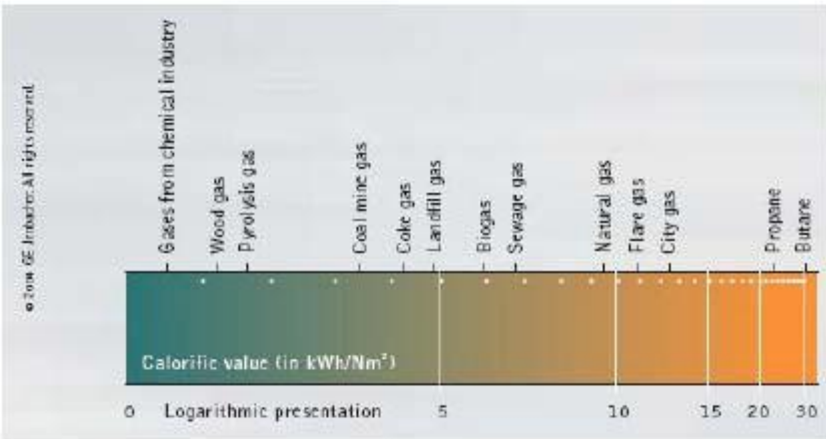


Figure 10 Representation of calorific value for various gas engine feedstock

29 Based on operation for 320 day per year and current operating regime (11 shifts per week)

30 AMH are predicting that electricity prices will rise by 11 to 15 % (or more) in 2006

31 AMH has indicated that the current supply of local coal is likely to be exhausted in the next couple of years, in which case the coal will be sourced from Dalby. This is expected to increase the price of coal by at least 30%.

5 Technical Risk Workshop

5.1 Background

One of the key deliverables of this study was an assessment of the technical and financial risks associated with the use of the proposed energy recovery technologies: biogas recovery, solids dewatering and energy recovery from dewatered solids. To broadly address the issues (and identify any "show-stoppers"), a Technology Risk Assessment workshop was held.

The workshop addressed the risks inherently associated with the implementation of new technology, including:

- current application(s) of the proposed technologies worldwide and in the meat industry;
- technical limitations;
- process unknowns;
- operational unknowns;
- environmental issues; and
- test work requirements to mitigate risk.

Representatives from MLA, AMH, Bridle Consulting and GHD attended a half-day session (23 May 2005) to workshop the risks associated with the implementation of energy recovery from waste material at the Dinmore site.

The specific aims of the workshop were to:

- Introduce AMH and MLA to the technologies under consideration in the Feasibility Study. The technologies are broadly groups into two areas – "dewatering" and "energy recovery";
- Identify the range of risks associated with implementation of each of the technologies;
- Identify a preferred dewatering and energy recovery technology suite by ranking the technologies currently under consideration; and
- Allow AMH and MLA to have direct involvement in the selection of a preferred technology for more detailed financial assessment.

A detailed overview of the workshop process/ranking and the associated minutes from the workshop are attached as Appendix J.

5.2 Outcomes

In summary, the outcomes from the workshop were:

Dewatering

- Mechanical dewatering using screw presses was the preferred option for dewatering of the waste solids;
- FAN Separator and Kilia are potential suppliers of screw press technology for this application;
- Two alternative configurations for Stage 1 dewatering were considered. Option 2 (dewatering of partially dewatered waste solids i.e. savealls retained) was preferred on a cost basis; and
- Filtrate polishing should consider a range of technologies to ensure that a cost effective solution is developed.

Energy recovery

- FBC technology scored the highest of the options considered and should be further assessed;
- Three other options were also considered potential technologies and should be considered further; FBG, Anaerobic (dry) Digestion and Grate Steam Boiler; and
- If thermal drying is required, a low temperature belt dryer is preferred.

Following the workshop, a further high-level assessment was undertaken of the preferred waste to energy technologies. This assessment aimed to further differentiate between the selected technologies, such that a single option could be developed in more detail. This assessment included:

- Development of a rough preliminary balance for the site;
- Estimation of capital and operating costs for each option; and
- Estimation of payback period for each of the options.

Based on this assessment, FBC was again identified as the preferred waste to energy technology. Section 6 develops the FBC case in more detail.

6 Preferred Energy Recovery Technologies

In Sections 4 and 5 of this report, the platform was laid for the selection of preferred (thermal) waste-to-energy technologies. The preferred technology is Fluidised Bed Combustion (FBC), although Fluidised Bed Gasification (FBG) and Anaerobic Digestion (AD) also offer potential benefits.

This section provides a preliminary conceptual processing and techno-economic assessment for the FBC, with brief comments on the other two options.

6.1 Fluidised Bed Combustion (FBC)

6.1.1 Possible Plant Configurations

The base case for the feasibility study is the operation of the AMH plant on an 11 shift per week cycle. Consideration is given to the future potential of the site to operate on a 14 shift per week cycle, although there is not likely to be a significant difference in plant size between 11 and 14 shift per week operation.

Three possible overall plant configurations have been considered:

1. Base Case - FBC operating on a feed moisture content of ~50 %, achieved using a two-stage FAN mechanical dewatering process;
2. Case 1 – FBC operating on a feed moisture content of ~30 %, achieved using an Andritz belt dryer; and
3. Case 2 – FBC operating on a feed moisture content of ~70 %, achieved using a one-stage FAN mechanical dewatering process.

It was necessary to consider a number of alternative cases, as the moisture content target of the base case (~50 % moisture using a two-stage FAN dewatering plant) is yet to be successfully demonstrated. Further mechanical dewatering test work is planned, although this will be completed after submission of the current Feasibility Study.

6.1.2 Selection criteria

Advantages of FBC

FBC technology is considered the preferred technical processing solution for the targeted AMH waste streams. The key advantages of this technology are:

- Robust to varying feed composition;
- Good turndown to varying demand loads/ feed availability;
- Steam turbine simple and proven technology;
- AMH Dinmore has large site steam/hot water requirement;
- Proven at appropriate scale to available feed components;
- Capability to process 50% moisture feeds (higher moisture content also possible with reduced energy recovery);
- Ability to co-feed biogas and coal; and
- In-line sulphur reduction possible.

Potential concerns/risks

There are a number of potential concerns associated with the application of FBC to AMH feed types. The key concerns and associated risks are:

- Waste mechanical dewatering currently unproven beyond ~60% moisture feed (cake from Stage 2 FAN Separator dewatering (including BP cake);
- Thermal dewatering of blended feed material also unproven, with vendors giving a mixed response regarding the potential for successful thermal dewatering of AMH feed (although it is noted that thermal dewatering of the BP Cake independent of other raw materials may reduce this risk);
- Plant trial of specific feedstock is recommended; and
- Capital intensity associated with plant being at very low end of commercial scale.

6.1.3 Envisaged process

Envisaged process concept basis

This initial process layout is based on interpretation of AMH energy site data. It is based on the following assumptions:

- 11 shifts per week (although layout unlikely to be changed significantly for 14 shift/week operation);
- 321 days operation per annum;
- 11 shift operation is initially anticipated, which induces a greater cyclical operating component on waste generation;
- Feed rate averages about 3.4 tph (average 50% moisture, although this needs to be proven), with 7.6 MW thermal content;
- Feed is a intimate mix of the various organic containing streams;
- Feed organic carbon is ~50% fats;
- Ash content is ~10% of the feed (dry);
- Co-firing of about 3.5 $_{MWth}$ biogas (based on 11 shifts per week, recovered from the existing lagoons, with 60% methane content, balance CO_2, with up to 3 000 ppm H_2S);
- Maximising power generation to attract RECs and potentially NGACs;
- Power generation matches feed availability - variance contained to +/-20%;
- Waste heat is used to displace steam (mainly for hot water) – this load is cyclical and requires confirmation from a detailed site energy balance;
- Minimising coal addition;
- Waste cardboard and plastic is shredded to appropriate particle size;
- Plant can access existing utilities (such as demineralised water) and power facilities;

- Integration with existing site operators and maintenance staff;
- Assumes plant meets site environmental approvals;
- Sulphur and possible odour emissions are contained with chemical addition to FBC (e.g. limestone absorbs sulphur)
- Single operating plant to simplify operations interaction (no core operation) and provide best economy of scale solution;
- Combined feed of ca. 11 MW_{th} approaches desired minimum scale by FBC vendors; and
- The Base Case excludes thermal dryer capital and operating cost (assumption is that mechanical dewatering will achieve the 50 % moisture content required, although this remains unproven).

Licence to operate (ref. SR0467, 19/8/2002)
A revised EPA and operating license would be required for a selected option. Specific compliance issues for the FBC include (to be discussed with short listed vendors/s):

- Start-up releases;
- Alarm detection and recording;
- Licence allows use of biogas as NG / alternative fuel substitute;
- Minimum emission release height and stack velocity;
- Particulate emissions (combustor design, residence time);
- Sulphur dioxide/trioxide emissions (waste is considerably lower sulphur content than coal);
- Nitrogen oxide emissions (requires control of combustion parameters);
- Solid waste handling;
- Waste processing within 24 h of collection on site;
- Condensate temperature control;
- Ammonia (if applicable); and
- Noise attenuation (semi-enclosed structure).

Design basis
This technical assessment indicates a feasible basis for a short-listed waste-to-energy option only. The design phase would require the following additional elements:

- A detailed site energy balance optimisation;
- Dynamic load simulation (over shifts and weekends);
- Realistic efficiency with varying load;
- Verifying range of contaminant levels;
- Development of desired plant operating philosophy;
- Optimising layout with assessment of capital implications;
- Possible pilot plant testing of representative feed mix;
- Confirmation of meeting environmental requirements (stack height, specified emissions); and
- Estimation of plant (boiler) corrosion and surface contamination management.

Potential process vendor options
There are numerous variations of fluidised bed combustors. The principle of using a (air blown) sand fluidised bed is considered desirable to assist with thermal control and complete combustion of these challenging waste feeds.
It is noted that most vendors request > 15 $_{MWth,}$ targeting ~15t/h steam. Possible vendors include:

STC (Sun Thermal and Combustion)

- Use a single drum ERK (Eckrohrkessel) boiler
- Built 5 MW_e Biomass Stapylton plant, Green Pacific Energy, Brisbane

EPI (Energy Products Idaho)

- Have 2 decades of experience with FBC
- Processed various abattoir feeds
- FBC operating at Gibson Island, Brisbane (paper mill waste), 1996

Babcock Hitachi KK

- 29 operating FBC incinerators, mainly Japan
- Scale typically 2-4 tph

Others (indicative only):

Seghers

- Sludge experience

Siemens

- Mainly wood residues P Scale 5-25 MW_e

Wartsila

- Modified rotating grate with refractory, wood residues
- Scale >5 MW_e

Aldavia

- Variation of combination of fluidised and moving grate elements
- Module scale 5 MW_e

The thermal yield of the processes described above is broadly similar, using a steam turbine. They differ mainly in the mechanical details of the combustor.

This review does not attempt to rank these options or the appropriateness of the technologies for the AMH Dinmore site. Such an assessment requires detailed commercial and technical discussions with each of the vendors.

6.1.4 Envisaged process layout – FBC

For illustrative purposes, we present information obtained for the Sun Thermal and Combustion FBC layout.

The FBC plant will consist of:

- Feed preparation;
- FBC bed management (air addition, sand circulation and ash/solids removal);
- The fluidised bed and boiler assembly;
- Gas clean-up (ash containment, chemical addition if required);
- Steam system;
- Steam turbine/ power generator; and
- Off sites-equipment.

Process description

Solid waste (50% moisture assumed) will be screw conveyed to feed hoppers for the FBC. An allowance for a $50m^3$ intermediate storage bin has been made as part of the dewatering estimate.

The FBC typically consists of a sand bed that is fluidised with air and mixed with waste feed added at appropriate feed point/s. Where possible, the feed is pre-heated with waste heat from the flue gas / hot water. Combustion temperature is managed at the lower end of the bed (below 450°C) to prevent softening/stickiness resulting from a high reactivity ash such as typically derived from biomass.

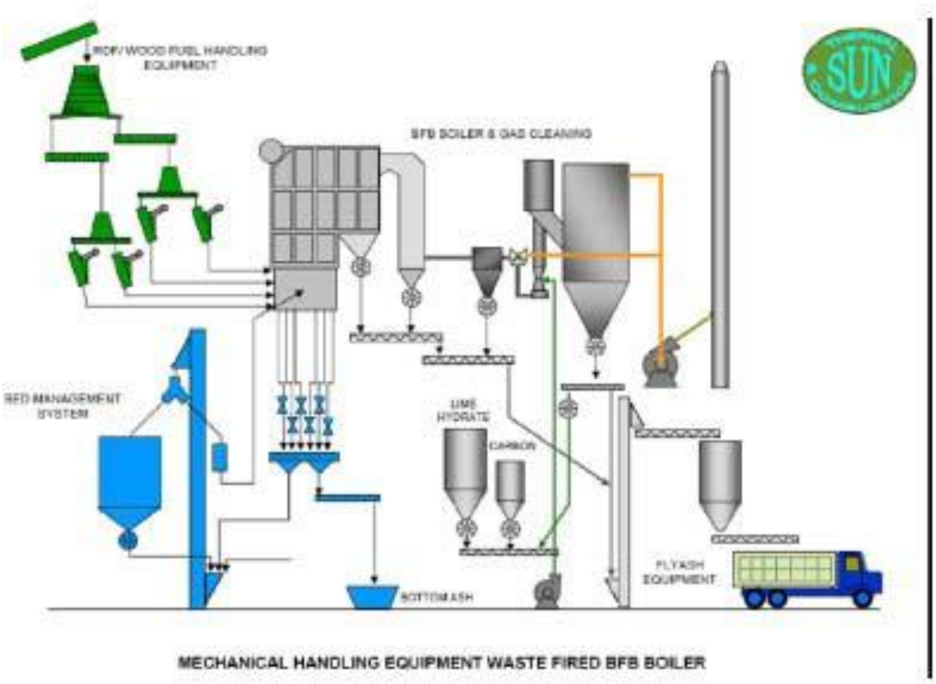
The circulating bed allows good heat transfer and mixing, and ensures a high carbon burn out (typically ~99%).
Ash is collected at the bottom of the bed, for removal and disposal.

Higher in the bed, biogas (and start-up) burners are provided to combust the biogas and waste in the circulating bed. This is typically at a temperature above 850°C. Sufficient residence time is provided to ensure low emission combustion, with control of NOx and minimise dioxin production. The hot gas passes over the boiler, where (superheated) steam is raised (notionally 45 bar, 450°C). A higher steam pressure/temperature allows a higher steam turbine power generating net efficiency.

Waste heat may be recovered from the flue gas, which has fly ash collection equipment before release to a stack.
Sulphur and other emission control can be managed where required by adding lime and or activated carbon to the FBC, which allows absorption of sulphur and other selected impurities (including polycyclic aromatics). Initial indications are that the AMH waste has modest levels of sulphur and low aromatics, but this would require verification.

The steam turbine is a typical single-stage condensing turbine, although back-pressure could be introduced and condensing completed with a hot water warming system (probably preferred for AMH). The power generated would be tied into the existing power distribution system at an appropriate level, and grid linked to ensure ability to export power when the AMH plant is on low load. This is also a requirement of securing RECs and NGACs for additional cash flow to the project.

Figure 11 FBC Mechanical layout



Detailed Equipment list

Appendix K contains a typical list of all major items included in the battery limits (plus exclusions) for the following areas:

- Fluidised Bed Combustor Assembly;
- Light Up Burners (1 Set Complete);
- On Line Bed Cleaning System;
- Fuel Feeding System;
- Boiler;
- Steam And Water Piping;
- Gas Cleaning Plant (1 Set Complete);
- Flue Gas Recirculation;
- Ash Handling (1 Set Complete);
- Water Preparation;
- Control & Instrumentation;
- Electrical (415 V Only) plus high Voltage (33 kV) Electrical;
- Turbine Generator Set;
- Condensing Plant[32];
- Civil Works; and
- Exclusions.

6.1.5 Impact of feed moisture content

A key driver for the current study was the possibility that the moisture content of the wet feed could be reduced acceptably to below 50% with (primarily) mechanical dewatering.

Mechanical drying uses a substantially smaller amount of energy than any process requiring thermal drying. The presence of moisture in the feed results in the latent heat and evaporation loss of water which is typically ~2.9 GJ/t water present in combustion.

[32] This could be optimised with potential for condensing for hot water duty

FBC vendors have indicated their preference for a maximum of 50% moisture in the feed solids but preferably lower.

Table 20 below provides indicative yields for the biomass waste (excluding the biogas component).

Table 20 Estimated impact of feed moisture on net power/thermal yields

Biomass moisture (7.6 MW feed FBC[33])	Net Power/ thermal yield Power MW_e	 Thermal MWth
70% moisture	0.9	1.6
50% moisture (base case)	1.6	3.0
30% moisture (low)	1.9	3.4
0% (dry)	2.1	4.4

The above suggest that a highly wet feed may just be thermally positive, taking into account ancillary losses (such as mechanical drying, etc).
Two mechanical dewatering trials were conducted during this study:

- A single stage FAN Separator trial; and
- A two-stage FAN Separator trial using FAN units operated in series.

Neither of these trials was able to demonstrate the ability to achieve <50% moisture in the combined feed. At the time of writing this report, a further trial with an alternative supplier of screw press technology (Screw Press Compactor or SPC, previous supplied by FAN GmbH but no longer supported) was scheduled for January 2006.
From the outset of the feasibility study, reduction in feed moisture content to an acceptable level for energy recovery was identified as a key risk. Results obtained from the two mechanical dewatering trails and the response from vendors regarding thermal dewatering suggest that moisture reduction of the feed remains a key unresolved risk for the project. A suitable solution is yet to be proven. Further work in this area is a crucial.

6.1.6 Ash

Based on the predicted composition of the raw feed (see Appendix C), the ash will tend to be fairly reactive (as anticipated with biomass), with a relatively high concentration of alkali metals such as sodium, potassium and calcium. This suggests it will be necessary to keep the ash below 500 ºC. The chlorine content of the feed is modest.

The heavy metal concentrations in the feed are indicatively low enough to consider the use of the ash for soil beneficiation purposes. Table 21 outlines the heavy metal content of the feed (based on assay results, Appendix C) and estimated heavy metal content of the ash. Based on comparison with broad Australian guidelines (MLA, 2002), the predicted heavy metal content of the ash would allow reuse of the ash for soil beneficiation purposes.
The sulphur content would yield ~20 to 25 kg/h of SO_2 emissions without sulphur reduction technologies[34].

Table 21 Heavy metal content of the raw feed and ash (predicted)[35]

[33] Excludes combustion stability and biogas portion for comparison
[34] Based on 14 shift per week operation and co-firing with biogas containing 0.1 to 0.5 % H_2S
[35] Ash heavy metal content was estimated based on a 10 fold increase in concentration in the ash compared with the raw feed material (on a dry basis).

Heavy Metal	Heavy Metal Concentration (mg/kg)	
	Raw Feed	Ash (estimate)
Arsenic	0.4	4
Cadmium	0.1	1
Chromium	14	140
Copper	18	180
Lead	1	10
Mercury	<0.03	<0.3
Nickel	6	60
Selenium	<0.1	<1
Zinc	81	810

6.1.7 Capital Estimate – Comparison of base case with Case 1 and 2

The capital estimate is based on the alternative plant configurations described in Section 6.1.1 and the design parameters in Section 6.1.2.

It is noted that the capital is dependent on the desired operating flexibility, feed variance and site details, which may all impact on the estimate.

The cost estimates presented in this section have been developed for the purpose of comparing options and may be used for preliminary budgeting. However, the scope and quality of the works has not been fully defined and therefore the estimates are not warranted by GHD. These estimates are typically developed based on cost curves, budget quotes for some equipment items, extrapolation of recent similar project pricing and GHD experience. The accuracy of the estimates is not expected to be better than about ± 30% for the items described in this report. A functional design is recommended for budget setting purposes.

The uncertainty in the capital estimate is related to site details and the ability to integrate with existing equipment. Owner's development costs and permitting are excluded.

Table 22 presents a summary of the capital costs associated with the base case plant configuration, which consists of:

- A two stage mechanical dewatering plant with an assumed moisture content of 50 % achieved (although yet to be demonstrated);
- Integration of biogas recovered from the existing anaerobic lagoons;
- An FBC supplied by Sun Thermal and Combustion;
- Power generation with a steam turbine;
- Site integration; and
- Engineering and contingencies (included in line item capital costs).

Table 22 Base case capital cost estimate for Waste to Energy Plant (using FBC)[36]

11 MW feed FBC (including biogas)	Capital estimate (A$m)
Two stage Mechanical dewatering (to <50% moisture)	$3m
FBC	$6.9m
Biogas (lagoon) recovery/integration	$1.9m
Power generation (3 MW) Hot water integration	$3.2m
Site integration/other/shredding	$2m (estimate only)
Total	***$17.0m***

The capital *without* the biogas portion is estimated to be ~***$13m***. The biogas adds relatively little cost - collection cost from the lagoons and a larger steam turbine, but minimal additional FBC feed handling or ash, and burner assemblies in the FBC.

Two alternative cases are recognised (see Section 6.1.1):

<u>Case 1.</u> A feed (30% moisture) dried with an Andritz belt (thermal) dryer - ***$20m***

<u>Case 2.</u> A 70% moisture feed, with only a single stage of mechanical dewatering - ***$17.5m***

Both options incorporate biogas co-firing. The higher moisture feed uses only Stage one FAN Separator mechanical dewatering, but has a larger mass flow to the combustor and material handling.

Coal could also be co-fired, but this does not draw RECs and is considered an optimisation outside the base-case, with no capital allowance made here.

6.1.8 Economic model - Comparison of Base case with Case 1 and 2

A simple financial model was developed to assess the economic feasibility of various scenarios. One of the key criteria used by AMH to assess capital works projects is a payback hurdle rate of 2 years. It is unlikely that the waste to energy options considered in this study will be able to achieve this criterion. As a consequence, AMH may seek involvement from a third party to fund this project(s).

The economic outcomes presented are very sensitive to the underlying assumptions, particularly with respect to the operating credits that can be obtained and any commercial arrangements between AMH and third party suppliers. These findings can therefore be considered preliminary and require review by potential third party project partners, such that their particular business assumptions are considered.

The assumptions made for this economic assessment include: P Operating 321 d/a;

- Design case operates at 11 shifts/week, operating case considers both 11 and 14 shifts/week operation;

[36] Excludes owners costs and assumes 'brownfield' site, with appropriate existing services

- Power at $47/MWh (current price);
- Allowance for RECs at the legislated cost (penalty) of $40/MWh for shortfalls in meeting the target. The actual price of the RECs will depend on market factors. In addition, the forecast cost of RECs will have a significant bearing on the overall financial viability. Such forecasting is beyond the scope of the current study;
- No allowance for the possibility of securing NGACs, although this should be further investigated;
- Current waste disposal is reduced to ash fraction only, with credit for disposal costs saved;
- Ash/solids are saleable at achieve $30/t ex gate (to be used as soil conditioners);
- Marginal steam condensate (for hot water heating) at $4/GJ (mixture of replacing NG and coal);
- Thermal balance indicative only (simple model);
- Steam turbine efficiency 31-33% (scale and temperature dependent);
- Spent steam condensed for water heating (back-up is air cooling);
- No steam sales allowed (although this is feasible);
- Economics with simple return on investment (ROI) - no gearing;
- Simple Pay back period calculation;
- Availability and integration with existing operations (for operators, maintenance team and overhead costs) at Dinmore;
- Standard plant meets acoustic levels required by site; and
- Biogas within reasonable proximity of proposed FBC (< 500m).

The economic assessment presented in Table 23 is based on an 11 shift/week operation, with comparison to a 14 shift/week operation presented in Table 24.

In each of the three cases considered, the biogas collected from the lagoons is assumed to be co-fired with the waste solids. This approach is considered optimal based on the scale of the plant and the moisture content of the feed. Co-firing with coal or NG could also be undertaking, although this is considered an optimisation of the cases presented. It is possible from a technical perspective.

The assessment presented in Section 6.1.7 indicates that mechanical drying to ~50% moisture provides significantly better economics than either a wetter feed or a drier feed incorporating thermal drying. The thermal drying (Andritz belt dryer) does improve the overall FBC thermal recovery by over 60% (compared to the 70% moisture alternative), but internal power and heat demand reduces the overall gain to ~25%. The significant capital penalty associated with using a thermal dryer has an overall detrimental impact on project economics from a payback perspective.

The RECs value has a significant impact on the economics – providing ~40% of the cash flow. The achievable REC value is dependent on negotiation and forecast price of these certificates.
The hot water value of $4/GJ is an estimate based on a mix of NG and coal based steam substitution for hot water heating. The plant hot water requirement is estimated as ~5 MW (not verified). Should this not be practical to implement, this credit would be lost.

As indicated, co-firing with biogas has been considered for each of the cases presented in Table 23. For comparative purposes, an economic assessment was also undertaken for a waste to energy system that did not co-fire with the biogas (details not presented). The ROI for this case was 5 % with a payback of 19.5 years. This case was therefore not considered further.
The three cases (Section 6.1.1) were also assessed based on operation with 14 instead of 11 shifts per week. As discussed previously, the capital cost to implement a waste to energy

program at the AMH Dinmore site is considered to be similar for both the 14 or 11 shift per week variations.

Table 23 Waste to energy economics (11 shift/week operation)

Variable	Base case: FBC 50% moisture + Biogas	Case 1: FBC 30% moisture (dryer) + Biogas	Case 2: FBC 70% moisture+ Biogas	Comments
Waste Feedstock MW_{th}	6.0	6.0	6.0	
Biogas MW_{th}	3.5	3.5	3.5	
Capital estimate	$17	$20	$17.5	A$m, 2005
Output				
Power MW_e	2.6	2.8	1.8	Before internal consumption
Hot water MW_{th}	4.3	4.6	3.2	Assume all used
Soil enhancer/ash	1021	1021	1021	tpa estimate
Income $m/a				
Power - internal	$0.93	$1.01	$0.66	A$m at $47/$MWh_e$
Power- RECs	$0.79	$0.86	$0.56	$40/MWh
Power - NGACs	-	-	-	No credit included
Hot water	$0.47	$0.51	$0.35	Steam etc at $4/GJ
Soil enhancer	$0.03	$0.03	$0.03	$30/t ex-gate
Reduction in GHG	-	-	-	No credit included
Waste disposal reduction	$0.59	$0.59	$0.59	70% moisture basis, $20/t
Total	**$2.81**	**$2.99**	**$2.19**	
Operating cost				
Variable costs	$0.20	$0.60	$0.22	Mainly energy inputs
Fixed costs	$0.85	$1.00	$0.87	Integrate with existing operations
Total	**$1.05**	**$1.60**	**$1.09**	
Net Cash flow $m/a	**$1.76**	**$1.40**	**$1.09**	
ROI%	**10.4%**	**7.0%**	**6.3%**	
Payback (years)	**8.2**	**11.8**	**12.6**	

Table 24 Waste to energy economics (14 shift/week operation)

Variable	**Base case:** FBC 50% moisture + Biogas	**Case 1:** FBC 30% moisture (dryer) + Biogas	**Case 2:** FBC 70% moisture+ biogas	**Comments**
Waste Feedstock MW_{th}	7.6	7.6	7.6	
Biogas MW_{th}	4.5	4.5	4.5	
Capital estimate	$17	$20	$17.5	A$m, 2005
Output				
Power MW_e	3.26	3.54	2.30	Before internal consumption
Hot water MW_{th}	5.4	5.8	4.0	Assume all used
Soil enhancer/ash	1300	1300	1300	tpa estimate
Income $m/a				
Power - internal	$1.18	$1.28	$0.83	A$m at $47/$MWh_e$
Power- RECs	$1.01	$1.09	$0.71	$40/MWh
Power - NGACs	-	-	-	No credit included
Hot water	$0.60	$0.65	$0.45	Steam etc at $4/GJ
Soil enhancer	$0.04	$0.04	$0.04	$30/t ex-gate
Reduction in GHG	-	-	-	No credit included
Waste disposal reduction	$0.75	$0.75	$0.75	70% moisture basis, $30/t
Total	**$3.58**	**$4.81**	**$2.78**	
Operating cost				
Variable costs	$0.25	$0.76	$0.28	Mainly energy inputs
Fixed costs	$0.85	$1.00	$0.87	Integrate with existing operations
Total	**$1.10**	**$1.76**	**$1.15**	
Net Cash flow $m/a	**$2.48**	**$2.05**	**$1.63**	
ROI%	**14.6%**	**10.3%**	**9.3%**	
Payback (years)	**6.8**	**9.7**	**10.7**	

6.2 Separate processing of (lagoon) biogas

The biogas could be processed separately either for co-firing with NG in one of the existing NG boilers or a gas engine assembly (GE Jenbacher or similar).

Removing the biogas from the FBC does not reduce the capital substantially, but does directionally reduce combustion stability with a low calorific feed, particularly at high moisture levels (> 50%). The varying nature of the feed components implies a high likelihood of high moisture events during operation.

The economics of this approach (as a stand-alone waste to energy project) will be sensitive to the ability to replace energy usage associated with NG exclusively or whether a reduction in coal consumption will also result. The majority of the NG consumed on the Dinmore site is consumed in a thermal dryer (direct heating). Due to concerns with contamination of the product that may result from direct heating with combusted biogas, it has been assumed that the biogas would replace only that portion of the NG used for steam generation. Precise numbers for NG usage associated with steam raising were not available. It is understood that NG is only used to supply peak demand (not met by the coal fired boiler) of up to 3 MW_{th} in normal operation or 11 MW_{th} with the use of the stand-by boiler.

The intermittent nature of steam raising from natural gas compared with the reasonably continuous rate of biogas generation suggests biogas would certainly replace some coal fired steam generation in practice. An economic assessment of this stand-alone case is shown in Table 25.

The key assumptions associated with this assessment were:

- Lagoons will require desludging and crust removal prior to installation of the covers ($200k);
- Lagoons will require ongoing maintenance to remove the crust as it forms (every 5 years) ($10k per lagoon per year of operation);
- There is a 15 % reduction in biogas generation rate once hydro-cyclones are in operation for enhanced fat recovery;
- Biogas will replace NG (70%) and coal (30%) for steam raising; and
- Pre-treatment of the biogas to remove H_2S is not required.

Table 25 Use of biogas as a stand-alone option

Variable	**11 shifts per week**	**14 shifts per week**	**Comments**
Biogas MW_{th}	3.5	4.5	
Capital estimate	$1.9	$1.9	A$m, 2005
Output			
Hot water/steam MW_{th}	3.15	4.01	Assume all used
Income $m/a			
Power- RECs	-	-	Only for electricity generation
Hot water	$0.43	$0.54	Steam at average price of $4.9/GJ
Reduction in GHG	-	-	No credit included
Total	**$0.43**	**$0.54**	
Operating cost	**$0.1**	**$0.1**	
Net Cash flow $m/a	**$0.33**	**$0.44**	
ROI%	**17.2%**	**23.4%**	
Payback (years)	**5.8**	**4.3**	

The assessment presented in Table 25 suggests that biogas recovery and burning for steam raising does not meet the AMH hurdle rate of 2 years payback.

There are a number of assumptions in this assessment that are worth testing to further assess the viability of the biogas recovery option as a stand-alone solution. These include:

- Costs for desludging and crust removal from the lagoons – the costs for this activity have been capitalised and are based on an estimate from an experienced contractor. The contractor indicated that a site visit would be required to firm up the price for this activity. A worst-case estimate has been presented i.e. $200K;
- A reduction in biogas generation rate of 15 % has been assumed based on the successful implementation of the fat-recovery hydrocyclone. If a FAN dewatering circuit is installed, organic load to the lagoons may actually increase, with resultant increase in biogas generation rate. Further assessment of the lagoons biogas generation rate should be undertaken in light of these potential impacts, which are currently unquantified;
- The study has allowed for all lagoons to be covered. An optimisation of this would be to not cover all of the lagoons, but only a sufficient number of lagoons such that the captured biogas will only replace only NG use rather than both NG and coal use (NG is more expensive that coal for stream generation). In a similar vein, it is noted that some of the lagoons appear to perform better than others (see Section 2.5.2) i.e. the specific

biogas generation rate differs significantly between the lagoons. In particular, lagoon 3 has a lower performance than the other lagoons. Therefore, an optimisation of this might involve excluding the cover and associated collection infrastructure from Lagoon 3. It is further noted that Lagoon 3 will be the most difficult to access and cover due to its restricted access; hence the costs to cover this lagoon may be higher than for the other lagoons;

- It has been assumed that the biogas would replace both NG (70 %) and coal (30 %) based on 2005 prices. This assumption should be tested by undertaking a more detailed site energy assessment to establish actual NG usage for steam raising and the likely increase in coal prices;
- The operating costs include $40K/annum for ongoing crust and sludge management. This is a conservative estimate and could be significantly reduced depending on the rate of crust formation and the associated operational issues created. Alternative desludging approaches should also be considered e.g. the “Sludge Rat”, which can be purchased or leased from Ultra Aquatic Technology;
- Collection of the biogas will change the emission profile form the AMH site. The biogas will move from a diffuse source to a point discharge (via either a flare or burner stack). A sophisticated flare has been included in the cost estimate ($150K) to allow for controlled venting during periods that the biogas cannot be used, with particular focus on H2S destruction. Development of a detailed operating procedure for off-gas management and negotiation with the EPA may allow for removal of the flare system from the design or installation of a more simple flare configuration; and
- A preliminary assessment of a stand-alone biogas co-generation facility was developed, indicating that about 1.6 MW_e and 1.5 MW_{th} (for a 37 % efficient gas engine) could be generated. Economically, the payback for this option would be in the order of 4 years (including RECs at $40 MWh). The capital cost for this option will be in the order of $4M (including lagoon covers), although this is a preliminary estimate as no quotes were obtained for the energy recovery section.

6.3 Fluidised Gasifier Option

6.3.1 Selection criteria

Advantages of (fluidised) Gasifier

Fluidised gasification technology is considered a potential technical processing solution for the targeted AMH waste streams, with the following advantages:

- Good turndown to varying demand loads/ feed availability;
- Low sulphur content in feed waste; and
- Capability to process feeds with up to 50% moisture content.

Potential concerns

- There are a number of potential concerns associated with the application of gasifier technology in the AMH case:
- Waste mechanical dewatering unproven beyond ~70% moisture feed (if mechanical dewatering is unable to achieve <50% moisture target);
- Greater complexity than FBC (gas cleaning);
- Limited track record for waste specific components; and
- Capital intensity associated with the scale of the proposed plant (low end).

6.3.2 Overall assessment

The significant site demand for steam directs the question to raising steam directly rather than indirectly. i.e. why produce a low calorific value syngas that requires chemical cleaning for a site with a high steam requirement?

The key concerns were:

- The lack of sufficient feedstock, with a processing target of > 25 $_{MWth}$ feed.
- Small-scale (<10 MW) gasifiers have largely been proven with wood waste.
- A high moisture and variable feed do not promote gasifier stability.
- Sludge biomass gasification has generally been considered as co-firing at a larger scale.

6.4 Anaerobic Digestion Option

6.4.1 Selection criteria

The AMH directive was to consider a *thermal* option to maximise waste-to-energy recovery. Anaerobic digestion (AD) is a non-thermal biological route to reduce the carbon content of organic waste. This approach was briefly considered in this study for comparative purposes. In addition, the difficulty in dewatering this feed material may make AD a preferred solution if AMH have a strong desire to implement a waste to energy project.

Advantages of AD
Anaerobic digestion technology is considered a potential technical processing solution for the targeted AMH waste streams, with the following advantages:

- Good turndown to varying demand loads/ feed availability;
- High waste fat content digests easily;
- Capability to process up to 85% moisture feeds;
- Can be designed to co-produces compost; and
- Track record with specified waste components.

Potential concerns
There are a number of potential concerns associated with the application of AD technology in the AMH case:

- Biogas energy recovery is at best ~50% (estimate) of thermal options;
- Compost may require additional processing / capital to be marketable;
- Processes organic fraction only (no plastic); and
- Requires appropriate sterilisation time/temperature step.

6.4.2 Overall assessment

The lower overall energy recovery penalises the anaerobic digestion option, with the overall capital comparable to the FBC option (assuming processing of digesting solids will require further processing to produce compost).

An estimate of recoverable power is up to 0.7 MW_e (excluding the lagoon biogas). This relatively high yield is attributed to the high degree of fat content in the organic solids. This power yield is similar to an >70% feed moisture FBC option.

Should no viable mechanical dewatering option be developed, (leaving the waste feed at over 70% moisture), GHD's view is that this option should be reconsidered against the FBC.

7 Conclusions

7.1 Overall

The corporate target of reducing fossil fuel usage at the Dinmore site by 10 % can be achieved with the implementation of a waste to energy program. Depending on the configuration adopted, 25 to 35% of the electrical needs and 15 to 25% of the steam/hot water needs of the site can meet through recovery of energy from solid waste and biogas generated on the site. This conclusion is premised on the ability to demonstrate that 50 % moisture can be achieved in the dewatered solid waste using mechanical dewatering technology.
The key conclusions for the specific areas of investigation for this report are as follows.

7.2 Stage 1 Dewatering

- Stage 1 dewatering using FAN Separator press screw separator (PSS) technology was trailed and achieved 70 to 75 % moisture content in the resulting cake. A design figure of 65 % was adopted based on vendor feedback, consideration of the limitations of the trials and review of the results of a previous trial;
- Resolving materials handling issues will be critical to the success of the Stage 1 dewatering process. The combination of solid waste streams currently generated on site are not readily blended or pumped. A suitable make-up water/recycled filtrate scheme will be required to allow robust feed to be established to the FAN PSS units;
- The filtrate generated by the FAN PSS units will contain 1 to 3 % w/w solids. The concept design proposes the use of a FAN CCS unit to recover the majority of these solids prior to pumping the filtrate to the anaerobic lagoons. Other alternatives could be considered for this duty, although test work to confirm their performance is required. Alternatively, the filtrate could be pumped to the anaerobic lagoons unclarified. An assessment of the impacts of this approach would be required;
- The capital costs for installation of a stand-alone Stage 1 dewatering circuit were estimated at $1.1M. Significant costs are associated with automating the process of conveying waste solids to a central mix tank. Some of these costs could be negated with the installation of a circuit designed to replace the existing saveall units, although the overall capital cost may be higher than the base case considered in this study; and
- A financial analysis of the stage 1 dewatering circuit as a stand-alone project indicated a payback period of 2.8 years (based on current operating parameters).

7.3 Additional Dewatering

- The FAN Separator screw press compactor (SPC) is no longer supported by the supplier; hence is was not considered in this study;
- Stage 2 dewatering using two FAN Separator press screw separators operated in series was trailed and achieved no better than 57% moisture (excluding the BP Cake) and 64% moisture (including the BP Cake);
- A preliminary cost estimate indicated that the capital cost for the Stage 2 dewatering system (if integrated with the Stage 1 dewatering concept) would be in the order of $1M;
- An alternative supplier of screw press technology, Kilia, was contacted to supply information and pricing on their KompriHydro screw press. At the time of writing this

report, no data had been received and hence evaluation of the potential of this unit could not be completed;
- Thermal drying of the solid waste was considered as an alternative to Stage 2 mechanical dewatering. A low temperature belt dryer is considered the safest alternative. Andritz supplied a budget estimate for supply and installation of a dryer to evaporate 3.3 tonnes water per hour; $4.4M;
- Capital and operating costs (energy penalties) for thermal drying are significantly higher than the mechanical watering alternative, however, the ability of the Stage 2 mechanical dewatering scheme to achieve <50% moisture remains unproven.

7.4 Covered Anaerobic Lagoons

- The recovery of biogas from the existing anaerobic lagoons has the potential to supply a significant fuel source. It is estimated that 3.5 to 4.5 $_{MWth}$ of energy would be available from the methane contained in the biogas. Energy could be recovered by natural gas substitution in the exiting gas fired boilers, although the site energy balance also suggests the biogas would also replace some coal-fired steam also generated on site;
- The existing crust and sludge associated with the anaerobic lagoons will need to be removed prior to covering the lagoons. A preliminary estimate of the costs associated with this activity by an experienced contractor was $200k. A more detailed costing should be determined, alone with consideration of a longer term strategy for continuous crust and sludge removal;
- The capital costs for installation of a stand-alone biogas recovery circuit were estimated at $1.95M. Significant costs are associated with automating the process of conveying waste solids the a central mix tank. Some of these costs could be negated with the installation of a circuit designed to replace the existing saveall units, although the overall capital cost may be higher than the base case considered in this study; and
- A financial analysis of the biogas recovery circuit as a stand-alone project indicated a payback period of 5.8 years (based on current operating parameters). A range of alternatives for improving the economics of this project was presented and requires further consideration.

7.5 Waste to Energy Concept

Challenging waste parameters

The AMH waste feed is challenging to process to energy due to fluctuating production rates, limited ability to store organic material on site and variable but overall high moisture content.

The waste quantity of ~6.0 $_{MWth}$ (11 shift per week Base Case) is large enough to be interesting, but is still on the low end of typical commercial waste-to-energy plants.

The supplementary production of 3.5 to 4.5 $_{MWth}$ of biogas recovered from existing lagoons provides an opportunity to combine the processing options into a single solution -simplifying plant operation and sharing capital cost.

Energy focus: Power

The proposal has focused on maximising power production rather than overall thermal efficiency. This is based on green power achieving RECs, which site steam does not. However, the site is well suited for combined power/steam and hot water integration.

Dewatering assumption: <50% moisture content

Mechanical dewatering is cost and thermally effective in removing some moisture, with a key assumption that a 2 Stage dewatering system can achieve <50% total moisture content. This assumption remains unproven and is a key risk with moving forward with the waste to energy project.

This moisture level enables a reasonable downstream thermal recovery. Feed moisture contents of over 70% severely curtail net energy recovery potential.

Technology shortlist

The preferred thermal technologies for further evaluation were fluid bed combustion (FBC) and (fluidised) gasification (FBG).

The FBC option is preferred over gasification in terms of greater compatibility with existing site steam raising, and a more proven track record with AMH specific feed components and the lower scale of feedstock availability.

While not lowest cost, fluidised bed technology offers robust flexible performance for challenging feeds, as well as good turndown.

This study focussed on thermal options, which precluded anaerobic digestion (AD). Although yielding a lower energy recovery, AD is the most robust process choice for a very wet feed. Should mechanical drying fail to deliver 50% moisture feed, it is recommended that anaerobic digestion be reconsidered as a competing option.

P FBC concept

The FBC conceptual layout includes co-firing the lagoon biogas component to maximise combustion stability, with estimated production of 2.6 MW_e and up to 4.3 $_{MWth}$ of hot water (displacing existing steam injection) for the Base Case proposed.

The proposed FBC plant includes waste feeding, the FBC and air control system, stack gas cleaning, boiler and steam turbine and appropriate ancillaries.

The estimated capital (+/- 30%) is $17M, with a net cash flow of ~$1.8M/a yielding an 8.2 year payback (10.4% ROI). This includes RECs credits, as well as reduced waste disposal cost, which contribute most of the net cash flow. The assessment excludes possible green credits for reducing GHG emissions from both unburnt biogas methane and waste decomposition, and (net) fossil fuel reduction.

Preferred FBC vendor

There are various potential vendors for the FBC/steam turbine concept. The technologies differ in mechanical detail, but broadly offer a similar approach in air combusting the waste stream over a moving bed, with ancillary burners.

The analysis has been largely based on the Sun Thermal Combustion FBC technology, which constructed an operating plant for 3.5 MW at Stapylton, near Brisbane. This should not be interpreted as Sun Thermal Combustion being the preferred vendor.

Possible vendors include:

- STC;
- EPI;
- BHK;
- Seghers;
- Siemens; and
- Aldavia.

This report does not assess the most appropriate technology licensor for AMH. It is noted that biomass projects have generally had delayed start-ups with first of a kind plants and experience is cardinal to ensure desired operating performance and reliability for a plant design.

8 Recommendations

8.1 Stage 1 Dewatering

- Consider developing a design and associated cost estimate for a dewatering circuit that would replace the existing saveall units. A concept flow sheet for such a flow sheet was developed in collaboration with FAN Separator, but was not further developed during this study. The current design basis requires conveying and mixing of the partially dewatered solids in a simplified Stage 1 dewatering circuit. Although potentially more capital intensive, replacement of the savealls would overcome the potential operational issues associated with materials handling and mixing of partially dewatered solids;
- If a decision on the waste to energy project is delayed, consider installing the Stage 1 dewatering concept as a stand-alone project. It is noted that the predicted payback of 3.7 years is above the AMH hurdle rate for capital investment of 2 years;
- Undertake an assessment of the potential impacts of the Stage 1 dewatering filtrate on the existing wastewater treatment facilities on the AMH Dinmore site. There will be an increase in overall wastewater nutrient and hydraulic load if the Stage 1 dewatering system is implemented;
- Consider undertaking a test work program to evaluate solids recovery from the filtrate stream. A FAN Separator CCS unit is specified in this report; and
- If a decision is made to proceed with the Stage 1 dewatering concept, the detailed design phase should focus on the key operational issues that may be associated with this process:
    - Conveying of waste solids to a central mix tank (consider redundancy);
    - Control of solids percentage in the mix tank by recycling filtrate;
    - Control of feed rate to the FAN PSS units to minimise cake moisture; and
    - Recovery of solids from the filtrate.

8.2 Additional Dewatering

- Complete and evaluate further Stage 2 mechanical dewatering trial using the SPC unit (scheduled for January 2006);
- Based on the results of the Stage 2 dewatering trial, consider developing a design and associated cost estimate for this process. The payback of installing the Stage 2 system as a stand-alone project should also be evaluated;
- Pending the results of the Stage 2 dewatering trial, undertake more detailed vendor discussions with Andritz regarding the process design issues, test work requirement and supply costs for a belt thermal dryer; and
- Consider thermal drying options for the BP Cake as a separate stream.

8.3 Covered Anaerobic Lagoons

- Consider installing a biogas recovery system as a stand-alone project. It is noted that the predicted payback of 5.8 years (possibly lower if electricity is generated) is above the AMH hurdle rate for capital investment of 2 years;
- Consider the various process optimisations available for biogas recovery to establish if a configuration can be developed that meets the AMH financial hurdle rate for payback within 2 years;
- Further evaluate the likely biogas generation rate from the anaerobic lagoons once operational information is available for the hydrocyclones currently being commissioned in the abattoir; and
- Arrange for a contractor(s) to visit site and develop a proposal and quotation for removing the crust and sludge from the existing lagoons.

8.4 Waste to Energy Concept

- Further detailed evaluation of the energy recovery options from solid waste should be deferred until the results of the SPC dewatering test work program are assessed. The success or otherwise of the mechanical dewatering circuit will be key in defining the economics and technical issues for energy recovery;
- If a suitable technology for mechanical dewatering to <50% moisture is not defined, it is recommended that anaerobic digestion be reconsidered;
- A site energy review is required to optimise the proposed layout, with particular emphasis on whether to maximise electricity or steam generation;
- Discussions with selected vendors (suppliers of FBC technologies) should be progressed to obtain an improved understanding of the commercial and technical issues associated with implementing waste to energy technologies on the Dinmore feed stocks;
- Vendors may recommend pilot testing. This should be considered on a case by case basis; and
- Pending agreement on the choice of FBC as the preferred technology and trailing the SPC dewatering unit, a detail design would be required to confirm waste composition and variation.

9 References

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