final report

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NCMC Energy and Wastewater Options Assessment for Energy Self-Sufficiency

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Executive summary

The “NCMC Energy and Wastewater Options Assessment for Energy Self-Sufficiency Project” was largely driven by the NCMC’s Board objective to identify a progressive strategy to move towards off-grid operation at their Casino abattoir and tannery facilities through adoption of renewable energy sources. As a result, the primary aims of this project were developed to align with and provide targeted information for NCMC’s consideration. The focus of this report is to:

— Review current abattoir and tannery operations at Casino site and investigate energy and wastewater options

— Investigate options to reduce energy costs through utilisation of waste generated (liquid and solid wastes) on site

— Optimise electricity obtained from renewable sources

— Broadly assess impact of nitrogen concentration of treated wastewater if energy recovery from wastes is adopted

— Assess how strategies to address these issues identified in this study will impact on investment plans currently in place for EC treatment of the tannery wastewater

The project was initiated with a site visit to the Casino site to meet with key NCMC and MLA representatives to define the study objects. Following agreement of these objectives, a project approach was developed and agreed.

The initial effort of the study focused on a thorough data collation and review step to gather and interpret all available data. The collated data enabled development of abattoir and tannery mass flows and the corresponding Process Flow Diagrams (PFDs), which were adopted as the design basis.

Based on this initial assessment, the liquid waste streams considered suitable for energy recovery were paunch screened effluent, saveall outlet, cattle wash liquid and EC influent/effluent. Solid waste streams considered for energy recovery were dewatered paunch, manure, hair screenings and saveall float (cases with and without saveall float, currently diverted to rendering, were considered). In this study, chrome liquour solid residues generated from the tannery facility were not considered as part of an energy recovery stream due to the high risk of unacceptable heavy metal contamination of the broader solids streams and associated residuals from energy production.

As part of this study, two (2) different energy recovery options were considered, with eight (8) associated sub-options, as follows:

Option 1 - Biological (anaerobic digestion)

– (1a) All solids to biological anaerobic digestion (INCLUDING saveall float and a small flow of saveall outlet for dilution) and all liquids to a separate anaerobic digestion process

– (1b) All solids to biological anaerobic digestion (EXCLUDING saveall float, with a small flow of saveall outlet for dilution) and all liquids to a separate anaerobic digestion process

– (1c) Liquid streams to biological anaerobic digestion and solid streams disposed of as per current site practices

– (1d) All solids to biological anaerobic digestion (EXCLUDING saveall float with a small flow of saveall outlet for dilution) and all liquid streams disposed of as per current site practices

Option 2 – Thermal (energy recovery from solid waste streams)

– (2a) All solids to thermal energy recovery (INCLUDING saveall float) and all liquid streams disposed of as per current site practices

– (2b) All solids to thermal energy recovery (EXCLUDING saveall float) and all liquid streams disposed of as per current site practices

– (2c) All solids to thermal energy recovery (INCLUDING saveall float) and all liquid streams to a separate anaerobic digestion process

– (2d) All solids to thermal energy recovery (EXCLUDING saveall float) and all liquid streams to a separate anaerobic digestion process

All liquid and solid waste streams were assessed for their potential to generate energy. The saveall float (a solid waste currently directed to rendering) has the highest potential for biogas generation/energy production, followed by saveall outlet (liquid waste), dewatered paunch (solid), EC influent (liquid), manure (solid), paunch screen effluent (liquid), cattle wash (liquid) and finally hair screenings (solid). This is consistent with findings from published red meat industry reports, which generally identify saveall float and dewatered paunch as the largest potential biogas contributors.

A high-level capital and operating cost assessment was performed for both biological and thermal energy options. The assessment concluded that the thermal processes were uneconomic due to the considerable parasitic energy load associated with treating solids with a high water content. As a result, thermal processes were not further analysed, and only biological options were considered for subsequent site-wide energy modelling using Homer Pro software.

A qualitative/quantitative comparison of the many forms of biological process options was undertaken, which considered feed limitation and waste generated, energy consumption, operational and maintenance requirements, odour issues and technology maturity.

Homer Pro modelling was undertaken to establish the life cycle cost of the biological (anaerobic digestion) options considered. Based on the modelling exercise, it was concluded that:

— Capital and operating costs for options 1a and 1b are prohibitive relative to the energy recovery from biogas generation. Payback periods in excess of 50 years were estimated.

— The amount of biogas produced from digesting all liquid and solid waste streams can meet electricity demand during peak demand periods on site. Excess gas generated on average demand could either be flared or used to generate power for sale to the grid.

— Grid power price, ability to sustainably generate revenue from “carbon credits” and export power prices are all pivotal variables when assessing the viability of the project.

— In options 1a and 1b, revenue generated from additional biogas production does not offset the relatively high capital cost of these options.

— Option 1c presents the lowest NPC option and is identified as the most viable option for the site. This option involves treating all liquid waste streams on site through a covered anaerobic lagoon (CAL) and generating a blend of electricity and steam. In addition, depending on the view of future electricity pricing, then solar PV addition to this option may also form part of the renewable mix.

— Based on Homer Pro modelling, additional electricity production from solar PV added to option 1c is potentially viable for higher grid electricity prices.

Based on the findings of this project, it is recommended that:

— Additional flow monitoring and sampling be undertaken to confirm the design basis. The assessment presented in this study relied heavily on historical data and a directed sampling program should be undertaken to confirm the key assumptions made in this report.

— Further design development of Option 1c should be undertaken to refine the capital cost for this option.

— Following refinement of option 1c, further Homer Pro modelling should be conducted to identify a preferred sub-option

— Develop a view of the movements of the electricity market (this is likely to be an internal NCMC process, such as business planning, discussions with energy retailers and discussions with specialist consultants). Similarly, NCMC should also develop a view on the future market for renewable energy certificates.

— Explore the potential for a solar PV installation in close proximity to NCMC’s operations in the event that grid prices increase (e.g. availability of land).

— Further explore funding options to determine if alternative approaches to offset Capital investment are available.

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1 Background

Northern Co-operative Meat Company Limited (NCMC) is a co-operatively owned venture that operates a range of facilities in north-east NSW, including a beef and veal processing plant, and tannery in Casino. As with all major facilities of this type, energy and water/wastewater management are both significant costs to the business, and also present significant challenges, with constantly changing risks and opportunities.

The Board of NCMC has defined an objective to progressively move towards off-grid operation of their facilities through adoption of renewable energy sources. Due to the nature of red-meat operations, there are a range of options available to generate energy from the organic waste streams generated as part of the meat processing. It is expected that implementation of renewable energy recovery from some or all of these waste streams can contribute towards the NCMC Board's objective. In addition, the integration of other renewable energy generation approaches e.g. photo voltaics (PV), could be part of an overall strategy.

For context, NCMC's beef and veal processing facility currently operate in the following configuration:

- Electricity is purchased from the grid
- Boiler is fuelled by biomass (sawdust and macadamia shells) purchased from an external supplier
- Gas demand is minimal and limited to forklifts etc.
- Hot water is primarily provided as a by-product of rendering operations, with some generated by boiler in the early morning (prior to rendering operations commencing)
- Abattoir facility produces wastewater streams (from kill floor, boning room, rendering, paunch and yards) that are treated by the screening and save all processes (Collected solids are rendered to recover tallow)
- Abattoir wastewater is then treated in an anaerobic dam with no gas capture
- Partially treated wastewater is polished in 7 facultative dams with combined capacity of 50 to 80 ML, prior to disposal via irrigation
- Expanding irrigation is currently planned to allow sustainable disposal of nitrogen-laden wastewater
- Tannery wastewater will produce solid waste streams with substantial organic content (hair and sludge from proposed future tannery electrocoagulation (EC) treatment system)

This project involves an investigation to identify the optimal energy (solid waste and wastewater management) solution(s) available to NCMC's abattoir and tannery operations at Casino, NSW. This project is the first step towards NCMC's long-term objective of being self-sufficient in terms of energy supply. The investigation will lead to specification of the most beneficial solution(s) to allow prescriptive business case development and implementation.

2 Project objectives

This report sets out the current operations at the abattoir and tannery and investigates energy and wastewater options to address NCMC's key project objectives:

— Reduce energy costs through utilisation of waste generated on site

— Increase electricity obtained from renewable sources

— Decrease nitrogen concentration of treated wastewater [1]

— Assess how strategies to address these issues identified in this study will impact on investment plans currently in place for EC treatment of the tannery wastewater

The scope of work is outlined in the proposal submitted on the 8th of September 2017 (GHD Document Number: 41 09228 93).

2.1 Scope and limitation

This report has been prepared by GHD for *Northern Co-operative Meat Company Limited* and may only be used and relied on by *Northern Co-operative Meat Company Limited* for the purpose agreed between GHD and the *Northern Co-operative Meat Company Limited* as set out in section 1.2 of this report.

GHD otherwise disclaims responsibility to any person other than *Northern Co-operative Meat Company Limited* arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided *Northern Co-operative Meat Company Limited* and others who provided information to GHD (including publically available research reports from MLA and AMPC that are specific for the NCMC site), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in

[1] Although this is not a major focus of the report, it is recognised that any renewable energy solutions do not ultimately lead to an increase in nitrogen load in the wastewater. Development of sustainable irrigation options and implementation of Electro Coagulation (EC) for tannery wastewater treatment and nutrient reduction and subject of detailed study by others.

connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

GHD has prepared the preliminary cost estimate set out in Section 4.2.3 and 4.3.2.5 and of this report ("Cost Estimate") using information reasonably available to the GHD employee(s) who prepared this report; and based on assumptions and judgments made by GHD.

The Cost Estimate has been prepared for the purpose of options assessment and comparison and must not be used for any other purpose.

3 Methodology

A site visit and data collation were conducted as part of this study to understand all aspects relating to the management of water and solids waste at the Casino site.

Abattoir and tannery mass flows were established to understand and review the current waste stream flows and composition. Following a thorough analysis, several energy generation options from solids and liquid waste streams were formulated. The most promising scenarios were selected for further energy modelling using HOMER Pro. Homer Pro modelling was used to model lifecycle cost of the scenarios carried forward.

4 Discussion and Results

4.1 Design basis

4.1.1 Data Collation

Following project inception, a data collation phase was undertaken to identify, as broadly as possible, the existing data that was available to inform this study. A summary RFI register that was used to track data requested and supplied is attached as Section 8.1.

In addition to the data supplied by NCMC, reports from previous research projects undertaken by MLA/AMPC were also utilised to define the design basis for this project.

4.1.2 Waste Characteristics and Flow

4.1.2.1 Abattoir Waste Characteristics

A key objective of this study is to identify the potential of generating renewable energy using liquid and/or solid wastes produced at the NCMC site. The ability to recover energy from abattoir organic waste streams is now well established and there are a growing number of examples of this in the Australian red meat industry (Johns Environmental, 2017)(Jensen and Batstone, 2012)(All Energy, 2017).

Based on review of the information provided as part of the data collation phase (Section 4.1.1), it was evident that there was limited, relevant analytical data routinely collected on the physico-chemical characteristics of the liquid and solid waste streams generated at the site (see below for further discussion). Based on this, GHD relied heavily on a previously published MLA project as discussed below (Jensen and Batstone, 2013).

In 2012, MLA undertook a wastewater management project to identify and address knowledge gaps around wastewater streams from mainly cattle and sheep processing facilities. As part of the study, wastewater surveys, collection and analysis were conducted across major abattoirs, including NCMC's casino site (Site D in this report).

A sampling program was undertaken for 23 streams at NCMC's Casino abattoir, with the location of sampling points as shown in **Fig 1**. The sampling event took place over four days and involved collection of composite samples for pertinent streams. This was found to be the most comprehensive sampling data available and was adopted as being broadly representative of the composition of NCMC waste streams. For this reason, the waste characteristics determined in 2012 were adopted for options comparison and energy recovery assessment in this study.

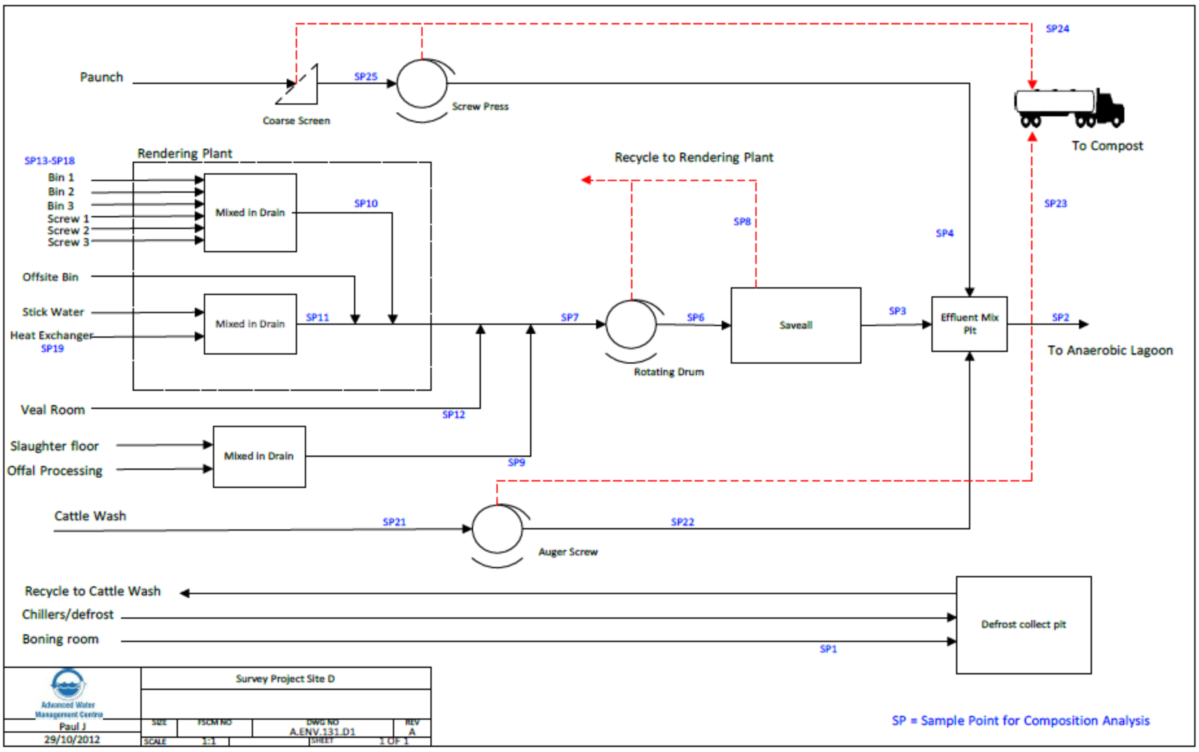


Fig 1 NCMC abattoir site water sampling (Jensen and Batstone, 2012)

As part of NCMC's monitoring practices, the mixed effluent stream is sampled quarterly. The sampling point is represented by SP2 in Fig 1. A total of four grab samples were performed between September 2016 and January 2017 and these sample results were available for this study. The recent NCMC sampled wastewater and MLA's 2012 results are provided below for comparison.

Table 1 Comparison of waste data

Parameter	Unit	NCMC Sampling Results			MLA Report (Jensen and Batstone, 2012)
		Minimum	Average	Maximum	
pH		6.25	6.64	6.78	
COD	mg/L	1,480	7,205	14,600	8,020
O&G	mg/L	349	830	2,029	978
TSS	mg/L	1,284	2,380	4,420	2,930
TKN	mg/L	19	157	257	402
NH_3-N	mg/L	4.3	35	63	38
TP	mg/L	28	42	56	41

The recent sampled analysis showed a large variability in wastewater results across summer and winter months. The average of four data points show COD and O&G values at 7,200 mg/L and 830 mg/L respectively and were approximately 10% on average lower than the sample results from MLA's 2012 report. The results for all other waste parameters also appears equivalent to or lower than the MLA data source. It is speculated that the decrease in organic content is related to the improved blood capture now diverted to rendering, although the small number of sampling events and large variance between each sampling event add uncertainty to this conclusion.

As both sample results are relatively equivalent, SP9 data and individual streams from MLA's 2012 report were adopted for this study due to the more extensive data set available. It is noted, however, that lower COD loadings in the wastewater would lead to reduced energy production from liquid streams.

Although several plant modifications and improvements were made post 2012, these were considered to have minimal impact on the likely wastewater compositions determined as part of the 2012 MLA sampling results. The sampling conducted is therefore considered to be broadly representative of the current waste loadings (on a per head basis). The following plant upgrades (existing or planned) were noted:

- Rotary screen replacement (upstream of saveall)
- Solid waste to render transfer system
- Improvement in capture of red stream to rendering (see above)
- Future EC plant installation

The calculated abattoir waste characteristics for all streams and associated mass flows are shown in Section 8.2.1. Note that these waste characteristics have been scaled to reflect forecast waste production loads for an ultimate kill rate of 1900 head per day (950 beef and 950 veal).

4.1.2.2 Tannery Waste Characteristics

In 2012, GHD undertook a design review of abattoir and tannery wastewater at the Casino site. The average values of tannery wastewater characteristics and the recent sampling provided by Inovin's EC trial is shown in **Table 2**.

For the purposes of design, the tannery wastewater sampled by Inovin will be adopted as the representative wastewater characteristics.

The tannery wastewater characteristics for known streams and mass flows are shown in Section 8.2.2.

Table 2 Tannery waste characteristics

Parameter	Unit	GHD Report (2012) Average over 4 years of data	Inovin EC Trial (2017)
Average daily flow	kL/d	511	1,000 (assumed design value)
pH		10.0	9.4
TCOD	mg/L	8,135	9,600
O&G	mg/L	180	923
TS	mg/L	3,530	6,403
TKN	mg/L	NR	809
NH_3-N	mg/L	229	281
TP	mg/L	11	11.8
Conductivity	mS/cm	10.3	15.4
Sodium	mg/L	NR	2721
Calcium	mg/L	359	330
Magnesium	mg/L	339	115
Chloride	mg/L	NR	2,339
Chromium	mg/L	47	3.2

4.1.2.3 Wastewater Flow

4.1.2.3.1 Mixed Pit Effluent Flow

The current wastewater flow is calculated based on daily kill rate and totalised flow readings (mixed effluent pit) provided by NCMC between 20 May 2016 and 22 September 2017. Based on this data, the average abattoir wastewater generation flowrate was calculated to be 3.11kL/head. It is interesting to note that the average wastewater flow for this period is observed to be significantly higher than that identified in the GHD study for NCMC in 2013 (Bridle and Poad, 2013), where the reported average value was 2.06 kL/head[2].

The 2012 wastewater flow values were lower than the preceding three years (3.06 kL/head) and were reported as being a result of improvements made to the plant. The current wastewater data shows that the water use has increased and returned to pre-2012 usage rates.

[2] Data to 7 October 2012.

During the 2012 MLA sampling event, the abattoir processed between 800 to 1,400 head per day (exact data was not provided) (Jensen and Batstone, 2013). For the six weeks prior to this sampling period, the average kill rate was 1,383 head per day (592 beef and 791 calf), which is on the high end of the stated range. For this study, this kill rate is forecast to increase to 1,900 head per day (950 beef and 950 veal).

4.1.2.3.2 Individual Stream Flow

All flows upstream of the effluent mixed pit have been determined based on flow fractions recorded in the MLA 2012 sampling report. It is recognised that this sampling period (4 days) is a relatively short monitoring period, however it was concluded that this was the best available basis to estimate flows. Additional monitoring of flows and compositions of wastewater streams should be considered as part of future project definition and design development.

To this end, GHD recommends additional sampling of the following stream in order to reduce uncertainty around mass balance and ascertain the extent/maximum potential for energy recovery. Additional flow monitoring and composite sampling for the following streams is recommended:

- Mixed effluent pit (flow and characteristics)
- Saveall float (flow and characteristics)
- Dewatered paunch (flow and characteristics)
- Cattle wash (flow and characteristics)

4.1.3 Process Flow Diagram

A process flow diagram (PFD) was developed for this study. The abattoir and tannery PFD is shown in **Fig 2** and **Fig 3**.

The PFD was developed based on site observations, MLA process flow sheet (Site D) and information from Inovin's electrocoagulation process. NCMC reviewed the PFD and endorsed it for use as basis of this report.

It is noted that the cattle wash auger has been out of service for several years and a feasibility assessment is underway to restore or replace the screen. For the purpose of this report, the cattle wash (stream 13 – prior to screening) was considered as a potential source of energy recovery.

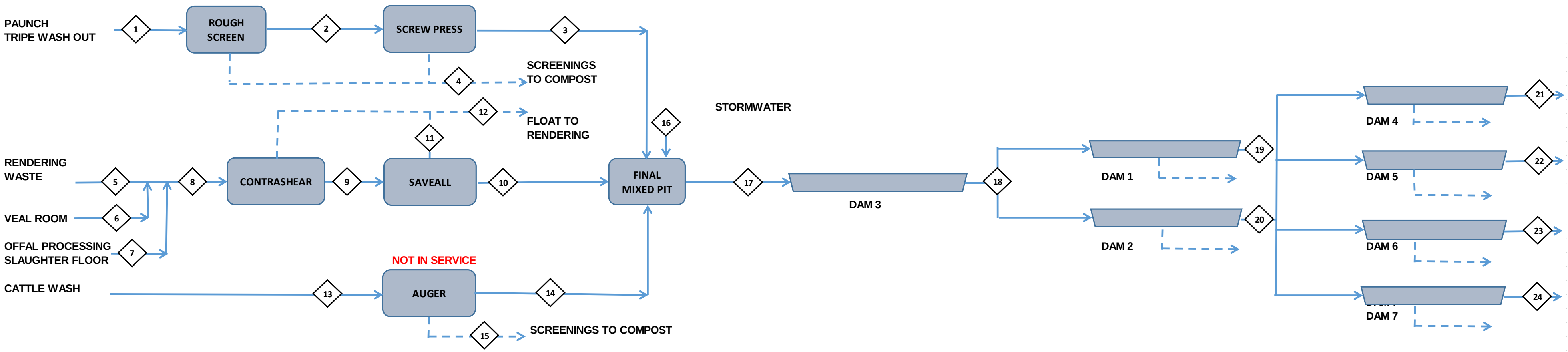


Fig 2 Abattoir Process Flow Diagram

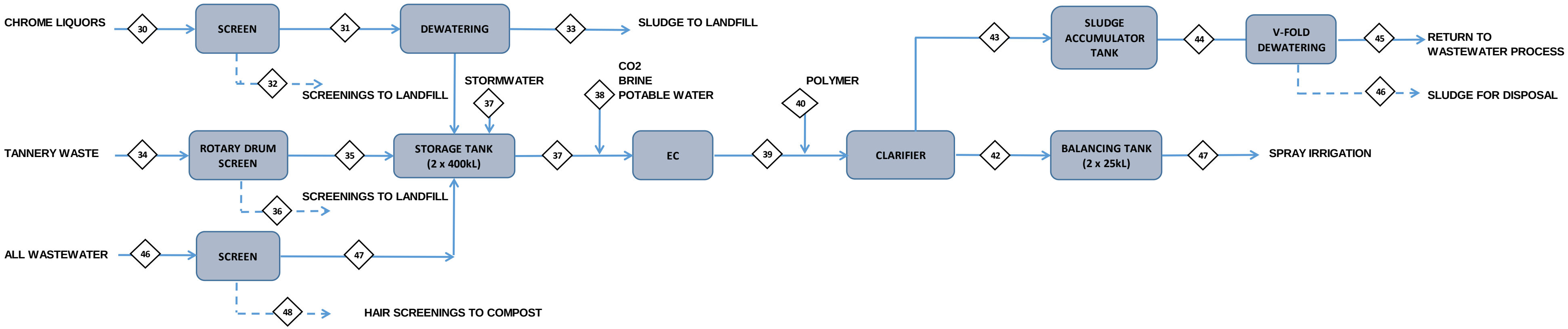


Fig 3 Tannery Process Flow Diagram

4.1.4 Mass Flow

The abattoir and tannery plant mass flows corresponding to the PFDs shown in Section 4.1.3 are tabulated in Section 8.2.

Table 3 outlines the key design assumptions that were used to develop the mass flows. Of principal importance in these assumptions is the use of historic water quality data to forecast these mass flows. Recent water quality data sets provided by NCMC as part of this study contained insufficient information to derive these mass flows (see discussion in Section 4.1.2.1). The MLA study undertaken by researchers from the Advanced Water Management Centre, University of Queensland, in 2012/13 (Jensen and Batstone, 2013) documents the results of an intensive water quality and flow rate assessment in October 2012. These flows have been factored up for this study, which assumes a base case kill rate of 1,900 head/day over a 5 day week.

Once mass flows were established, biogas yields from solid and liquid streams were calculated based on the assumptions outlined in **Table 3**. Biogas yields are documented in Section 4.2.2.

Table 3 Design Assumptions

Parameter	Value	Unit	Comments/References
Kill Rates			
Beef Kill Rates	950	per day	Forecast as advised by NCMC
Veal Kill Rates	950	per day	Forecast as advised by NCMC
Daily Kill Rates	1900	per day	Addition of beef and veal kill rates
Flow Rates			
Daily Abattoir Wastewater Flow (measured downstream of mixed effluent pit)			Provided by NCMC. Flow rate was only used where a daily kill rate was recorded for that particular day.
Abattoir Wastewater Flow Rate	3.11	kL/head	This value was calculated by averaging the total abattoir wastewater flow per month divided by total kill rate per month for the period between 20/5/16 to 22/9/17. The volume of water per head was significantly higher than that reported during a previous assessment in 2012 (~2.1 kL/head).
Abattoir Wastewater Flow Extrapolation	1	-	It is likely that flow extrapolation to 1,900 kill number/day is not a directly linear increment, as there will be some flow efficiencies as a result of increased production. However, this number is maintained at 1 (proportional), as the mass balance is forecasting solids load, which will be linear with kill number (factoring in the difference between the contribution of beef versus calves).

Parameter	Value	Unit	Comments/References
Rendering Waste flow	19	% of total flow	Percentage of total mixed effluent flow. Sum of Sample Point 10 & Sample Point 11. (AMPC Strategic evaluation of RD&E Opportunities for Water Reuse and Recycling.)
Beef Slaughter Floor	34	% of total flow	Percentage of total mixed effluent flow. Sample Point 9. (AMPC Strategic Evaluation of RD&E Opportunities for Water Reuse and Recycling at Australian Abattoirs.)
Veal Room	22	% of total flow	Percentage of total mixed effluent flow. Sample Point 12. (AMPC Strategic Evaluation of RD&E Opportunities for Water Reuse and Recycling at Australian Abattoirs.)
Combined Red Stream (sum of rendering waste, slaughter floor and veal room)	75	% of total flow	Percentage of total mixed effluent flow. Sample Point 7. (AMPC Strategic Evaluation of RD&E Opportunities for Water Reuse and Recycling at Australian Abattoirs.)
Cattle Wash (upstream of auger screw)	19	% of total flow	Percentage of total mixed effluent flow. Sample Point 21. (AMPC Strategic Evaluation of RD&E Opportunities for Water Reuse and Recycling at Australian Abattoirs.)
Paunch Effluent (downstream of coarse screen and upstream of screw press)	9	% of total flow	Percentage of total mixed effluent flow. Sample Point 25. (AMPC Strategic Evaluation of RD&E Opportunities for Water Reuse and Recycling at Australian Abattoirs.)
EC influent flow	1.1	ML/day	GHD assumed value
EC effluent flow	1	ML/day	Inovin's proposal
Wastewater Characteristics			
Hair Sludge Characteristics and Tonnages			Provided by NCMC
Abattoir Wastewater Characteristics			Abattoir stream characteristics based on MLA NGERS and Wastewater Management – Mapping Waste Streams and Quantifying the Impacts Report (A.ENV.151) MLA results were collected using composite sampling over 4 days in 2012. This method of sampling accounts for the variation of stream composition throughout the day and is a better representation of

Parameter	Value	Unit	Comments/References
			grab samples provided by NCMC. Hence, MLA stream characteristics were used as basis for this project.
Abattoir Mixed Pit Effluent Characteristics			Mass balance performed to calculate mixed effluent stream characteristics.
Electrocoagulation Influent Characteristics			EC influent characteristics (average and mean values) calculated from data provided from EC trial results using 'Control value' columns. Data recorded from 18/1/17 to 31/1/17.
Electrocoagulation Effluent Characteristics			EC effluent characteristics (average and mean values) calculated from data provided from EC trial results using '1 Pass Iron' columns which are highlighted yellow. Data recorded from 18/1/17 to 31/1/17.
Electrocoagulation Sludge Characteristics			EC sludge characteristics (average and mean values) calculated from data provided from EC trial results using '1 Pass Iron' columns. Data recorded from 17/1/17 to 31/1/17.
EC Unit			
Electrocoagulation capacity	1	ML/day	This is based on 5ML/week and 5 day operation for 540T capacity
Electrocoagulation sludge	5,125	kg/ML	Based on Inovin's PowerPoint presentation proposal
Contaminant removal across V-fold	20	%	Not used in calc
Biogas			
Biogas Production (Liquid Phase)	0.35	m^3/kgCOD removed	GHD assumed value based on previous industry experience
COD Reduction Across Anaerobic Digestion (Liquid phase)	90	%	GHD assumed value based on previous industry experience
Biogas Gross Calorific Value (GCV) (Liquid digestion)	25	MJ/m^3	GHD assumed value based on previous industry experience
Biogas Gross Calorific Value (GCV) (Solid	22	GJ/t	GHD assumed value based on previous industry experience

Parameter	Value	Unit	Comments/References
digestion)			
Methane Percentage at 25 MJ/m^3 (Liquid Digestion)	70	%	GHD assumed value based on previous industry experience
Methane Percentage at 22 MJ/t (solid digestion)	65	%	GHD assumed value based on previous industry experience
Dewatered Paunch Biomethane Potential (BMP)	313	m^3 methane/tVS feed	BMP test results performed for this stream at Site D (NCMC Casino Plant). Referenced from MLA NGERS and Wastewater Management – Mapping Waste Streams and Quantifying the Impacts Report (A.ENV.151)
Cattle Wash BMP	323	m^3 methane/tVS feed	BMP test results performed for this stream at Site D (NCMC Casino Plant). Referenced from MLA NGERS and Wastewater Management – Mapping Waste Streams and Quantifying the Impacts Report (A.ENV.151)
Manure BMP	220	m^3 methane/tVS feed	GHD assumed value based on previous industry experience
Saveall Float BMP	805	m^3 methane/tVS feed	BMP test results performed for saveall float at Thomas Foods Abattoir 2016. Referenced from AMPC Reviewing On-Plant Waste Stream Biomass Co-digestion Options and Identifying Technologies for Optimum Mixing, Co-digestion and Reuse Report. This BMP value was adjusted downwards; as there is higher fat content in lamb waste (the Thomas Foods Abattoir produces a mixture of beef and lamb carcasses).
Hair Screenings BMP	500	m^3 methane/tVS feed	GHD assumed value based on previous industry experience
EC Influent BMP	300	m^3 methane/tVS feed	GHD assumed value based on previous industry experience
Combined Red Stream BMP	1,204	m^3 methane/tVS feed	BMP test results performed for this stream at Site D (NCMC Casino Plant). Referenced from MLA NGERS and Wastewater Management – Mapping Waste

Parameter	Value	Unit	Comments/References
			Streams and Quantifying the Impacts Report (A.ENV.151).

4.2 Development of options

4.2.1 Background

As part of this study, a number of different energy recovery options for organic waste streams generated on the NCMC site were considered. Principal considerations were as follows:

— All solid and liquid waste streams were potentially available for energy recovery, as per the PFDs presented in **Fig 2** and **Fig 3**.

– The saveall float (stream 12), which is currently treated through the rendering plant for tallow production, was included as a potential source of feedstock for energy production, although sub-options with and without saveall float were assessed. Ultimately, there would be an economic trade-off between the production of tallow (and energy associated with hot water production) versus the production of electricity/energy.

– Chrome liquors solids residues (stream 32 and 33) were not included due to the risk of heavy metal contamination of other solids. Existing disposal approaches were assumed to continue.

– The auger used to treat the cattle wash wastewater (stream 13) was assumed to be available, although it is noted that the auger to dewater this stream is currently out of service. From an energy recovery perspective, the advantage of dewatering this stream would need to be considered depending on the option developed.

– Hair screenings (stream 48) are considered suitable for energy recovery via either thermal of biological processes.

– Installation of the EC will remove part of the COD and nitrogen load from this stream. In the event that a renewable energy scheme was installed, it may be possible to turn off the EC (saving power and operating costs) to allow energy to be recovered from the COD in this stream. The additional nitrogen load would also need to be considered and potentially removed using an alternative technology. Similarly, the impact of chromium on the final digested solids would also need to be considered. This would form part of any more detailed consideration of options.

  — Solid and liquid streams were not combined

  Solid waste streams considered were:

  – Dewatered paunch (stream 4)

  – Manure (stream 15) – assumed auger would be brought back on line

  – Hair screenings (stream 32)

  – Saveall float (stream 12) – sub options considered with or without this stream

  Liquid waste streams considered were:

  - Paunch screened effluent (stream 3)
  - Saveall outlet (steam 10)
  - Cattle wash liquid (stream 14)
  - EC influent (stream 37)

- Depending on the total solids limits required for each technology employed, some liquid wastewater (saveall outlet, stream 10) could be used to dilute the combined solids waste streams such that optimal solids loads are achieved
- Both biological and thermal energy recovery processes were considered for the solid wastes.
- Nitrogen balancing – as part of the scope of this study, NCMC require that the implementation of any solution need not necessarily reduce the amount of nitrogen that is present in the wastewater, but could not lead to an increase of nitrogen loading (due to the requirements for sustainable irrigation of the wastewater). Based on the proteinaceous nature of the solid and liquid waste from red meat abattoirs, it is expected that any application of anaerobic digestion to these waste streams will lead to an elevation of nitrogen (in the form of ammonia) in the digestate liquor from these systems. On that basis, an allowance in the capital cost estimates has been made for ammonia removal (using ammonia stripping) to ensure nitrogen levels do not exceed current limitations.

4.2.2 Energy Generation from Solid and Liquid Wastes

As part of this study, two (2) different energy recovery options were considered, with eight (8) associated sub-options, as follows:

Option 1 - Biological (anaerobic digestion)

- (1a) All solids to biological anaerobic digestion (INCLUDING saveall float and a small flow of saveall outlet for dilution) and all liquids to a separate anaerobic digestion process
- (1b) All solids to biological anaerobic digestion (EXCLUDING saveall float, with a small flow of saveall outlet for dilution) and all liquids to a separate anaerobic digestion process
- (1c) Liquid streams to biological anaerobic digestion and solid streams disposed of as per current site practices
- (1d) All solids to biological anaerobic digestion (EXCLUDING saveall float with a small flow of saveall outlet for dilution) and all liquid streams disposed of as per current site practices

Option 2 – Thermal (energy recovery from solid waste streams)

- (2a) All solids to thermal energy recovery (INCLUDING saveall float) and all liquid streams disposed of as per current site practices
- (2b) All solids to thermal energy recovery (EXCLUDING saveall float) and all liquid streams disposed of as per current site practices

– (2c) All solids to thermal energy recovery (INCLUDING saveall float) and all liquid streams to a separate anaerobic digestion process

– (2d) All solids to thermal energy recovery (EXCLUDING saveall float) and all liquid streams to a separate anaerobic digestion process

4.2.2.1 Scenario 1a

In this scenario, all solid and liquid waste streams would be processed through biological anaerobic digestion processes (except for those waste streams identified in Section 4.2.1). The estimated contribution of each stream to the production of biogas (as m^3/day) is shown in **Fig 4**. It is evident that a large proportion (52%) of available energy (in the form of biogas) could be derived from the saveall float stream, although this stream is already beneficially reprocessed to produce tallow. Other streams each produce relatively small biogas contributions, with saveall outlet flow being the next largest contributor at 22 % of the available biogas energy. Overall, about 46,000 m^3/day of biogas could be produced.

Based on the pie chart in **Fig 4**, it can be concluded that saveall float (solid waste) has the highest potential for biogas generation followed by saveall outlet (liquid waste), dewatered paunch (solid), EC influent (liquid), manure (solid), paunch screen effluent (liquid), cattle wash (liquid) and finally hair screenings (solid). This is consistent with findings from reports published for red meat industry (Heusser, 2017) which generally indicates saveall float and dewatered paunch as the largest biogas contributor.

To consider the benefits of tallow production versus energy (biogas) production, a simple trade-off calculation indicated that the loss of revenue from tallow production (at $600/tonne of tallow) would not be totally off-set by the energy that could be produced from the biogas. This includes consideration of the reduction of approximately 2 MW of thermal energy that would be saved from discontinuing rendering. However, the difference between the two approaches was not large and thus there is flexibility available depending on the market value of tallow versus electricity. This is further discussed as part of the Homer modelling work (Section 4.2.5).

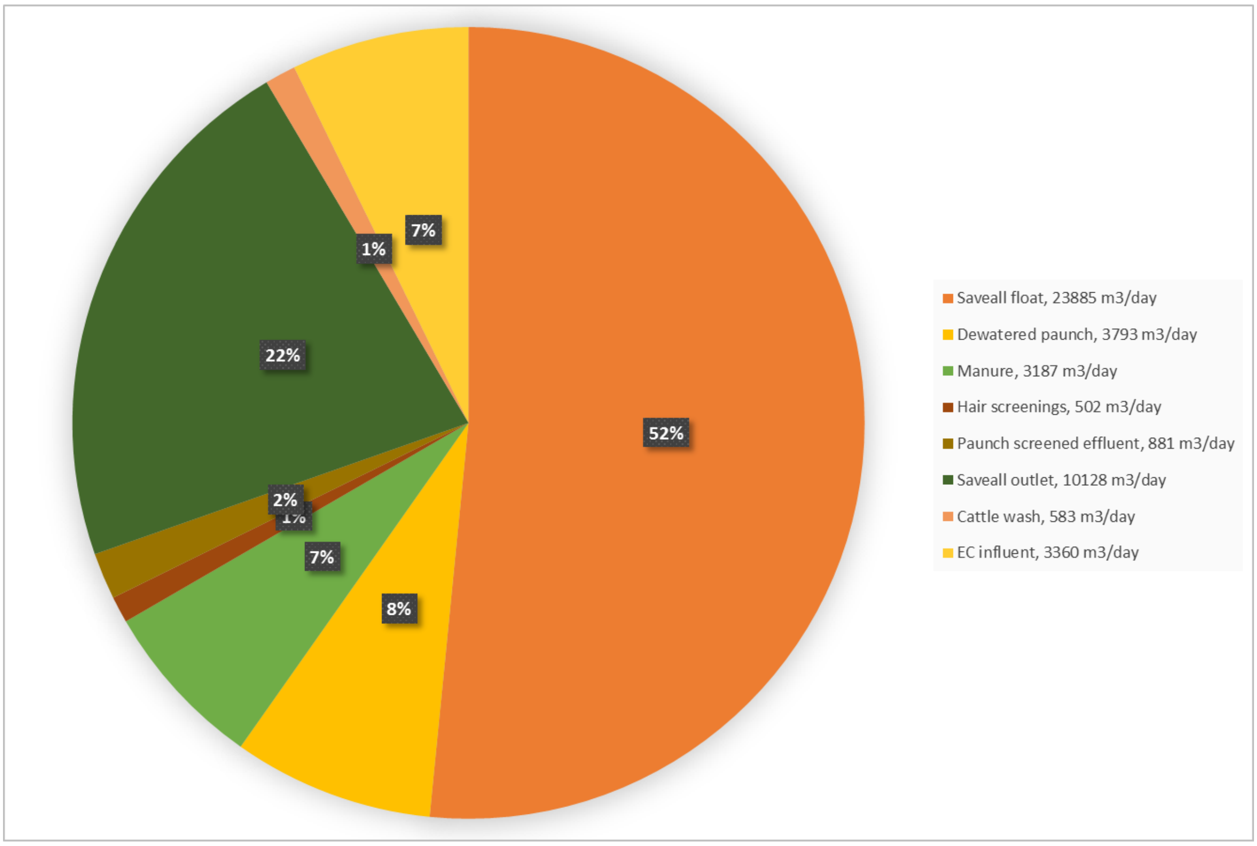


Fig 4 Relative contribution of biogas production from each stream (Scenario 1a)

4.2.2.2 Scenario 1b

Scenario 1b is equivalent to scenario 1a except that the saveall float is not included for energy production and is continued to be processed for tallow production. For this scenario, about 67% of the available energy (as biogas) is available from the liquid streams, with the remaining 33% of energy can be recovered from the solid waste streams. In total, it is estimated that about 22,500 m^3/day of biogas could be generated, which is approximately half of that generated under scenario 1a. In addition, approximately two-thirds of the biogas originates from liquid stream wastes and one-third from solids waste.

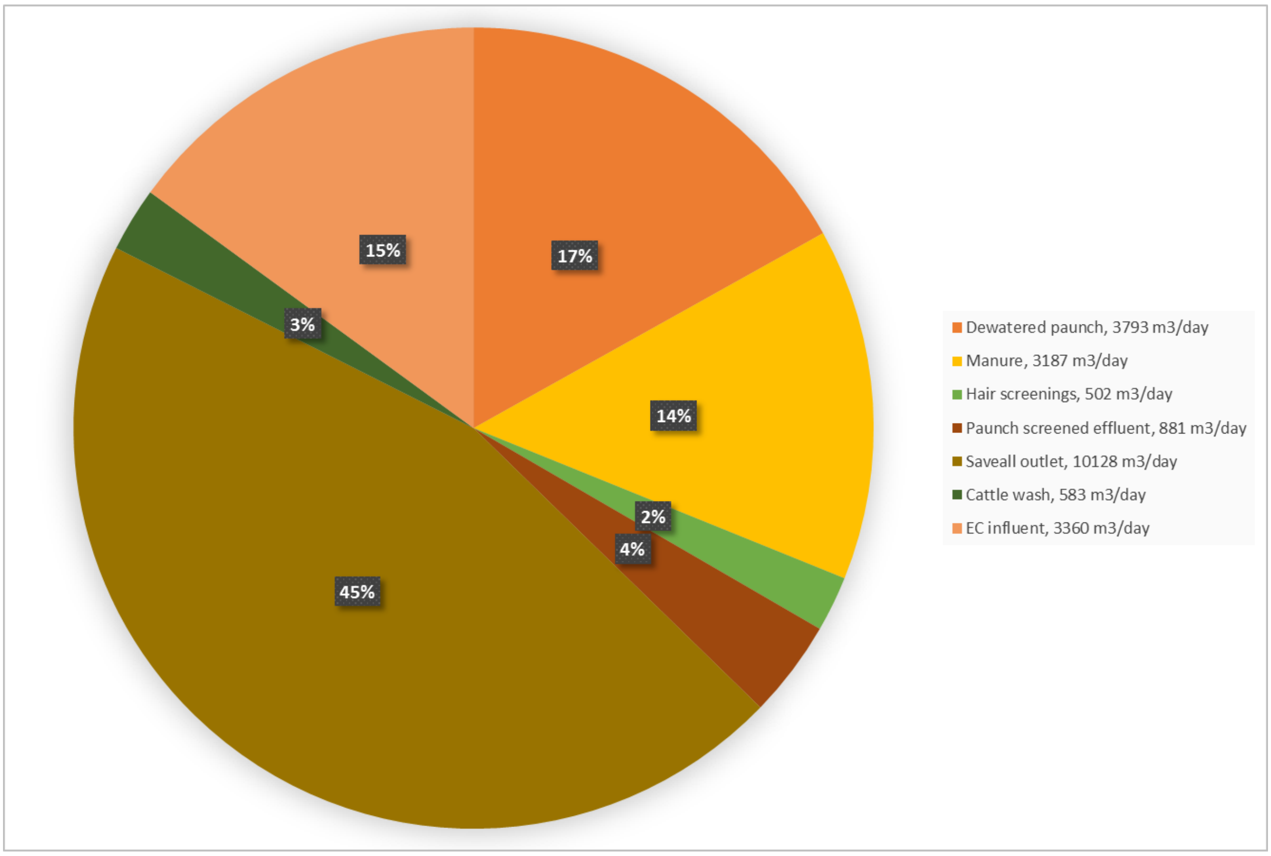


Fig 5 Relative contribution of biogas production from each stream (Scenario 1b)

4.2.2.3 Scenario 1c

Under scenario 1c, only liquid streams are considered for anaerobic digestion, giving a forecast total biogas yield of 15,000 m^3/day, with almost 70% of the biogas being generated from the saveall outlet. This scenario is essentially equivalent to the liquid stream components of scenario 1a and 1b, expect that there is slightly more (about 5%) liquid flow from saveall outlet available, as this small flow is not being directed the solid waste stream for dilution.

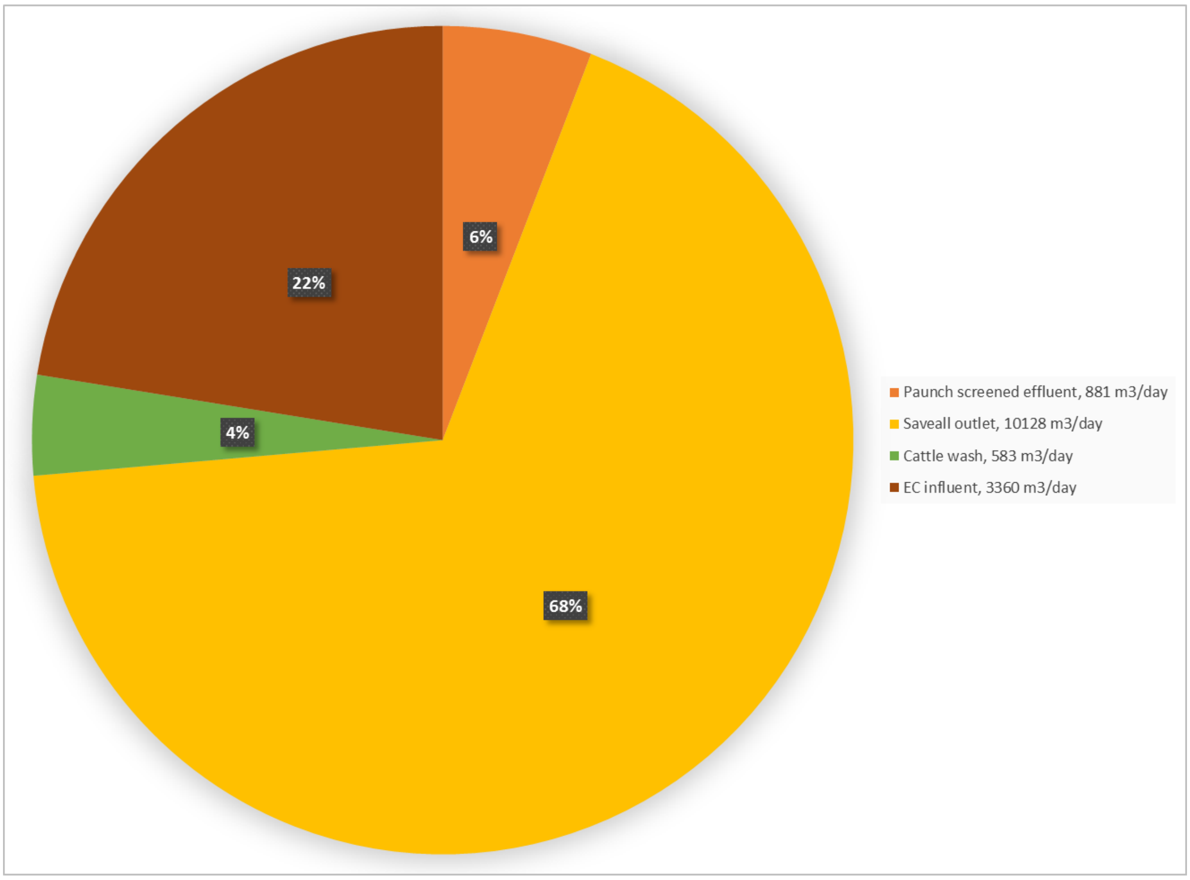


Fig 6 Relative contribution of biogas production from each stream (Scenario 1c)

4.2.2.4 Scenario 1d

Under scenario 1d, only solid streams are considered for anaerobic digestion, giving a forecast total biogas yield of 8,000 m^3/day. Note that the saveall float was not considered in this scenario. The majority of the biogas is forecast to be generated from the dewatered paunch and manure streams, with minor contributions (<10%) from the hair and saveall outlet dilution water.

4.2.2.5 Scenario 2a to 2d

The application of thermal processes for the recovery of energy from solid wastes was assessed and found to be uneconomic. Additional details are provided in Section 4.2.4 of this report. Further detailed assessment of these scenarios was therefore not considered.

4.2.3 Process Options

The following treatment unit operations were considered for the energy and wastewater options assessment. Each of these is discussed in summary below and a comparison between the options is presented in Section 4.2.4.1.

Options considered were:

Liquid Waste Anaerobic Digestion

— Covered Anaerobic Lagoon (CAL)

— Anaerobic Flotation Reactor (AFR)

— Anaerobic Membrane Reactor (AnMBR)

Solid Waste Anaerobic Digestion

— Adsorption-Biooxidation (A-B) Process – note that this is a process that adsorbs soluble COD onto biomass (liquid phase COD to solid phase), with subsequent energy recovery from this biomass in a solid phase anaerobic digester required

— Continuously Stirred Tank Reactor (CSTR)

— Plug Flow Reactor

— Mixed Plug Flow Reactor (ie. DVO®)

Thermal Energy Recovery from Solid Waste

• Thermal Gasification

4.2.3.1 Covered Anaerobic Lagoon (CAL)

Covered anaerobic lagoons (CALs) are typically simple, deep (>4 m), earthen (or lined) ponds comprising a purpose built cover over the entire surface area to captures the biogas, trap odours and assists in reducing heat loss. Alternatively, above ground or below-ground reactor tanks can be converted to CAL systems to capture and extract biogas.

The CAL system usually has a single feed pipe at one end and overflow outlet is at the opposite end. Many of the solids entering the lagoon remain suspended by the gas produced in the lagoon; however, some will settle to the bottom of the lagoon where they use up reactor volume over time. It is also possible for short-circuiting to occur should the influent contain high level of solids. For this reason, CAL systems are typically utilised for liquid waste stream.

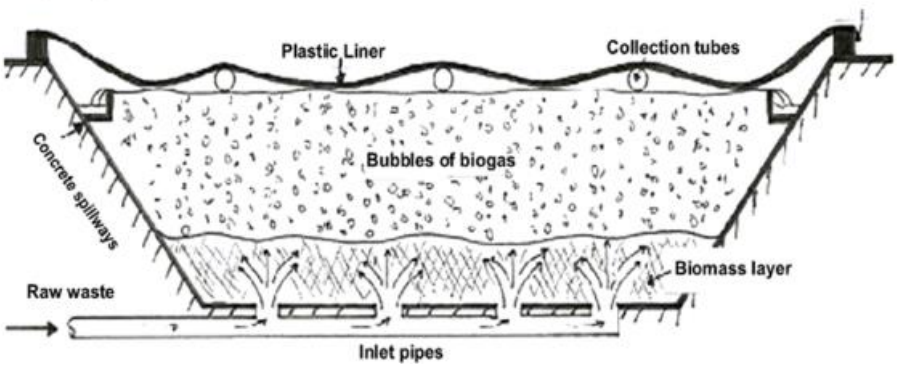


Fig 7 Schematic of Covered Anaerobic Lagoon

The adoption of CALs in the red meat industry for biogas production from liquid wastes has accelerated over the last decade, largely due to the relatively low cost of these systems (particularly where existing anaerobic lagoons are in place) and the amenability of abattoir wastewater to anaerobic digestion. MLA/AMPC have undertaken a number of studies on CALs in recent years and this technology is now relatively mature in the industry and the risks well understood.

An issue often overlooked with CALs is the need to clean out settled solids every 5-10 years. This involves taking the CAL off-line for a number of months and using dredges and earthmoving equipment to remove accumulated solids. More recent CAL cover designs have taken this requirement into consideration.

4.2.3.2 Anaerobic Flotation Reactor (AFR)

A schematic of the reactor is shown in **Fig 8**. The influent waste stream is introduced at the bottom of the vessel. As biogas generated from anaerobic digestion rises, a lift is created that forces the wastewater upwards and concurrently mixes thoroughly with the sludge. The effluent from the vessel is pumped to an external white water tank where biogas is introduced. Under pressure, biogas accumulates in the tank to form white water, and is re-introduced to the bottom of the flotation unit, where solids and fats float to the top. The integrated flotation unit recovers the floating sludge and recycles it back into the reactor. The liquid effluent stream is extracted from beneath the flotation layer and contains minimal solids.

The AFR technology is suited to treating wastewater containing fats, oils, and greases (FOG) and/or biodegradable solids such as proteins and starch. The reactor design allows for a higher organic loading rate (compared with conventional anaerobic digestion) and a taller reactor tank (some 15 metres) resulting in a smaller footprint than conventional anaerobic digestion. This would allow the anaerobic treatment plant to be easily located adjacent to the abattoir where the gas can be utilised, in this way, and costs for gas handling over extended distances is removed.

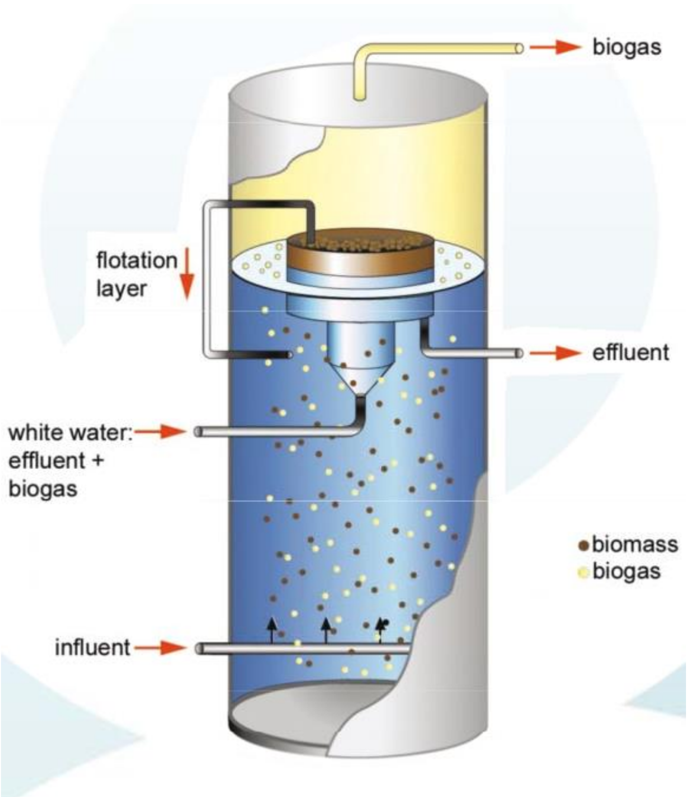


Fig 8 Schematic of Anaerobic Flotation Reactor (Paques BIOPAQ®)

4.2.3.3 Anaerobic Membrane Bioreactor (AnMBR)

The schematic shown in **Fig 9** demonstrates a microfiltration membrane modules/cassette set up in a tank. The anaerobic membrane bioreactor technology combines the biological digestion process with a direct solid–liquid separation by membrane filtration. By using micro filtration membrane technology (with pore sizes ranging from 0.05 to 0.4 µm), MBR systems allow the complete physical retention of bacterial flocs and virtually all suspended solids within the bioreactor. Due to the nature of the membranes, frequent chemical cleaning may be required when fouling occurs (blockage of membrane pores).

Due to the risk of fouling, AnMBR technology is intended for low solids and FOG effluent only. The operation and maintenance of AnMBR can be complex and challenging, as it requires membrane air scouring to maintain a low trans-membrane pressure (TMP) and cleaning when membrane fouling occurs. The frequency of membrane replacement is another component to consider when selecting this technology.

AnMBRs are only installed in a small number of industrial facilities to date.

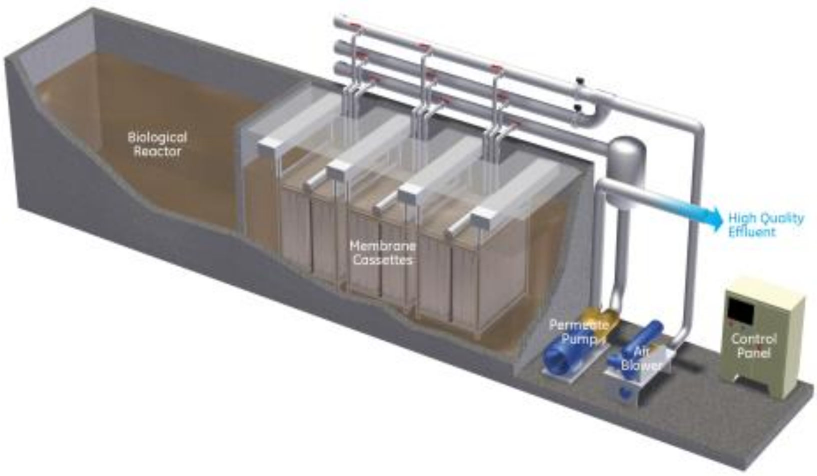


Fig 9 Anaerobic Membrane Reactor (Membrane Europe Ltd.)

4.2.3.4 Adsorption/Bio-oxidation (A/B) Process

Adsorption/Bio-oxidation is a sequential treatment of activated sludge using a high-rate aerobic treatment (Adsorption) which removes considerable solids, followed by a further bio-oxidation (B) of the clarified liquor from A.

A-stage partitioning to solids has been effectively used in activated sludge to partition organics from soluble to particulate phases. In its basic form, short sludge ages (< 1 day) are used together with short hydraulic retention times (< 1 hour) to limit aerobic oxidation of organics. Solids are subsequently digested through anaerobic digestion to recover energy. This can be combined with a B-stage, in which high-rate nitrification is used together with limited simultaneous denitrification to achieve nitrogen removal, with some residual nitrates.

Laboratory-scale testing with abattoir wastewater has been trialled with promising results. A high rate sequencing batch reactor with short SRT and HRT was used to adsorb both COD and phosphorous (and to a lesser extend nitrogen). The resulting biosolids were highly digestable under anaerobic conditions. Although this approach is yet to be operated commercially for abattoir wastewater, the ability to produce readily digestable biosolids in a compact treatment plant makes this a potentially compelling alternative to the use of CALs for liquid phase COD digestion for biogas production.

4.2.3.5 Continuously Stirred Tank Reactors (CSTR)

Continuously stirred tank reactors are typically cylindrical tanks made of concrete or steel and complete with fixed or floating roof and potential for biogas tank storage. The influent is mixed using gas mixing, pump mixing or mechanical agitator to maximise digestion rate. A generic schematic of a CSTR is shown in **Fig 10**.

For a well-mixed CSTR, the solids retention time (SRT) is equivalent to the hydraulic retention time (HRT) i.e. there is no decoupling of biomass or liquid retention times. Because of this, CSTR is unable to achieve guaranteed retention time, which means some waste leaves the system in a partially digested state. The resultant digested solids are therefore not fully inert and may contain pathogens. Short-circuiting can also be due to mixing efficiencies.

There will also be some waste that is processed longer than necessary in the reactor, which in turn reduces system efficiency. These are common problems for CSTRs, although the reactor can handle large variation of influent and toxicity/inhibition issues as the concentration of inhibitory compounds is diluted by a factor of around 25:1 for a HRT of 25 days. CSTR feed solids are typically limited to 5%.

Although CSTR systems have not been used in the red meat industry in Australia, they have attracted significant attention for the digestion of food wastes, with several examples of such facilities in Australia e.g. Earthpower, Sydney and Richgro plant, Jandakot, with variable success.

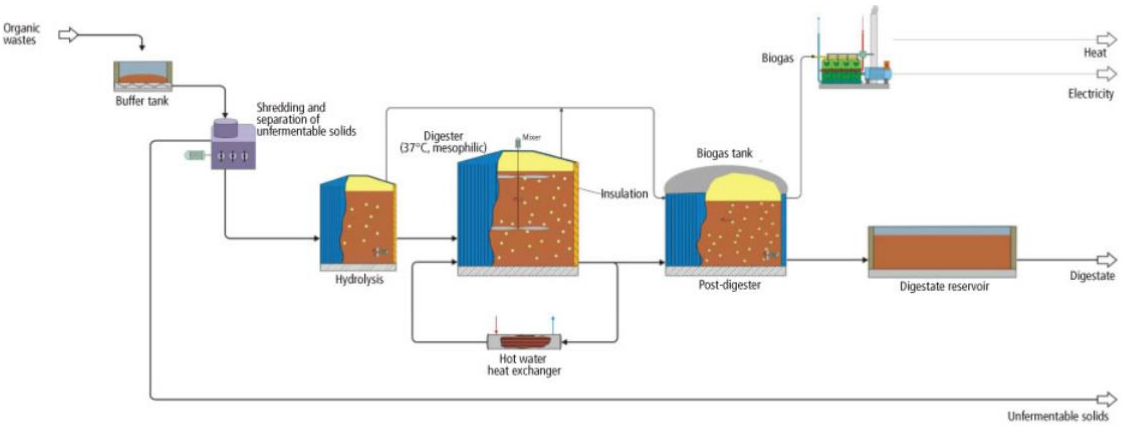


Fig 10 Schematic of Continuously Stirred Tank Reactors (CSTR) - Generic

4.2.3.6 Plug Flow Reactor (PFR)

A typical plug flow reactor is shown in **Fig 11**, where agitators are transversely located to avoid the formation of floating and sinking sludge. The plug flow reactor is suitable for waste streams that have low inhibitory levels, as it is susceptible to shock loadings and toxicants (heavy metals, non-volatile bio-resistant organics) that might accumulate in the sludge.

The technology is ideal to process solid waste streams (typically > 11%) and have been mainly applied to manure management on intensive livestock farms.

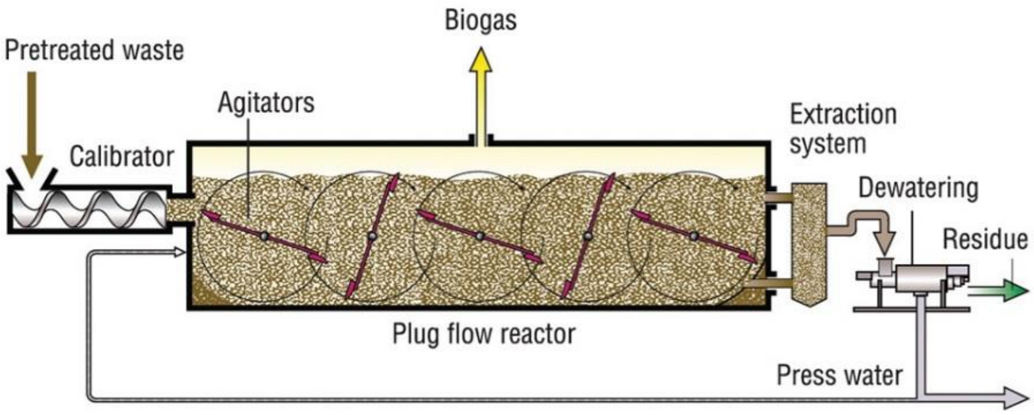


Fig 11 Schematic of Plug Flow Reactor (Strabag-Umweltanlagen GmbH)

4.2.3.7 Mixed Plug Flow Reactor

The mixed plug flow reactor is a hybrid of the CSTR and plug flow process. In the mixed plug flow reactor shown in **Fig 12**, waste flows longitudinally and is continuously mixed through the channel in a 'corkscrew' fashion using recirculated biogas for mixing. As fresh waste enters the system, processed waste is pushed out of the other end of the vessel. From there, the effluent is pumped to a solids separator where it separates the influent waste stream into solid and liquid fractions to achieve approximately 35% solids (depending on the nature of the digested solids).

The reactor breaks down carbon-based molecules only and therefore no nutrients are removed (nitrogen, potassium or phosphorous are not removed but may become solubilised). The digested solids fraction has been re-used as dairy bedding replacement or sold as fertiliser.

The mixed plug flow reactor is able to handle inhibitory risks that the CSTR and plug flow processes may be susceptible to. In addition, this technology is able to guarantee a retention time, which means every unit of waste that goes the digester spends a guaranteed number of days in the reactor. This overcomes the issue of partially digested solids associated with CSTR technology. This system can also handle higher solids than the CSTR (~ 10 %TS), making the reactor half the size of a CSTR.

The DVO mixed plug flow system has been successfully used in more than 100 facilities in the USA and the first facility in Australia is currently under construction.

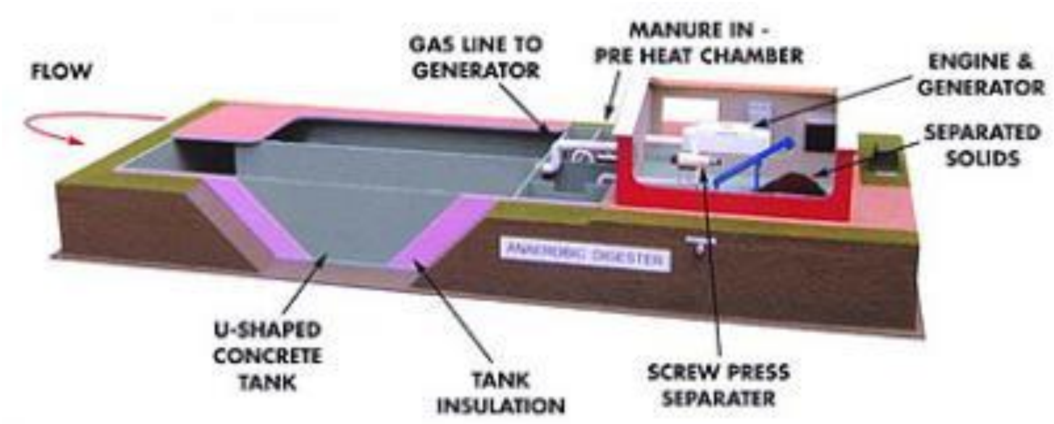


Fig 12 Schematic of Mixed Plug Flow Reactor (DVO)

4.2.4 Energy production using non-biological processes

A detailed review of thermal systems that may be applicable for energy recovery in the red meat industry was prepared by Bridle Consulting in 2011. Since this review of pyrolysis and gasification options, the only Australian supplier known to be still operating is Pyrocal (previously known as BigChar).

Pyrocal have now sold approximately 14 gasifiers both in Australia and overseas processing green wastes, agricultural residues, wood wastes, bagasse and edible nut shells plus other organic substrates and have successfully demonstrated the processing of abattoir solid wastes (although no commercial facilities are known). Their head office and manufacturing facility is located in Toowoomba, Queensland.

Based on the availability of technologies, the only approach considered as part of this study was the Pyrocal gasifier. Two scenarios were investigated in detail - scenario 2a and 2b (as introduced in Section 4.2.2). **Fig 13** shows the process flow and associated mass and energy balance for scenario 2a (all solid waste streams, including the saveall float).

Capital and operating cost estimates were prepared for the two scenarios 2a and 2b. Based on this assessment, the economics for this option were poor, and hence these options were not considered further in this study and Homer Pro modelling of these scenarios was not undertaken. The major downside of this approach was the water content of the solids (even when dewatered in a screw press) was a significant parasitic energy load for the process.

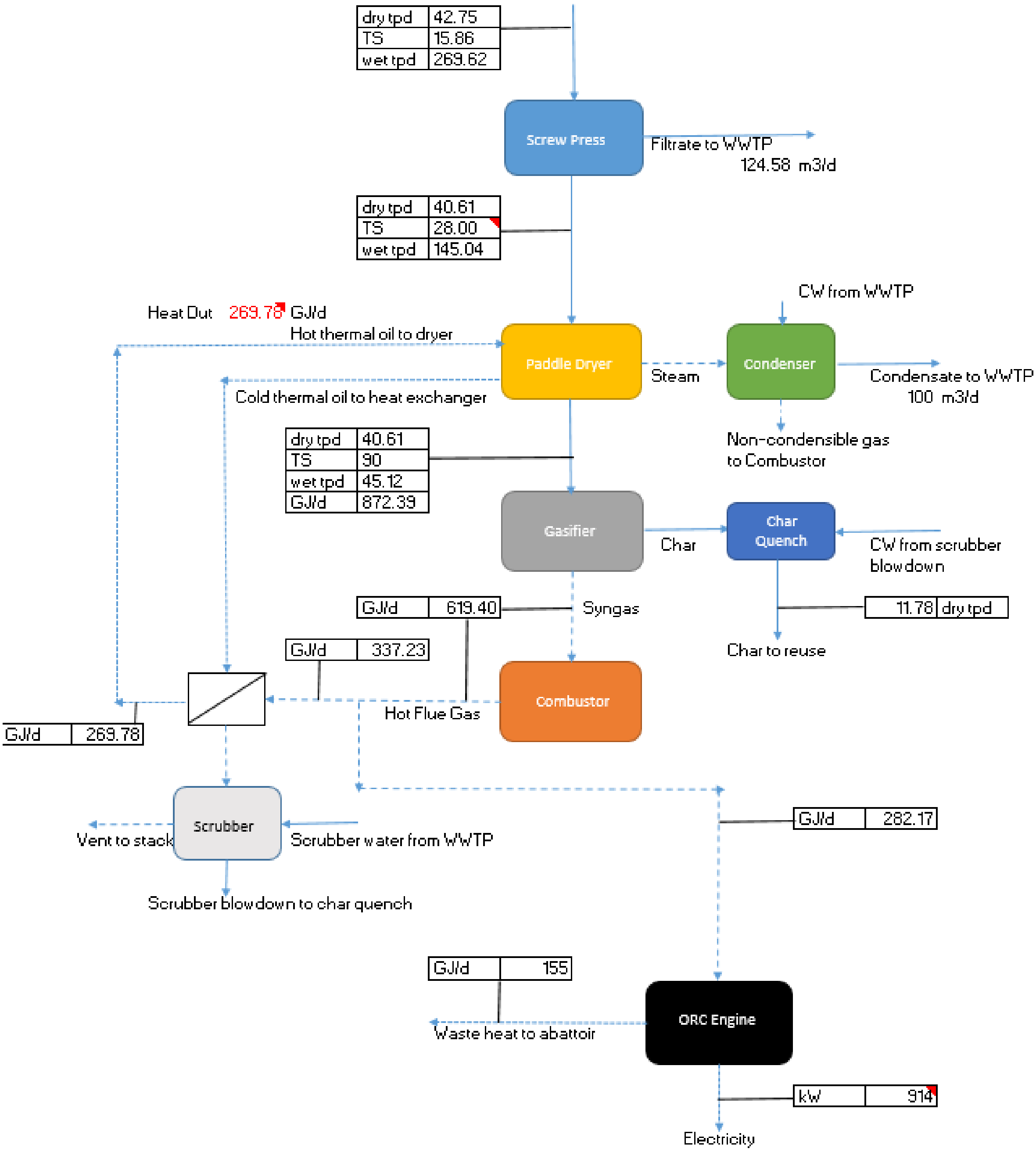


Fig 13 Process flow and mass and energy balance for a gasifier system (scenario 2a)

Table 4 Financial assessment of thermal recovery of energy from solids

Characteristic	Scenario 2a	Scenario 2b	Comments
Capex	$21.1M	$12.3	Turn-key cost excluding owners costs
Opex	-$0.34M	+$13K	Balance of operating costs versus revenue from electricity, waste heat recovery and biochar sales
Simple pay back	>50 years	n/a	No net operational cost recovery to cover capital expended.

4.2.4.1 Comparison of Options and Scenarios

A qualitative/semi-quantitative comparison between the anaerobic digestion technology alternatives (excluding thermal options) as discussed in Section 4.2.3 is presented in **Table 5**. The thermal option was not pursued further due to the poor financial performance of this option (Section 4.2.4).

Table 5 **Anaerobic Digestion Comparison**

Technology	Covered Anaerobic Lagoon (CAL)	Anaerobic Flotation Reactor (AFR)	Anaerobic Membrane Reactor (AnMBR)	Adsorption/Bio-oxidation	Plug Flow Reactor	Continuously Stirred Tank Reactors (CSTR)	Mixed Plug Flow Reactor
Waste stream	Liquid waste only (TS <3%) Ability to accept liquid waste containing fats, oils and greases	Liquid waste digestion (<3%TS) Ability to accept liquid waste containing fats, oils, and greases (FOG) Liquid waste digestion only, low tolerate to high solids	Mixed liquid and solid waste (TS 1–2 %) Unable to accept FOG feed streams and high solid streams	Liquid waste only	Mixed liquid and solid waste (TS 11-13%) Ability to handle high solids influent, resulting in less wastewater requirement for dilution	Mixed liquid and solid waste (TS 3-8%)	Mixed liquid and solid waste (TS >9%)
Construction	Lagoon or tank in ground	Above ground vessel, usually up to 15m	Above ground tank with membrane within tank or externally	Above or below ground tank	Above ground concrete tank	Usually concrete, steel, RFP above ground	Usually concrete underground systems to minimise temperature fluctuations
Process	Ability to handle shock loads, however there is a risk of short-circuiting for high solids influent	High COD removal efficiency (>90%) No mixing requirements	High retention of solids hence minimal solids in effluent stream Does not remove nutrients	Require additional downstream anaerobic digestion process	Guaranteed retention time Susceptible to shock loadings and toxicants (heavy metals,	Simple technology. Biomass loss with the effluent outflow	Stable temperature and robust structure Reactor breaks down carbon-

Technology	Covered Anaerobic Lagoon (CAL)	Anaerobic Flotation Reactor (AFR)	Anaerobic Membrane Reactor (AnMBR)	Adsorption/Bio-oxidation	Plug Flow Reactor	Continuously Stirred Tank Reactors (CSTR)	Mixed Plug Flow Reactor
	High retention times Lowest COD removal efficiency (60-90%) and subject to seasonal fluctuations. High heat loss through cover and difficult to keep warm in winter Recirculation system required	Does not remove nutrients	Consistent effluent quality	Low retention time therefore low overall volume Good nitrogen removal, redirect carbon to anaerobic digestion Requires ammonia-based aeration control; not operated to achieve complete nitrification Large quantity of sludge disposal	non-volatile bio-resistant organics). Solids settling to the bottom of the reactor Temperature stratification, i.e. undesired thermal gradients may exist.	Requires heating (to 37C) and very good mixing Heat loss and variable temperature due to large tanks Solids can settle to the bottom of the reactor and interrupt mixing Limited to 5%TS in the feed	based molecules only and does not remove nutrients (nutrients may be solubilised).Can operate at 10 %TS
Energy	Low gas, high heat loss through cover	High gas	High aeration energy requirement	Low aeration energy requirement		Low gas, high parasitic load for mixing and heating	High gas, low parasitic load (5-9%) mixing and heating needs
Operation and Maintenance	Simple process to operate Periodic de-	Minimal operator requirements	Minimal operator requirements Submerged	Minimal operator requirements	Simple process to operate Shutdown and	May require skilled operators for optimisation	Minimal operator requirements

Technology	Covered Anaerobic Lagoon (CAL)	Anaerobic Flotation Reactor (AFR)	Anaerobic Membrane Reactor (AnMBR)	Adsorption/Bio-oxidation	Plug Flow Reactor	Continuously Stirred Tank Reactors (CSTR)	Mixed Plug Flow Reactor
	sludging required, accumulation of float (scum, fats, oils and grease) will require removal and can be difficult and expensive (depending on size and cover design)		membranes require cleaning and replacement at the end of life (approximately 5 years)		cleaning may be expensive (more than CSTR and AnMBR).	Difficult to clean out settled solids	
Biosolids/waste	Unguaranteed retention time (ie. risk of short-circuiting and incomplete pathogen destruction) Biosolids difficult to remove		Biosolids difficult to remove			Unguaranteed retention time (i.e. risk of short-circuiting and incomplete pathogen destruction) Biosolids with poor pathogen. Need extra stabilisation.	Digested solids are stable as guaranteed SRT/HRT, can be sold as fertiliser or reused as dairy bedding replacement Separated digested liquid stream can be directly irrigated without damaging crops, although nitrogen

Technology	Covered Anaerobic Lagoon (CAL)	Anaerobic Flotation Reactor (AFR)	Anaerobic Membrane Reactor (AnMBR)	Adsorption/Bio-oxidation	Plug Flow Reactor	Continuously Stirred Tank Reactors (CSTR)	Mixed Plug Flow Reactor
							removal may be required.
Odour	Fugitive odours from cover leaks	Potential for minor odour issues	Potential for minor odour issues	Potential for minor odour issues	Potential for minor odour issues	Fabric roof prone to leakage/damage	Excellent odour control as usually in ground with solid roof and >97% VFA removal.
Technology maturity	Simple and widely used process with many applications in the abattoir industry	Many applications in the food and beverage industries (high organic load content and high FOG), similar to abattoir industry	No known applications in the red meat industry	Used in municipal applications. Laboratory-scale trials on abattoir waste have been promising.		Established process in many applications	Widely used and well established process for manure digestion in the dairy industry in the USA. Some examples of use for abattoir waste. First example under construction in Australia at a large dairy.
Relative Footprint	Large	Small	Small	Small/Medium	Medium/ large	Small/Medium	Medium
Relative Capital Cost	Low	Medium	High	Medium/High	High	Medium/High	High

4.2.5 Preferred Options for Homer modelling assessment

Based on the options presented in Section 4.2.3, there are a range of potential configurations of anaerobic digestion technologies that could be considered for the solid and liquid waste streams produced at the NCMC site.

For the purposes of the site energy modelling, the following configurations were considered. These are not necessarily the final technical solution, but broadly represent the capital and operating costs that would be applicable for each stream and, as such, suitable for energy modelling scenarios.

Liquid streams – A covered anaerobic lagoon (CAL) would be constructed at the existing Dam 3 site. The existing dam would be desludged and a CAL constructed at the existing dam site. Biogas generated from the dam would be piped back to a co-generation engine located at the NCMC site. Ammonia would be scrubbed from the CAL liquid digestate using a scrubber, producing ammonium sulfate for sale.

Solid streams – A DVO mixed plug flow reactor would be constructed adjacent the NCMC site. Biogas generated from the system would be piped to an adjacent co-generation engine located at the NCMC site. Ammonia would be scrubbed from the liquid digestate (following dewatering in a screw press) using a scrubber, producing ammonium sulfate for sale. The digested solids would be sold as fertiliser. Note that the DVO-option has a relatively high capital cost for solids digestion, hence a comparison/sensitivity case with reduced Capex was also modelled.

Capital and Operating costs for these options are presented in the next section (**Table 9**).

4.3 HOMER Pro Modelling

4.3.1 Overview

4.3.1.1 Energy modelling using HOMER Pro

The HOMER Pro® microgrid modelling software by HOMER Energy is one of the world's leading hybrid microgrid modelling and optimisation packages. The term 'microgrid' is used to refer to a discrete energy system consisting of one or more energy sources (such as conventional or renewable power generation), a load and demand management control system (with or without energy storage), and one or more energy loads that can operate in parallel with or independently of the main power grid. In the current market, microgrids are being considered by many end-users of the electricity market to reduce power costs through a range of approaches, from installing 'behind-the-meter' solar PV generation and battery storage systems to using waste streams (such as process off-gas and biogas) for onsite generation.

HOMER Pro is aimed at modelling grid-connected or isolated systems containing one or many of the aforementioned components, and then optimising the size and configuration of the proposed solutions to identify the lowest net present cost (NPC) option. The strength of the software is in the capability to develop a single system containing all potential components being considered by the user (along with component details such as capital cost, efficiencies, fuel costs etc.) and modelling several thousand possible configurations to find the lowest cost option. As it is designed for modelling hybrid energy systems, HOMER Pro comes packaged with renewable resource data (e.g. solar and wind data) and a library of components currently available in the market, including solar panels and inverters, gas and liquid fuelled engines (including biogas), batteries, and many others. The initialised details for these components can be adjusted by the user to better match project-specific information and to account for local markets.

This software is ideal for modelling a system such as that being considered by NCMC, and allows GHD to consider a very wide range of potential solutions in a short period of time (in particular due to the number of different components being considered in this system). The findings from this initial assessment can then be used for inform subsequent stages of study, at which point the software may be used again to refine the selected option and inform a business case for implementation.

4.3.1.2 Energy modelling cases

For this study, three (3) cases have been modelled, broadly categorised by digester and wastewater infrastructure options as follows (using scenario numbering as per Section 4.2.2):

- Scenario 1a: Digestion of all solids and liquids: highest capex – highest gas production
- Scenario 1b: Digestion of part solids and all liquids: medium capex, medium gas production
- Scenario 1c: Digestion of all liquids streams only: lowest capex, lowest gas production

The energy modelling inputs differ for these three options in the following areas:

- Gas production

— Digester and wastewater infrastructure capital and operating costs

— Thermal load profile (due to removal of rendering steam demand in option 1a)

4.3.2 Development of inputs

This section details the development of the technical and economic inputs used in the energy modelling process. These are derived either from information provided by NCMC (such as electrical and thermal load profiles) or from in-house GHD knowledge (such as unit rates for generation equipment).

4.3.2.1 Biogas availability

The amount of biogas available in each of the three scenarios is presented in **Table 6**. The total biogas value presented below is the figure that is used for the energy modelling. The biogas availability is assumed to be a constant value year-round.

Table 6 Biogas availability

Parameter	Unit	1a	1b	1c
Biogas production from solids	m^3/day (@65% methane)	32,791	8,373	0
Biogas production from liquids	m^3/day (@70% methane)	14,963	15,425	15,424
Calorific value of methane (LHV)	MJ/m^3 (20°C, 1 bar)	33.4	33.4	33.4
Biogas energy from solids (LHV)	GJ/day	711	182	0
Biogas energy from liquids (LHV)	GJ/day	349	360	360
Total biogas (LHV)	**GJ/day**	**1060**	**542**	**360**

4.3.2.2 Electrical load profile

The electricity load profile used in the energy modelling for NCMC's operation has been developed from RFI-020 (Section 8.1), which provided half-hourly electricity load data on each of NCMC's two feeders.

The analysis of the load data is broken down into the following two areas:

— Consideration of relative production levels and determination of scaling factors required to reflect future electricity demand

— Development of hour-by-hour electricity profile to be used in the energy modelling process

These two areas are discussed further below.

4.3.2.2.1 Relative production levels and determination of scaling factors

The provided electricity demand data was provided between July 2016 and June 2017. It is understood that the production levels to be assumed for the energy modelling are higher than those that were achieved during the 2016/17 financial year, and as such it was anticipated that a scaling factor would be required to be applied to the provided data to bring it in line with the anticipated production.

To assess this assumption, a graph was developed to show the electricity consumption (in kWh/day) against the corresponding daily production (in kg/day). This graph is presented in **Fig 14**.

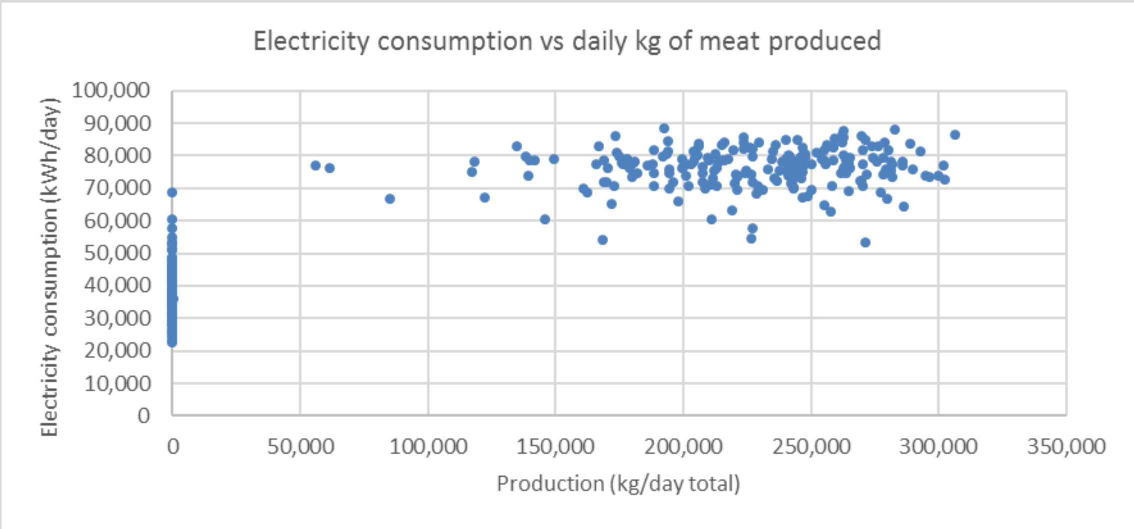


Fig 14 Electricity consumption vs. meat production

The expectation was that a relationship between production and electricity consumption would be identified that would allow the load to be scaled up for increased production. The findings were instead as follows:

— A baseload power consumption (ranging from approximately 25 MWh/day to 55 MWh/day) is present even on days of no production – this was expected,

— The electricity consumption ranges from 55 MWh/day to 90 MWh/day on production days with no apparent relation to the scale of production on that day – this was not expected.

The result of this finding is that the facility appears to have two levels of electricity consumption: production days and non-production days - whether the production is 150,000 kg/day or 300,000 kg/day, the range of electricity consumption does not change.

Accordingly, it is considered that no scaling factor is required to adjust the provided data in line with increased production expectations.

4.3.2.2.2 Development of load profile for energy modelling

In the analysis of the provided load profile, it was identified that many of the weeks in the year were not full 5-day production weeks. This was corroborated in discussions with NCMC, which indicated that 3.5 or 4-day weeks were common during the period for which data was provided.

Whist the analysis in the previous section identified that the data does not need to be scaled up to match projection production figures, it was considered necessary to adjust the provided data to reflect a full 5-day working week load profile in alignment with increased throughput. This was achieved by identifying days of abnormally low week-day electricity demand and replacing them with the load profile from an adjacent full production day. The period over Christmas was not adjusted as a shutdown is typical at that time.

The original and modified demand profiles are shown in **Fig 15**. The adjusted days are shown in red. The modified profile shown is the one that has been used in the energy modelling process.
It is noted that this electricity demand is the total of the demands from the two feeders that provide power to the plant. For the purpose of this assessment, the loads have been combined and considered as a single load.

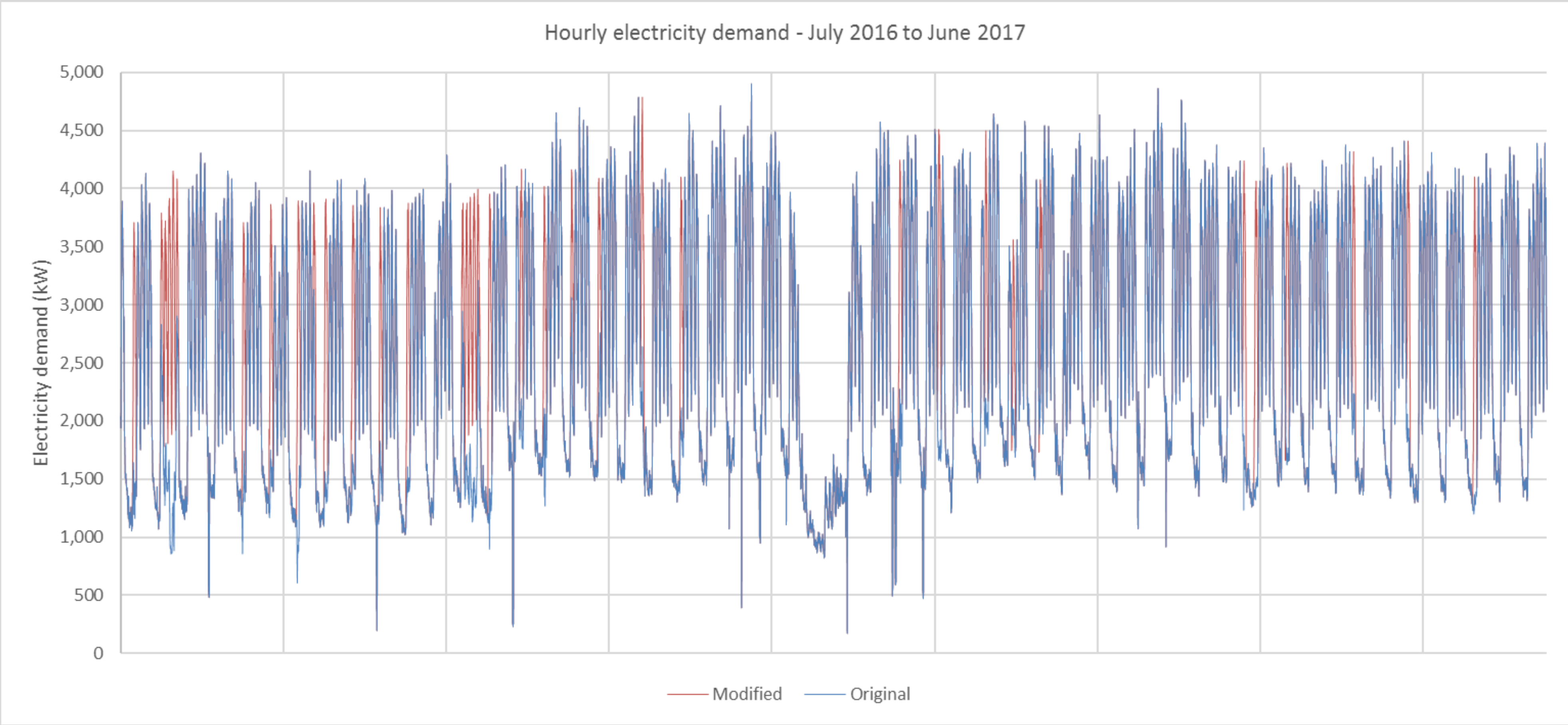


Fig 15 Annual electricity demand profile

As part of the load analysis, a load duration curve was produced from the modified profile – this is shown in **Fig 16**.

The load duration curve is used to identify the percentage of time throughout the year that the load is at or above a certain point. For example, it can be seen that while the load peaks at almost 5,000 kW, it is only above 4,000 kW for 10% of the year. Similarly, it can be seen that the load is at or above 1,000 kW for almost 100% of the year.

This information can be used to identify how much power generation can be easily incorporated into the plant's load profile. For example, if sufficient biogas can be generated to produce 1,000 kW of electricity, then that electricity will be readily consumed within the plant for almost 100% of the year. If 3,000 kW of electricity can be produced from the available gas, then that electricity will only be fully consumed within the plant for 40% of the year – for the remaining 60%, a portion of that available gas will need to be flared or used to generate power to be exported to the grid.

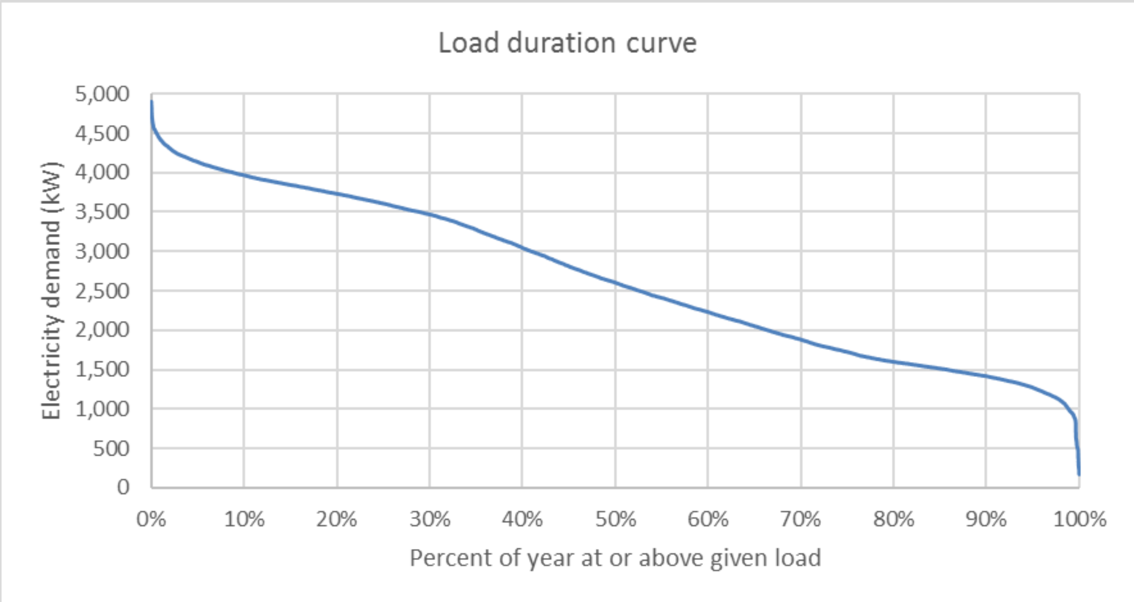


Fig 16 Load duration curve

4.3.2.3 Thermal load profile

The thermal load for NCMC's operations were developed based on AGL's Thermal Data Analysis report (published November 2013) which was provided by NCMC in response to RFI-025.

The relevant information from the AGL report is provided in **Fig 17**, which shows two weeks' worth of thermal load data. The load is divided into the following streams:

- Thermal power to rendering (steam, in kW)
- Thermal power to hot water (in kW)
- Thermal power recovered from rendering steam as hot water (in kW)
- Total thermal power required

A daily profile can be clearly seen from the data, with thermal demand reducing to zero on weekends.

For the purpose of energy modelling, this curve is represented as follows:

- Zero or minimal load between 10 pm and 4 am
- Ramp up to full load between 4 am and 6 am
- Full thermal load from 6 am to 9 pm
- Ramp down to zero or minimal load between 9 pm and 10 pm

The thermal power demand is nominally broken down into the following components:

- Thermal power to rendering: 8,000 kW
- Thermal power to hot water: 2,000 kW
- Thermal power recovered from rendering steam as hot water: 6,000 kW

It is understood that the production levels as of the time of publishing of the AGL report (Nov 2013) were similar to those that NCMC are wishing to achieve. As such, these thermal demand values have not been scaled to account for an increase in production.

For the purpose of energy modelling, there are two relevant thermal cases:

1. Business as usual as per existing demands
2. Removal of rendering steam demand due to digestion of solids

For case 1, the thermal load remains as per the aforementioned breakdown and the aforementioned profile.

For case 2, the rendering steam demand is removed, however the hot water thermal load increases from 2,000 kW to 8,000 kW as the hot water is no longer recovered from the rendering steam (which provided 6,000 kW of hot water). The profile for case 2 is considered to be the same as for case 1.

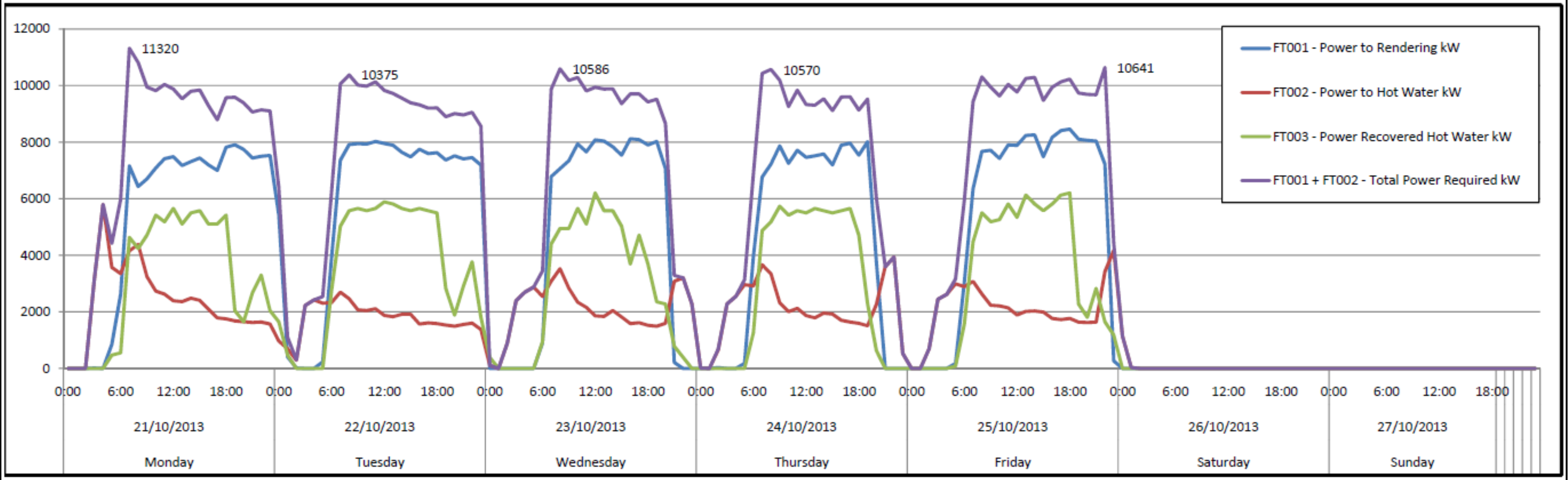


Figure 3: Plant data 21st to 27th November 2013

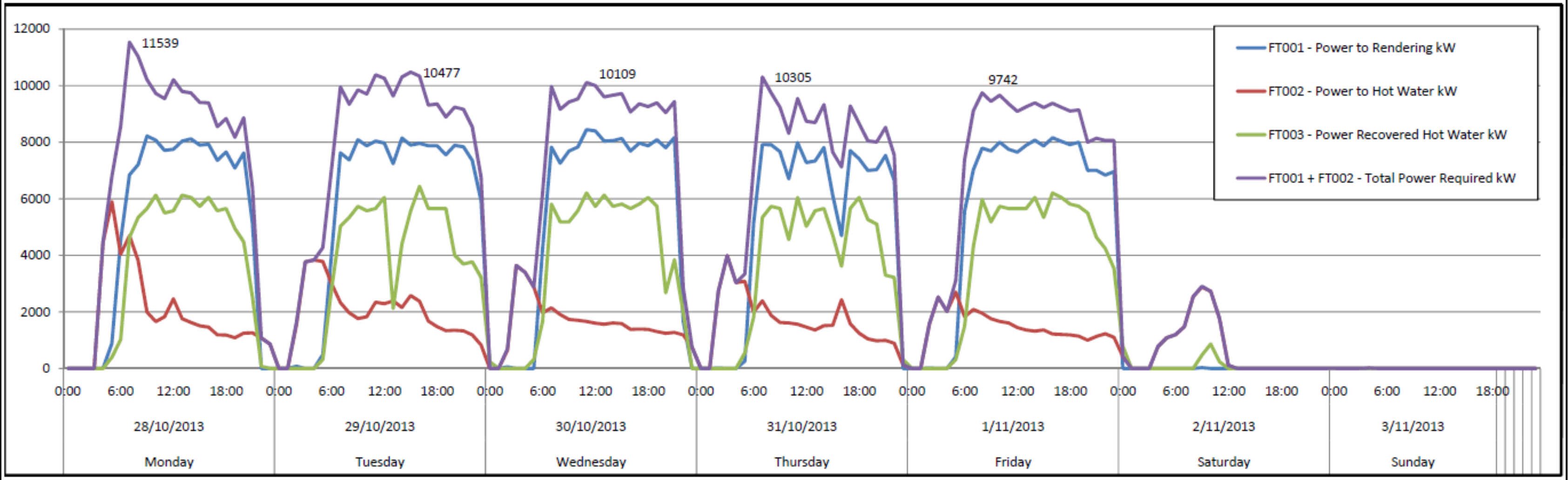


Figure 4: Plant data 28th Oct to 3rd Nov 2013

Fig 17 Thermal load profile from AGL Thermal Data Analysis (Nov 2013)

4.3.2.4 Power and fuel prices

4.3.2.4.1 Power price

The power price information provided by NCMC (from RFI-022) is shown in **Fig 18**.

Energy Charges as at 04/10/17	Rate	Unit
Peak	7.705	c/kWH
Shoulder	7.705	c/kWH
Off-Peak	4.624	c/kWH

Regulated Charges as at 04/10/17	Rate	Unit
AEMO Participant Charge	0.0374	c/kWH
AEMO Ancillary Charge	0.0480	c/kWH

Network Charges as at 04/10/17		
Network Provider:	CNRGYP	
Tarriff:	BHND3AO	
Demand & Capacity		
	Rate	**Unit**
Shoulder Demand (kVA)	7.673	$/kVA
Peak Demand (kVA)	8.4806	$/kVA
Off-Peak Demand (kVA)	2.2961	$/kVA
FIXED	**Rate**	**Unit**
Network Access Charge	17.854	$/Day
Volume		
Off-Peak	2.1443	c/kWH
Shoulder	2.6414	c/kWH
Peak	2.8482	c/kWH

Environmental Charges as at 04/10/17	Rate	Unit
ESC Charge	2.651	c/kWH
SREC Charge	4.000	c/kWH
LREC Charge	8.900	c/kWH

Metering Charges as at 04/10/17	Rate	Unit
Metering Charge	212.300	$/Meter
Supplementary Metering Charge	25.000	$/Meter

Fig 18 NCMC-provided power tariff components (from RFI-022)

Based on GHD's experience with similar projects, it is understood that the environmental charges are incurred as a percentage of the shown figures as follows:

— ESC charge: 15%

— SREC charge: 7%

— LREC charge: 14%

The power tariff components used in the modelling were calculated from the above figures as follows:

— Consumption charge (c/kWh) = energy charges + network volume charges + regulated charges + portion of environmental charges

— Demand charge ($/kVA) = network demand/capacity charge

The remaining charges (metering charges, network access charges) have not been included as they are relatively small costs and are consistent across all options.

The calculated rates are provided in **Table 7**.

The timing of the tariff periods (i.e. off-peak, shoulder, and peak) were determined based on the electricity demand data provided in RFI-020.

Table 7 Power tariff components

Period	Times	c/kWh	$/kVA
Off-peak	10 pm – 7 am	8.795	2.296
Shoulder	9 am – 5 pm & 8 pm – 10 pm	12.373	7.673
Peak	7 am – 9 am & 5 pm – 8 pm	12.580	8.481

4.3.2.4.2 Boiler fuel price

Boiler fuel prices were derived from NCMC's response to RFI-021 – Fuel consumption and prices, which provided three years of fuel consumption data.

The following observations and assumptions were made:

- The fuel mix varied over the three years between the three fuel components (pine sawdust, hardwood sawdust, and nutshell).
- A blend of 40/30/30 (pine/hardwood/nutshell) was used as a nominal blend. This appeared to be representative of an average blend over the three years.
- Calorific values of the fuels were assumed as follows based on GHD's experience and publicly available typical figures (on a dry basis):
  - Pine sawdust: 18 GJ/t
  - Hardwood sawdust: 18/GJ/t
  - Nutshell: 20 GJ/t
- The prices used, based on the figures provided in the RFI response, are as follows:
  - Pine sawdust: $17.30/m^3
  - Hardwood sawdust: $17.30/m^3
  - Nutshell: $45/m^3 (based on the provided price of $90/tonne and provided density of 500 kg/m^3)
- A moisture content of 25% has been assumed for the fuel on an as-provided basis
- Based on the above, the blended fuel parameters were calculated as follows:
  - Calorific value (dry): 18.6 GJ/t
  - Cost: $57/tonne

4.3.2.5 Capital and operating costs

Capital and operating costs for generation equipment and associated infrastructure (e.g. biogas gensets CAPEX and OPEX) are incorporated in the HOMER Pro modelling software and have been adjusted by GHD based on recent experience and market information. The capital and operating cost basis for these components is detailed in **Table 8**. The total capital and operating cost for each option is calculated based on the infrastructure included in the option (e.g. number of biogas gensets or amount of installed solar PV) and the unit costs presented in this table.

Table 8 Generation equipment capital and operating costs

Component	Basis	Unit	Value
Biogas genset CAPEX – no heat recovery	Typical figure based on GHD's experience	Million $/MW	1.6
Biogas genset CAPEX – with heat recovery	Typical figure based on GHD's experience	Million $/MW	1.85
Biogas genset OPEX – no heat recovery	Typical figure based on GHD's experience	$/hour/MW	20
Biogas genset OPEX – with heat recovery	Typical figure based on GHD's experience	$/hour/MW	25
Biogas genset major overhaul – no heat recovery (required every 60,000 fired hours)	Typical figure based on GHD's experience	Million $/MW	0.5
Biogas genset major overhaul – with heat recovery (required every 60,000 fired hours)	Typical figure based on GHD's experience	Million $/MW	0.6
Solar PV CAPEX	Typical figure based on GHD's experience	Million $/MW	2
Solar PV OPEX	Typical figure based on GHD's experience	$/kW/yr	20

The capital and operating costs of the digesters and associated infrastructure are presented in **Table 9**. The total capital and operating costs for a given configuration are made up of the total of the corresponding cost items from **Table 8** and **Table 9**.

It is noted that an additional operating cost has been included in the 'business as usual' case to account for the cost of running the electro-coagulation unit that is anticipated to be brought online in the near future. Based on information available to GHD, bringing this unit online will cost approximately $350,000/year associated with cost of power, chemicals, and anode replacement. In any of the modelled scenarios (1a, 1b, 1c), this will not be required, and therefore this operating cost will be avoided. The inclusion of this operating cost in the 'business as usual' case accounts for this saving.

Table 9 Digester and associated infrastructure capital and operating costs (excluding energy generation costs presented in Table 8)

Component	Basis	Unit	1a	1b	1c
CAL CAPEX					
CAL CAPEX base case		Million $	7.9	7.9	7.9
CAL CAPEX high case (+20% CAL CAPEX)		Million $	9.5	9.5	9.5
CAL CAPEX low case (-30% CAL CAPEX)	Retrofit of existing dam 3	Million $	5.5	5.5	5.5
CAPEX for 2 km pipe to CAL	Based on 6 inch pipe @ $40k/inch/km	Million $	0.48	0.48	0.48
Blower/chiller and flare at CAL	Based on high level GHD estimate	Million $	0.4	0.4	0.4
HV cable and electrical interconnection to pumps at CAL	Based on high level GHD estimate	Million $	0.26	0.26	0.26
All-in costs for the CAL - base case		Million $	9	9	9
All-in costs for the CAL - high case (+20% CAL CAPEX)		Million $	10.6	10.6	10.6
All-in costs for the CAL - low case (-30% CAL CAPEX)		Million $	6.7	6.7	6.7
CAL OPEX					
Allowance for desludging CAL	$1M allowance every 5 years	Million $/yr	0.2	0.2	0.2
Solids digester CAPEX					
Solids digester CAPEX base case		Million $	19.8	12.3	0
Solids digester CAPEX low case		Million $	14.8	9.3	0
Solids digester OPEX					
Staff	1 staff member at $100,000/yr	Million $/yr	0.1	0.1	0
Ongoing operation cost	3% of CAPEX p.a.	Million $/yr	0.52	0.32	0
Revenue from sale of digested solids and ammonia		Million $/yr	-1.0	-0.4	0
Lost revenue from lack of tallow production		Million $/yr	1.3	0	0
Total solids digester OPEX		Million $/yr	0.92	0.02	0
Total CAL and solids digester CAPEX – base case		Million $	28.8	21.3	9
Total CAL and solids digester CAPEX – low case		Million $	21.5	16	6.7
Total CAL and solids digester CAPEX – high case		Million $	30.4	22.9	10.6
Total CAL and solids digester OPEX		Million $/yr	1.12	0.22	0.20

4.3.3 Modelling, Results and Analysis

4.3.3.1 Modelling using HOMER Pro

The inputs detailed in the preceding sections have been entered into the HOMER Pro software and modelled to identify the lowest possible net present cost (NPC) option for each scenario.

4.3.3.1.1 Economic parameters

The modelling was undertaken using the following economic parameters:

— Project life: 7 years

— Discount rate: 8%

These rates have been selected in order to reflect NCMC's desire for a project payback period in the order of 5 years. A discount rate of 8% is considered to be typical of a project of this nature. With a project life of 7 years, the relative NPC standing of the different options provides a good indication of the payback period that may be achieved i.e. if the NPC of one of the options is lower than the base case after a project life of 7 years, then it may meet NCMC's requirements.

It is noted that the majority of this assessment has not considered the impact of large-scale generation certificates (LGCs) that might be generated under the Large-scale Renewable Energy Target. The basis and impact of this assumption is discussed further in Section 4.3.3.5.

4.3.3.1.2 HOMER Pro methodology

The approach taken by the software to calculate NPC is broadly as follows:

— Identify all possible hardware configurations based on the inputs provided by the user (e.g. number and size of gensets)

— Identify all economic cases to be analysed (e.g. CAPEX sensitivity cases, grid price sensitivity cases)

— Model the system hour-by-hour to determine the power and thermal consumption/ production and associated costs for each hour throughout the year and for the life of the project

When determining hour-by-hour operation, the model considers the following (at a high level):

— Electricity and thermal demand in that time step as dictated by the input load curves

— Amount of biogas available to produce electricity to meet the required power demand

— Amount of thermal energy (if any) recovered from the biogas gensets to offset thermal load

— Amount of fuel required in the boiler to provide the remaining thermal load

— Amount of grid power required to meet the remaining power demand (if any)

— The cost associated with all of the above, including operating costs and refurbishment costs associated with running the equipment (e.g. gensets) to provide the generation.

The software undertakes this process for all of the possible equipment and sensitivity case combinations that are physically possible, and then presents the results in order of lowest NPC.

4.3.3.1.3 Presentation of results

The results presented in the following section reflect the lowest NPC option for each case as determined through the process described in Section 4.3.3.3.1.

4.3.3.2 Sensitivity cases

Sensitivity cases have been run for the following:

— Capital cost high and low cases for CAL and solids digesters – the sensitivity to these factors are shown in all of the results graphs below. The low Capex case for solids digesters reflects the potential the use a lower-capital cost approach to solids digestion, but may not deliver all the benefits of DVO digester e.g. reduced energy recovery, reduced ability to on-sell digested solids as fertiliser, reduced reliability etc.

— Electricity price high case (at 10c/kWh and 15c/kWh for off-peak and shoulder/peak respectively) – the sensitivity to this variable is shown in as the ‘high business as usual’ case and in the ‘1c – high grid price’ case

— Exported power sale price – this is shown for option 1a in Section 4.3.3.4.

— Impact of a nominal allowance of $40/MWh for LGCs – this is shown in Section 4.3.3.5.

4.3.3.3 Results

4.3.3.3.1 Selected option for each scenario

The results presented in the charts in this section correspond to the lowest NPC option for that simulation. The exact configuration of the selected solution e.g. number and size of gensets, inclusion of solar PV etc. will vary from option to option depending on the specifics of that simulation. The optimal configuration (lowest NPC) is therefore an output from the model.

The selected configurations for each scenario and sensitivity case, as selected by the optimisation software based on lowest NPC, are shown in **Table 10**. The results shown in the following sections (i.e. the NPC, CAPEX, and OPEX graphs) correspond to the selected configuration from this table.

Table 10 Selected solutions for each scenario and sensitivity case

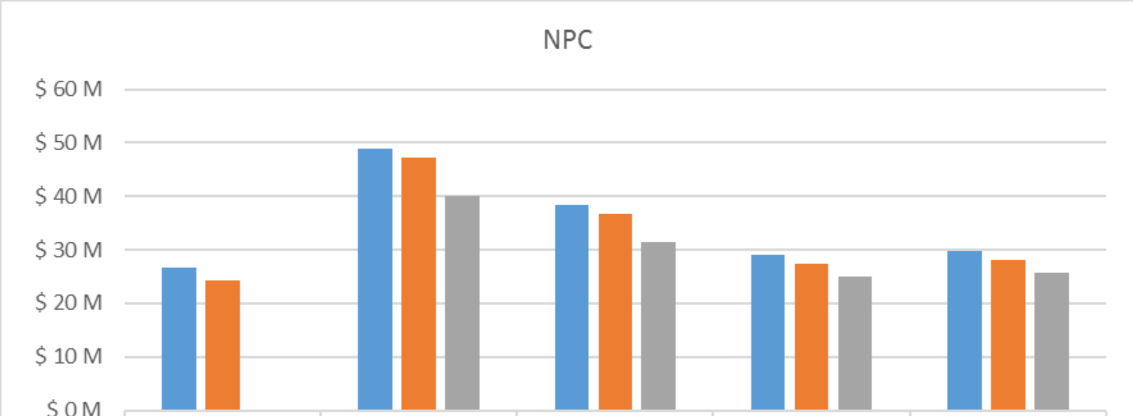
Scenario	High CAPEX	Mid CAPEX	Low CAPEX	Low CAPEX, 5c/kWh sellback
1a	2 x 1MW biogas gensets 2 x 1MW biogas gensets with HR	2 x 1MW biogas gensets 2 x 1MW biogas gensets with HR	2 x 1MW biogas gensets 2 x 1MW biogas gensets with HR	3 x 1MW biogas gensets 2 x 1MW biogas gensets with HR
1b	1 x 1MW biogas gensets 2 x 1MW biogas gensets with HR	1 x 1MW biogas gensets 2 x 1MW biogas gensets with HR	1 x 1MW biogas gensets 2 biogas gensets w HR	2 x 1MW biogas gensets 1 x 1MW biogas gensets with HR
1c	1 x 1MW biogas gensets 1 x 1MW biogas gensets with HR	1 x 1MW biogas gensets 1 x 1MW biogas gensets with HR	1 x 1MW biogas gensets 1 x 1MW biogas gensets with HR	1 x 1MW biogas gensets 1 x 1MW biogas gensets with HR
1c - high grid price	2 x 1MW biogas gensets 2 MW solar PV	2 x 1MW biogas gensets 2 MW solar PV	2 x 1MW biogas gensets 2 MW solar PV	1 x 1MW biogas gensets 1 x 1MW biogas gensets with HR

4.3.3.3.2 NPC, capital, and O&M results

The NPC, capital cost and O&M (including electricity cost) of the selected solutions for each of the scenarios are presented in **Fig 19**, **Fig 20** and **Fig 21** respectively.

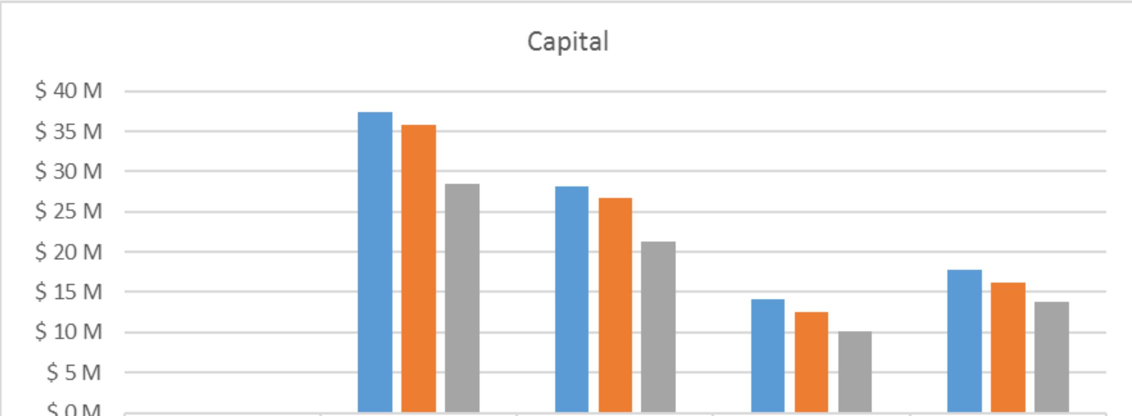
It can be seen that the business as usual (BAU) option presents the lowest NPC of all of the scenarios, indicating that the payback period exceeds 7 years for all scenarios. It should be noted that the 'high' case for BAU reflects the 'high grid price' sensitivity case discussed above. This is included for comparison to the '1c – high grid price' case – this is discussed further below.

Scenario 1c presents the most favourable of the remaining options, which can largely be attributed to the lower capital cost of the infrastructure required in that option. As is seen in **Fig 20**, the capital cost of options 1a and 1b far exceed that of the other options, even in the low CAPEX sensitivity cases. Given the short payback period to be achieved, the capital costs of these projects is prohibitive.



	Business as usual	1a	1b	1c	1c - high grid price
High	$26,746,080	$48,915,920	$38,414,620	$29,029,120	$29,679,760
Mid	$24,317,910	$47,335,920	$36,834,620	$27,449,120	$28,099,760
Low		$40,005,920	$31,504,620	$25,079,120	$25,729,760

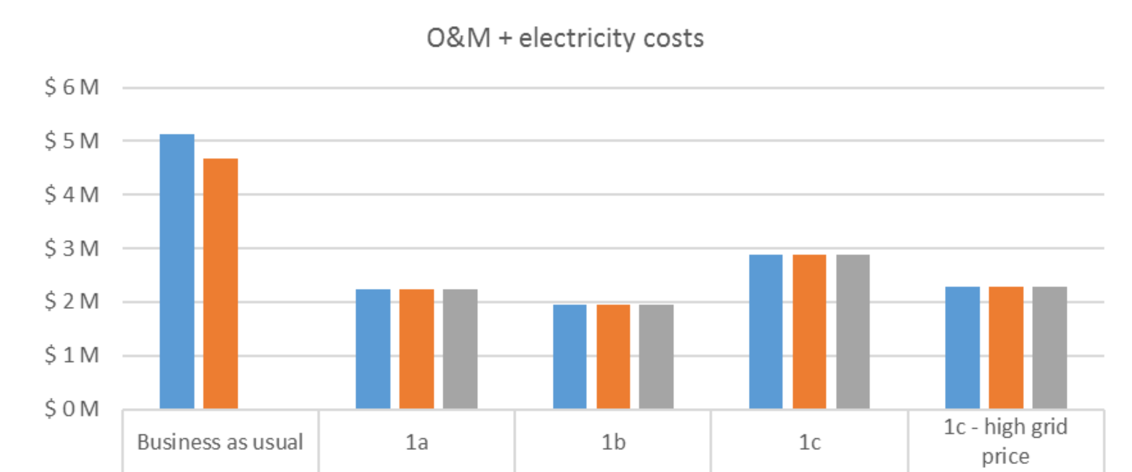
Fig 19 NPC comparison



	Business as usual	1a	1b	1c	1c - high grid price
High	$0	$37,320,000	$28,220,000	$14,070,000	$17,820,000
Mid	$0	$35,740,000	$26,640,000	$12,490,000	$16,240,000
Low		$28,410,000	$21,310,000	$10,120,000	$13,870,000

Fig 20 Capital cost comparison

The annual operating costs (which include grid-purchased electricity costs) shown in **Fig 21** reflect the impact of biogas generation – increased biogas generation enables more biogas-fired generation, which in turn reduces annual grid purchases.



	Business as usual	1a	1b	1c	1c - high grid price
High	$5,137,185	$2,227,257	$1,958,105	$2,873,234	$2,277,933
Mid	$4,670,799	$2,227,257	$1,958,105	$2,873,234	$2,277,933
Low		$2,227,257	$1,958,105	$2,873,234	$2,277,933

Fig 21 Annual O&M and electricity cost comparison

The '1c – high grid price' sensitivity case assesses the impact of increasing grid price on the viability of scenario 1c. In the low CAPEX sensitivity case, the NPC of '1c – high grid price' is $25.7 million, which is marginally lower than the BAU high grid price case of $26.7 million. This is achieved through a combination of the following:

— Additional capital spent on 2,000 kW of solar PV at the site to offset increasing power costs

— Lower annual O&M/electricity costs of '1c – high grid price' in comparison to the base 1c scenario

This finding highlights the significance of power price on the viability of projects of this nature - a marginal increase (in the order of 15-20%) on power price can impact the viability of the project.

The impact of this addition of 2,000 kW of solar PV to the solution is seen more clearly in **Fig 22** and **Fig 23**. These figures show the NPC, CAPEX, and OPEX under scenario 1c (for the low CAL CAPEX case) for the lowest NPC case ***without*** solar and the lowest NPC case ***with*** solar.

The configuration for each of these cases is:

— *With solar*: 2 MW solar PV, 2 x 1 MW biogas gensets

— *No solar:* 1 x 1 MW biogas gensets, 1 x 1 MW biogas gensets with heat recovery

The following can be seen:

— The NPC is marginally higher for the *no solar* case than for the *with solar* case

— The CAPEX is noticeably higher in the *with solar* case (as would be expected)

— The OPEX is significantly lower for the *with solar* case.

The fact that the addition of solar PV only becomes preferably in the high grid price case indicates that there is a tipping point (of grid price) at which solar PV can provide lower-cost electricity.

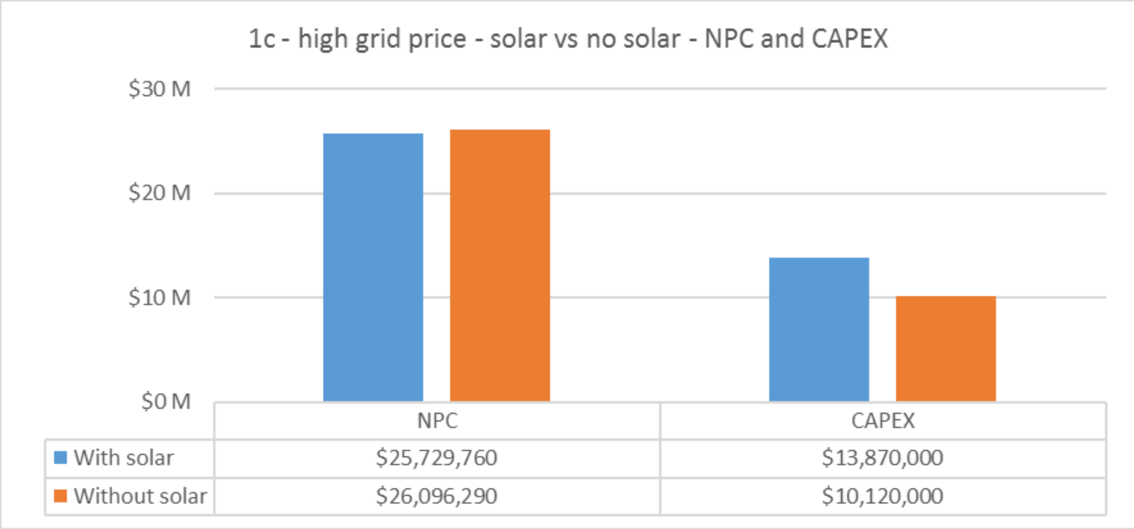


Fig 22 Comparison of solar vs no solar – NPC and CAPEX

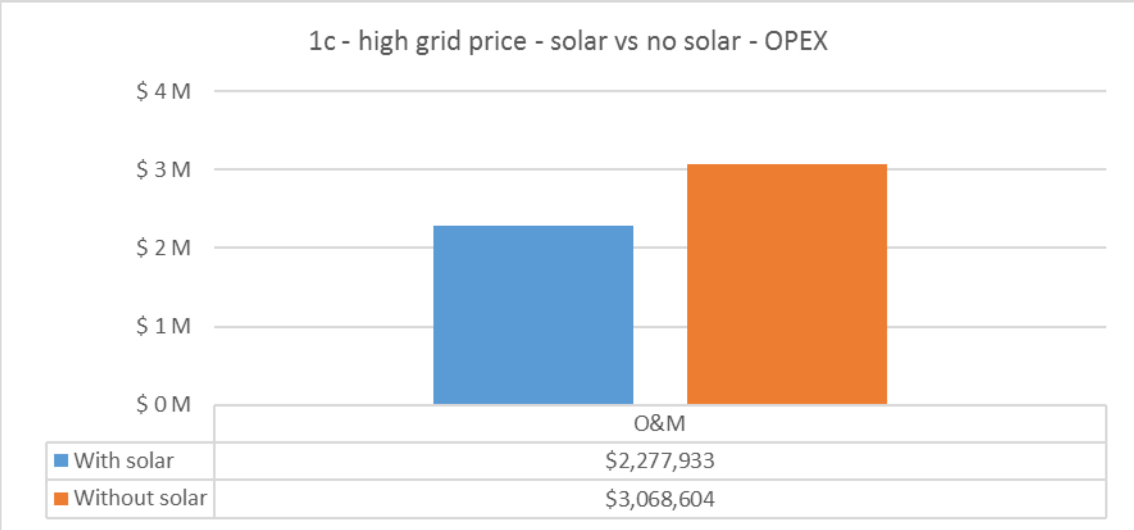


Fig 23 Comparison of solar vs no solar – OPEX

4.3.3.3.3 Operational metrics

A number of operational metrics have been compared for the base case simulation for each scenario. These metrics are:

— Renewable penetration % (measured as a % of renewable power/thermal generation relative to the project power/thermal consumption)

— Grid energy purchased

— Annual boiler fuel consumption

These metrics assist in visualising the operational changes that are achieved by implementing these solutions.

The renewable penetration figures shown in **Fig 24** paint a clear picture – increased biogas production results in an increased renewable penetration.

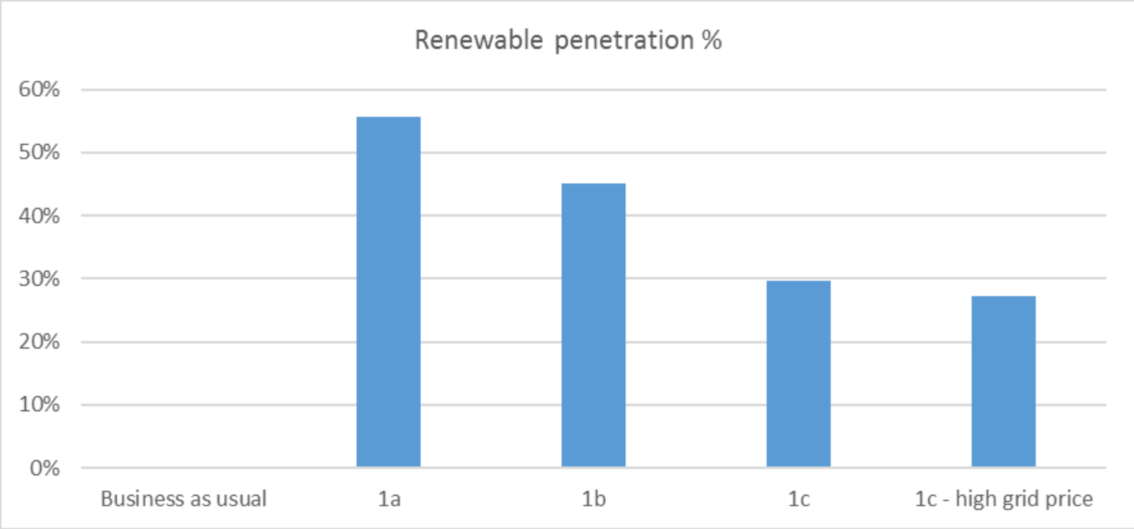


Fig 24 Renewable penetration % comparison

The high penetration achieved in 1a is a result of the combined effect of producing power from biogas and from offsetting boiler fuel with heat recovered from the biogas waste heat recovery systems. This effect is still pronounced in 1b, and reduces further to option 1c due to the lower biogas production.

It should be noted that this calculation does not consider the biomass used in the boiler to be renewable energy, which results in 0% renewable penetration in the BAU case.

Similarly, the amount of grid energy purchased in each scenario is inversely proportional to the amount of biogas that is produced – as shown in **Fig 25**.

It is interesting to note that the grid energy purchase decreases in the grid price sensitivity case. This shift is due to the inclusion of 2 MW of solar PV in the optimised solution in an attempt to reduce the operating cost incurred by the higher grid prices. This change reflects how critical the grid electricity price is to an analysis of this nature.

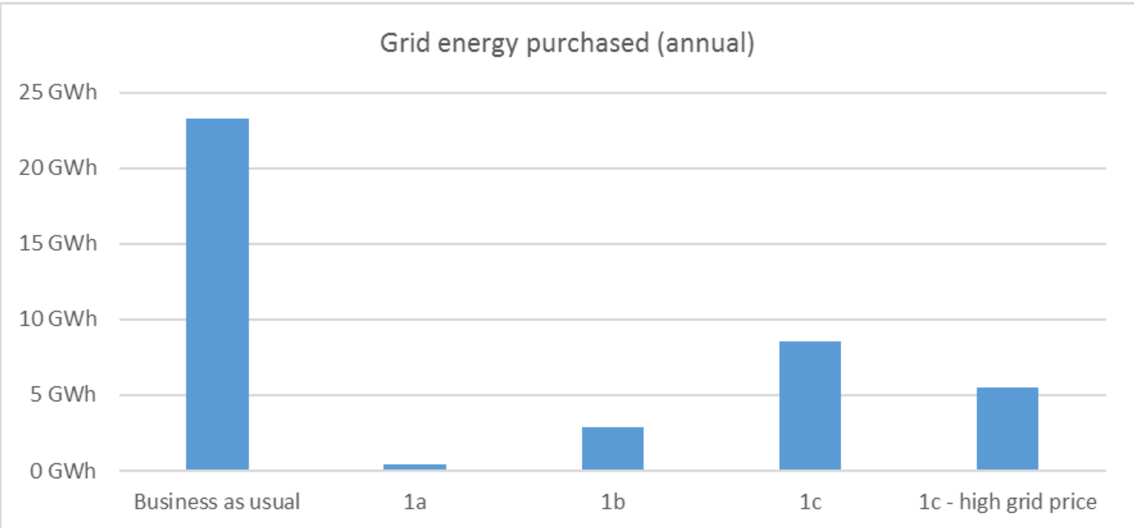


Fig 25 Annual grid electricity purchase comparison

Fig 26 shows annual boiler fuel consumption, and is again inversely proportional to the amount of biogas produced. A higher biogas production enables more heat recovery from the biogas genset waste heat recovery systems. This provides cost-effective thermal energy and displaces the biomass that would otherwise be used.

Again, the high grid price sensitivity case shows a change in the pattern – the amount of fuel consumed is equal to that of the BAU case. This reflects the fact that no waste heat recovery gensets have been included in the optimised case. It should be noted that this is a very marginal difference – a very close 2nd-best NPC option includes heat recovery with one of the biogas gensets, which then brings it in alignment with the base case 1c option.

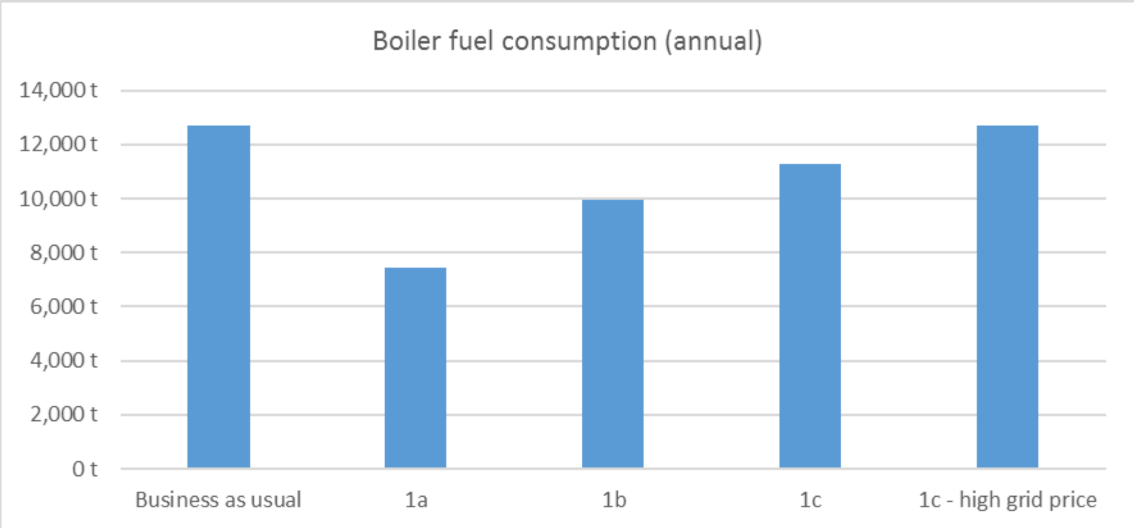


Fig 26 Annual boiler fuel consumption comparison

4.3.3.4 Export power sale price sensitivity case

A sensitivity case has been run to assess the impact of including an export power sale price of 5c/kWh. The results from these models are shown in **Fig 27** and

Fig 28. Scenario 1a was used for this analysis as it has sufficient excess of biogas to enable substantial power export.

The following observations can be made:

— The NPC of the 5c/kWh sellback option is lower than the other cases, as would be expected

— The CAPEX of the optimised case is increased, reflecting the installation of additional generation infrastructure to capitalise on the revenue stream that has now been included

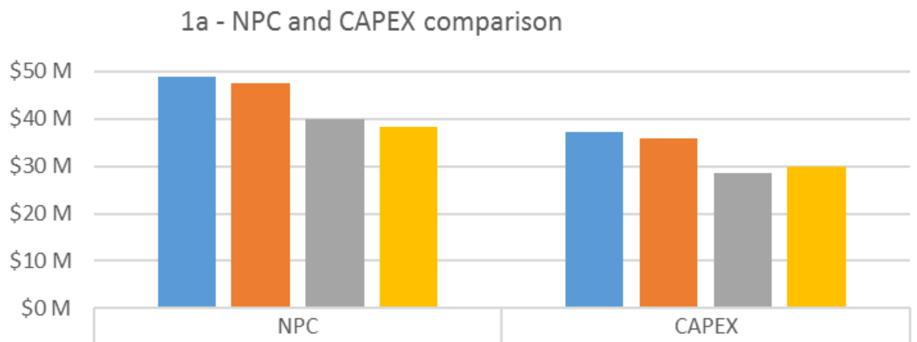
— The annual operating cost is reduced, reflecting the impact of the revenue generated from sale of generation from biogas

While these results are favourable, the magnitude of the changes are not sufficient to make the option competitive. The base case BAU option NPC of $24 million is still far lower than the sellback sensitivity case presented here.

The following aspects impact these results:

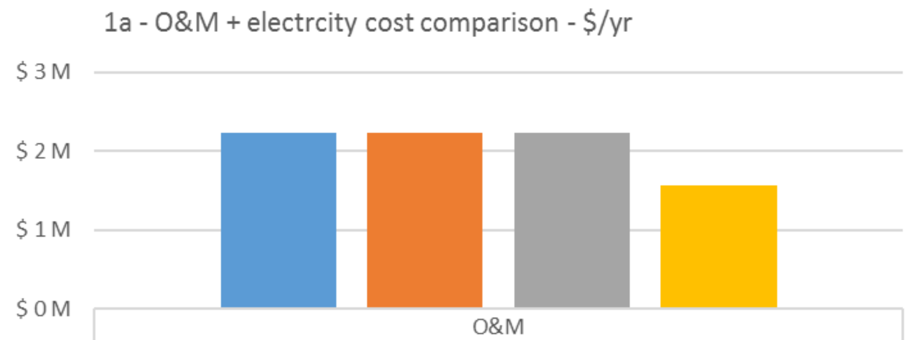
— The grid sale price of 5c/kWh is only marginally higher than the operating cost of the engines, which in itself is 2-2.5c/kWh,

— A higher grid price may be achievable, however this must be negotiated with the energy retailer.



	NPC	CAPEX
High	$48,915,920	$37,320,000
Mid	$47,335,920	$35,740,000
Low	$40,005,920	$28,410,000
Low, 5c/kWh sellback	$38,134,600	$30,010,000

Fig 27 NPC and CAPEX comparison – export sale price sensitivity case



	O&M
High	$2,227,257
Mid	$2,227,257
Low	$2,227,257
Low, 5c/kWh sellback	$1,560,512

Fig 28 O&M and electricity – export sale price sensitivity case

4.3.3.5 Large-scale Generation Certificate (LGC) impact sensitivity case

Under the Large-scale Renewable Energy Target, eligible renewable energy generators can generated large-scale generation certificates (LGCs) which can be sold on the LGC market or under contract to other individuals or organisations at a negotiated price. LGCs are typically sold to electricity retailers who are required to surrender a set number of certificates every year to the Clean Energy Regulator.

One LGC is created for every MWh of eligible renewable electricity that is generated and either exported to the grid or used to displace grid-sourced electricity.

The upper limit for the value of an LGC is approximately $90, which results from the penalty that must be paid by retailers for failing to meet their allocated target. Historically, the price has varied from as low as $20/certificate to the maximum of approximately $90/certificate. The value of a certificate is market-based, and cannot be predicted.

While GHD cannot comment on the future price or expected price of a LGC, it is noted that there is a high level of uncertainty in the future market due to the recent influx of large renewable power projects in Australia. It is also noted that there are specialist consultants who are able to provide a view of the future market based on their proprietary modelling. It may be in the interest of NCMC to engage one of these parties to undertake such a process for this project.

To consider the potential impact that LGCs may have on this project, a sensitivity case using a nominal LGC value of $40/MWh has been carried out. The following approach has been taken for this sensitivity case:

— Use the calculated NPC from the 'low CAPEX' sensitivity case for options 1a, 1b, 1c, and 1c – high grid price,

— For each of the selected configurations for these options, identify the annual MWh produced from the biogas gensets or solar PV,

— Use the nominal value of $40/LGC to determine the revenue generated each year,

— Use the same financial assumptions (7 year project life, 8% discount rate) to determine the impact of this revenue on the NPC of each option.

The impact on NPC is shown in **Fig 29** for each scenario.

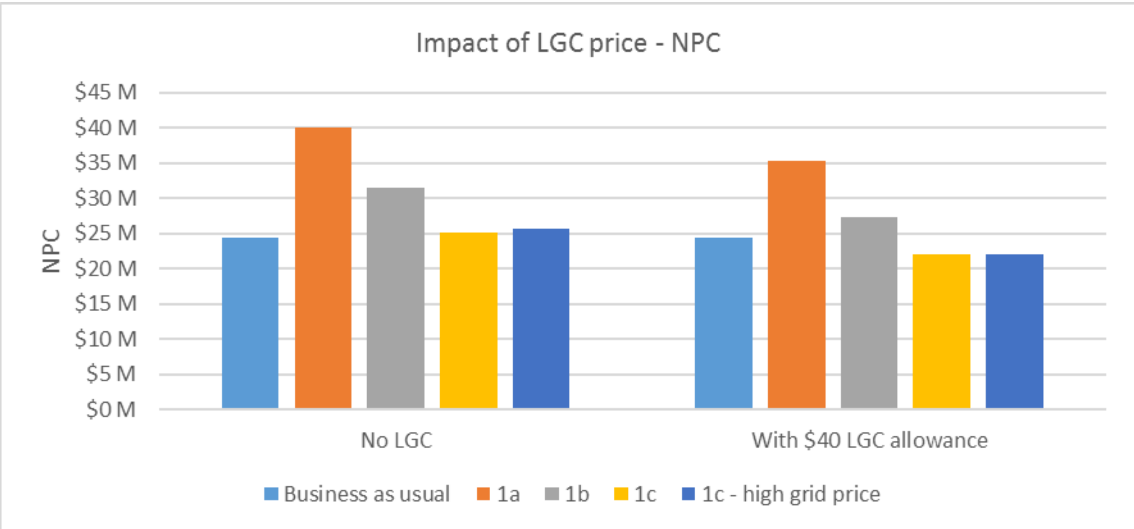


Fig 29 Sensitivity case for nominal $40/MWh LGC price – NPC comparison

The following observations can be made:

— Consideration of LGC provides a clear benefit to the options that generate renewable energy (in comparison to the business as usual case),

— With this allowance include, scenario 1c remains the preferred option.

4.3.4 Modelling Conclusions

A number of conclusions can be drawn from the analyses in the preceding sections. These are detailed below.

The capital cost of options 1a and 1b are prohibitive

The capital cost of options 1a and 1b, even in the 'low' CAPEX sensitivity cases, are prohibitive in comparison to the energy savings that can be made.

When compared on the basis of the 7-year cycle that has been modelled, it can be seen that the CAPEX of options 1a and 1b (at $28.4 million and $21.3 million respectively) are almost as high or higher than the 7-year NPC of the BAU case (at $24.3 million). This indicates that the potential savings to be made from offsetting grid electricity and boiler fuel costs cannot recoup this capital expenditure within a 7 year period.

The potential gas production exceeds on-site requirements

As is evidenced by option 1a, more gas can be produced by digesting all waste streams than can be used onsite.

The amount of gas produced on site can provide approximately 5 MW of continuous electricity production, while on-site electricity demand peaks at just under 5 MW and averages approximately 2.7 MW. As the gas cannot be stored onsite, any excess gas must be either flared or used to generated power to be sold to the grid (this option is discussed further below).

The result of this is that the overall utilisation of the biogas is lower than for the option/s with lower gas production (such as 1c). As the heightened gas production comes at the expense of high capital cost, the overall value proposition of 1a is lower than 1c.

The overall conclusion from this is that finding the 'sweet spot' of gas production versus capital cost is critical in identifying the optimum solution.

Grid power price is pivotal to the viability of the project

The viability of a project of this nature is always heavily dependent on the grid power price being incurred by the operation. The key 'product' of the project is displacing grid-purchased electricity, and as such, the price of that electricity dictates that value that can be gained.

NCMC's current power price is relatively low in the context of the current electricity market, and as such it is difficult to develop an economically feasible project. If the grid price increases, or the tariff that NCMC is on changes, a different outcome is possible.

This is highlighted by the '1c – high grid price' sensitivity case, which actually provides a lower NPC (in the 'low' capital cost case) than the BAU option at that same increased power price. It should be noted that the power price in that case was only increased in the order of 15-20% - any more drastic increases would exacerbate this effect.

An alternative benefit of reducing dependence on grid-supply electricity is that it separates NCMC's operating costs from the electricity market, therefore reducing the uncertainty associated with future power price changes.

Option 1c is the most viable option of those considered

Option 1c presents the lowest NPC option of those considered in this assessment. While it is not lower than the BAU case at this stage, there may be room for optimisation that will bring it closer to commercial viability.

Revenue from selling excess power improves the appeal of options 1a and 1b

For the options with higher gas production (i.e. 1a and 1b), the sale of excess power to the grid provides an additional revenue stream and offsets some of the ongoing operational costs of the plant.

This was considered in this study by modelling option 1a with an export sale price of 5 c/kWh, which is typical of wholesale electricity market prices. While this figure is typical of what is experienced in the industry, it can only be determined by discussions with the network retailer (or other party who may be interested in purchasing the power) – this would need to be considered and addressed further by NCMC in future if this option is taken forward.

As can be seen from **Fig 27** and **Fig 28**, the revenue generated does not offset the high capital cost associated with option 1a. The following comments can be made in regards to this:

— The value of consuming power on-site is much higher than exporting to the grid due to the different between grid purchase price (8-13c/kWh) and grid sale price (5c/kWh),

— The actual revenue generated from selling excess power is actually lower than 5c/kWh due to the operating cost of the biogas gensets (in the order of 2-2.5c/kWh),

— Exporting power to the grid adds an amount of capital cost and technical/commercial complexity to the project.

Solar PV can be attractive if the power is consumed onsite and if grid price increases

Installation of solar PV may be an attractive option under the following circumstances:

— If the power generated from the solar PV is consumed onsite to offset high grid power prices (i.e. option 1c). In options 1a and 1b, installation of solar PV is not attractive as it simply increases the oversupply of electricity available onsite and incurs additional capital costs

— If grid power prices increase

In the context of a higher grid price (in the order of 15c/kWh), adding solar PV to option 1c will enable NCMC to further reduce their reliance on the grid and reduce costs incurred from high grid prices.

4.3.5 Modelling Next steps

Based on the discussions above, the following steps are recommended:

— Consider whether the modelled payback period needs to be reviewed

— Explore opportunities for optimising option 1c to reduce capital cost (additional design to refine Capex estimate)

— Conduct further sensitivity analyses on the optimised option 1c in order to further understand the viability of the project

— Develop a view of the movements of the electricity market (this is likely to be an internal NCMC process, such as business planning or discussions with energy retailers or specialist consultants)

— Explore the potential for a solar PV installation in close proximity to NCMC's operations for the event that grid prices increase (e.g. availability of land)

— Further explore funding options (see Section 4.4 below) to determine if alternative approaches to offset Capital investment are available.

4.4 Project Funding Opportunities

MLA recently published a review of renewable energy technology adoption within the Australian red meat industry (All Energy, 2017). Within this report, a range of so-called “innovative” funding alternatives were described, along with a range of potential commercial models. To complement this report, we undertook a brief review of funding opportunities from the NSW and Federal Government perspectives.

There is currently no up-front “renewable energy” project-specific grant funding support currently available through the NSW Department of Planning and Environment, however there may be opportunity to access funding support via the following programs:

— Department of Industry - Jobs for NSW scheme (see Fact Sheet)

— Department of Premier and Cabinet – Growing Local Economies (See FAQ’s)

The Jobs for NSW Scheme provides funding support is in the form of specifically developed loans from \$200k to \$5 million to support investment and growth in a regional business.

The NSW Growing Local Economies program is one of six funds administered under the \$1.3 billion Regional Growth Fund, which will invest in projects that facilitate regional development. These funds aim to enable essential infrastructure, support arts and culture, enhance and build sporting infrastructure, improve regional voice and data connectivity, invest in our mining-impacted communities, spur job creation and deliver local infrastructure.

Most federal funding support for these types of projects is now trailing rather than up front, in the form of tradeable credits such as Large Generation Certificates (LGC’s) – currently trading around \$80/MWh (but trending down), or ACCU’s under the Emissions Reduction Fund.

ARENA’s Advancing Renewables program may be worth exploring, however, ARENA does not fund activities that are commercially viable without ARENA support. They offer 50% matched funding with the Applicant, but will only provide the minimum amount of funding to allow the Activity to proceed. ARENA has legislated funding through to 2022 and will fund activities that are expected to advance renewable energy technologies towards commercial readiness, improve business models or reduce overall industry costs. The most suitable ARENA program for innovative energy solutions is the Advancing Renewables programme, which, if eligible can take the form of a grant.

Note that there is generally a condition that secured funding support provided under one of the various programs will render a project ineligible for funding under another program.

Key considerations and links or contacts for follow up are set out **Table 11** below.

In addition to these government funding opportunities, a range of privately funded arrangements are also possible. GHD is aware of a European superannuation fund that is currently investing in “industrial water projects”, and the NCMC waste to energy project may be of interest.

Table 11 Potential funding opportunities for a renewable energy project at NCMC

Funding Program & Proponent	Eligibility Criteria and Assessment	Timing Constraints	Funding details	Recommended Actions and Traffic Light	Link or contact details
Jobs for NSW Department of Industry	• More than 30% of the $190 million Jobs for NSW fund will be invested under the Regional Jobs Now Portfolio to support the growth of businesses and jobs outside of metropolitan Sydney, Newcastle and Wollongong	• TBC	• Business loans or loan guarantees ($200k up to $5M) – various eligibility criteria	Contact Dept. of Industry to explore whether the proposed project may be eligible for funding support under the program.	Brendan Elliott, Client Engagement Advisor Department of Industry Ph. 02 9338 6604 https://www.jobsfornsw.com.au/funding/regional-support Dean Storchenegger, Snr Key Account Manager, Renewable Energy Department of Industry Ph 02 8222 4107
Growing Local Economies NSW Department of Premier and Cabinet	The Growing Local Economies fund is open to projects that: • have the capacity to deliver jobs and economic growth • help regional communities capitalise on their strengths or broaden and reposition their industry base • demonstrate benefits beyond one organisation • have a minimum project size of $1 million • align with state and	• Opened for submission of business cases (applications) on 17 August 2017. • The fund will remain open for applications until funding has been fully allocated (total fund value $500M).	• Min project value $1m • Unclear whether project will be eligible but worth exploring whether there is a pathway for support under this or another NSW Govt funding program supporting regional communities.	Contact Dept. of Industry to explore whether the proposed project may be eligible for funding support under the program. May be worth exploring whether the broader benefit of the proposed project is in securing ongoing employment in a regional community.	https://www.nsw.gov.au/improving-nsw/regional-nsw/regional-growth-fund/growing-local-economies/

Funding Program & Proponent	Eligibility Criteria and Assessment	Timing Constraints	Funding details	Recommended Actions and Traffic Light	Link or contact details
	regional priorities and achieve a Benefit to Cost Ratio greater than 1.0. • The Growing Local Economies fund targets public and common use infrastructure — for example, multiple electricity or gas connections on council land that can be used by businesses. • Projects that are on private land and have no clear public benefit, such as funding for construction of a new factory on private land, are ineligible.				
Innovation Fund *Clean Energy Finance Corporation (CEFC)*	• CEFC invests in: ○ Renewables (including **waste-to-energy**) and related technologies ○ Energy efficiency and related technologies • Some previously funded projects focused on **reductions in waste to landfill and waste-to-energy for industry**.	• None. • Can apply at any time. Extensive financial details and analysis of proposed project is required in submission to CEFC	• This is **not a grant** • CEFC instead provides loans at attractive rates (weighted average of the five-year Federal Gov. Bond Rate). • Amount of loan is case-by-case based on satisfactory assessment and due diligence of the proposal	Economic modelling to indicate if project can generate return. Submit proposal to CEFC.	https://www.cefc.com.au/submit-proposal/faqs.aspx#2279

Funding Program & Proponent	Eligibility Criteria and Assessment	Timing Constraints	Funding details	Recommended Actions and Traffic Light	Link or contact details
Emissions Reduction Fund (ERF) *Clean Energy Regulator (C'wealth Gov.)*	• The project appears to fit in the aim of the fund which is to reduce greenhouse gas emissions and account for the reduction using different methods • However, ACCUs may have to be generated using the 'Facilities Method' which requires the proponent to have submitted National Greenhouse and Energy Reporting (NGER) reports for the previous four years.	• Must be registered with Clean Energy Regulator (CER) prior to project delivery. • Proponent should not commit to the project or sign any contracts for execution until registered with the Regulator as this would disqualify the project.	• ERF is not a grant program; it does not provide upfront funding. Rather, the project must show that greenhouse gas emissions are lower than the original system (baseline) to earn Australian Carbon Credit Units (ACCUs) which can be sold. • Inclusion in the ERF is not allowed if other State or Federal Government funding is received. • Previous auction in Dec 2017 had an ACCU value of $13.08 per tonne of abatement.	Confirm eligibility of the project for either Facilities Method or Alternative Waste Treatment approach in discussions with the Regulator 	http://www.cleanenergyregulator.gov.au/ERF/About-the-Emissions-Reduction-Fund
Advancing Renewable Program *Australian Renewable Energy Agency (ARENA)*	• ARENA fund development of new technologies from early-stage research phase to pre-commercial phase. • Project is unlikely to be eligible unless it can be positioned as a 'demonstrator' or pilot-stage project which can be used to develop the	• Two stage application; i) Expression of interest; ii) Full Application. • EOI can be submitted at any time.	• ARENA does not fund activities that are commercially viable without ARENA support. • ARENA will only provide the minimum amount of funding to allow the Activity to proceed. • Grants are expected	Commercial viability of project to be confirmed. Engage with ARENA if project can be positioned as 'demonstrator' or 'trial' of a technology. 	https://arena.gov.au/funding/programs/advancing-renewables-program/

Funding Program & Proponent	Eligibility Criteria and Assessment	Timing Constraints	Funding details	Recommended Actions and Traffic Light	Link or contact details
	technology more widely. • Need to establish whether this aligns with the proponent's risk appetite and the choice of preferred technology		to be between $100,000 and $50 million with at least 50% matched funding by the Applicant.		

5 Conclusions and Recommendations

Based on the findings of the project, the following observations and conclusions were made:

1. Due to the limited waste characteristics and flow data in the abattoir and tannery facilities, the MLA published report in 2012 was heavily relied on to establish current mass flows. Mass flows that are representative of the actual operations are pertinent to ascertain mass loads and extend of energy recovery potential. The MLA 2012 data source adopted was considered broadly representative of the current operation due to the comprehensive sampling program undertaken.

2. A comparison of MLA 2012 waste characteristics and NCMC's quarterly sampling results indicated minor discrepancies in the organic loadings (within 10% range) which is likely attributed to an improved blood capture process diverted to rendering. Other waste parameters showed minor discrepancies, but overall was considered consistent and in agreement with one another. The consistency of data provided confidence in the reliability of MLA data source, which was subsequently adopted as the design basis for energy modelling.

3. Several plant improvements were made following MLA's sampling program in 2012. One major change was improvement of blood capture stream to rendering, which would most likely increase total rendering flow and organic loading. As a direct consequence, saveall float and mix effluent pit flows may be overestimated in this study (up to 10% based on assessment of the small available dataset), but this is not expected to significantly alter the findings of Homer Pro modelling.

4. Eight (8) different energy recovery options comprising liquid and solid wastes were considered. The options were categorised into two groups; biological and thermal processes. The biological process considers anaerobic digestion as the core process, whereas thermal process considers pyrolysis and gasification options.

5. Analysis of the biological scenarios identified the following biogas generation potential:

    a. Option 1a (all solid and liquid waste streams) has the potential to generate the largest amount of biogas at around 48,000m^3/day. A large proportion of biogas generation was derived from saveall float (52%) followed by saveall outlet (22%).The impact of including saveall float in Option 1a would result in a loss of tallow production and associated revenue. The lost revenue could not be totally off set by the energy produced from the biogas, although this depends heavily on tallow market value and electricity pricing.

    b. Option 1b (similar to Option 1a excluding saveall float) has the potential to generate around 22,500m^3/day of biogas, which is approximately half of Option 1a. This indicates that saveall float is a large contributor to biogas generation.

    c. Option 1c (only liquid stream) has the potential to generate around 15,400m^3/day of biogas. Saveall outlet is the major contributor (68%) of potential biogas generation from liquid wastes.

   d. Option 1d (only solid stream excluding saveall float) has the potential to generate around 8,000m^3/day of biogas.

   It was concluded that saveall float (solid waste) has the highest potential for biogas generation followed by saveall outlet (liquid waste), dewatered paunch (solid), EC influent (liquid), manure (solid), paunch screen effluent (liquid), cattle wash (liquid) and finally hair screenings (solid).

6. A high-level capital and operating cost assessment was performed for biological and thermal energy options. The assessment concluded that the thermal processes were uneconomic (in the context of this study). As a result, the thermal option was not further developed in this study.

7. The Homer Pro modelling undertaken provided the following findings:

   a. Capital and operation cost for options 1a and 1b are prohibitive in comparison to the energy saving that can be made from biogas generation.

   b. The amount of biogas produced from digesting all liquid and solid waste stream can supply electricity demand during peak period. Excess gas generated on average demand would either be flared or used to generate power to be sold to the grid, resulting in an overall low utilisation of biogas

   c. Grid power price, ability to generate revenue from renewable energy credits and export power prices are all pivotal variables when assessing the viability of the project. In option 1a and 1b, revenue generated from excess gas does not offset the high capital cost of these options.

   d. Option 1c presents the lowest NPC option and is the most viable option for the site.

   e. Based on Homer Pro modelling, addition electricity production from solar PV added to option 1c should be considered if grid electricity prices increase.

Based on the conclusions from this study, the following recommendations are made:

1. Additional flow monitoring and sampling be undertaken to confirm the design basis. The assessment presented in this study relied heavily on historical data and a directed sampling program should be undertaken to confirm the key assumptions made in this report.

2. Further design development of Option 1c should be undertaken to refine the capital cost for this option.

3. Following refinement of option 1c, further Homer Pro modelling should be conducted to identify a preferred sub-option

4. Develop a view of the movements of the electricity market (this is likely to be an internal NCMC process, such as business planning, discussions with energy retailers and discussions with specialist consultants). Similarly, NCMC should also develop a view on the future market for renewable energy certificates.

5. Explore the potential for a solar PV installation in close proximity to NCMC's operations in the event that grid prices increase (e.g. availability of land).

6. Further explore funding options to determine if alternative approaches to offset Capital investment are available.

6 Key messages

When considered from the broader perspective of the red meat industry as a whole, there were a number of key findings of this study that may be applicable to other producers. These are:

— It is possible to generate sufficient energy (electricity, heat and chilled water) from solid and liquid waste streams generated at a red meat processing facility to meet all site needs and progress to an "off-grid" operation. Export of energy may also be possible (electricity, heat or chilled water).

— The ability to achieve off-grid operation is sensitive to production rate, capital cost of infrastructure, cost of power (both existing and forecast), cost and type of feedstock for heat generation and revenue generated from the range of renewable energy certificate schemes (both existing and forecast).

— The implementation of solar PV for energy production may become a consideration as part of the energy mix for a site as power prices increase – this requires a site-specific assessment.

— Hurdle rates for project payback may need to exceed 7 years, although this may be shorter depending on local power (electricity, coal, gas etc.) prices and the view of the producer on the stability of the renewable energy certificate market.

— The adoption of biogas production technologies leads to a new suite of health, safety and environment risks that need to be considered as part of a robust project implementation.

— Consideration of the processing on site (e.g. slaughter, boning, rendering, further processing, tanning, cold storage etc.) and location of the facility and other sources of biomass, can offer other opportunities that will make these facilities more viable

— Support from Commonwealth and State governments may offset capital costs and reduce payback periods

— A renewable energy options assessment model has been developed that can be applied to other red meat production facilities.

7 Bibliography

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Jensen and Batstone, September 2013, A.ENV.0151. *NGERS and wastewater management – mapping waste streams and quantifying the impacts*, MLA

Bridle and Poad, February 2013*, NCMC Abattoir and Tannery Wastewater Upgrade – Design Review*, GHD

Heusser, September 2017, *Reviewing on-plant waste stream biomass co-digestion options and identifying technologies for optimum mixing, co-digestion and reuse*, GHD

8 Appendix

8.1 Data Collation and Gap Analysis

RFI REGISTER

PROJECT NO. **41/31242**

CLIENT **NORTHERN CO-OP MEAT COMPANY LIMITED**

PROJECT **ENERGY AND WASTEWATER OPTIONS ASSESSMENT**

DATE **Updated 6/12/17**

RFI Summary	
Open	0
Closed	28
Total	28

REFERENCE NO.	TYPE	RAISED BY	ASSIGNED TO	DATE RAISED	RESPONSE REQUIRED BY	DESCRIPTION	IMPORTANCE OF INFORMATION	DISCIPLINE	CATEGORY	RESPONDANT	DATE REPLY RECEIVED	RESULT IN VARIATION (Y/N)	VARIATION VALUE	STATUS	SUITABILITY OF INFORMATION PROVIDED
RFI-001	Request for Information (RFI)	GHD	NCMC	16-Oct-17	20-Oct-17	Abattoir and tannery: wastewater and effluent flow and quality data (last 2-4 years) in the format and with the information available as per RFI description. Raw data in Excel spreadsheet format.	Essential	Process	Information Required	Uploaded 27-10-17. 22/11/17 - With regards to the Treated Effluent spreadsheet, you should refer to the “1 Pass Iron” column for the expected EC effluent quality.	27-Oct-17			Closed	The data provided for abattoir wastewater (liquid stream) is currently sufficient to proceed with the next task, pending a few clarifications. There were 4 sampling results provided for abattoir wastewater. This would be supplemented with data from detailed sampling conducted by UQ in 2012. Inovin's clarification provided 27/11/17.

RFI-002	Request for Information (RFI)	GHD	NCMC	16-Oct-17	20-Oct-17	Abattoir and tannery wastewater treatment solid-stream quality/quantity (last 2-4 years) (e.g. wet-tonne/annum and %total solids for screenings, sludge, paunch waste, manure and FOG)	Essential	Process	Information Required	We have no data for Bobcat sweeper,as they are not using it now.The paunch material is 960wet-tonne/annum	10-Nov-17		Closed	Hair analysis, paunch, screenings and compost provided. GHD will need to use some data from previous MLA/UQ studies, particularly for solids loadings that could be used for energy production.
RFI-003	Request for Information (RFI)	GHD	NCMC	16-Oct-17	20-Oct-17	MLA report prepared by AWMC (Paul Jensen and Marie-Louise Pype) comparing 5 abattiors (Cassino being one of them).	Essential	Process	Information Required	Advised that Chris Hertle - GHD was obtaining data.			Closed	AWMC have provided the report to us, noting that Site D refers to the Casino plant. A copy of the report has been provided to NCMC.
RFI-004	Request for Information (RFI)	GHD	NCMC	16-Oct-17	20-Oct-17	Provide list of dates for plant changes/upgrades for reference.	Essential	Process	Information Required	Uploaded 03-11-17	03-Nov-17		Closed	We require further clarification to close this RFI. Clarification provided 27/11/17
RFI-005	Request for Information (RFI)	GHD	NCMC	16-Oct-17	20-Oct-17	Results of sampling recently conducted on site by AWMC.	Essential	Process	Information Required	Advised that - GHD was obtaining this data.			Closed	GHD have received all available information from AWMC.
RFI-006	Request for Information (RFI)	GHD	NCMC	16-Oct-17	20-Oct-17	Abattoir kill numbers and imported waste volumes (last 2 -4 years)	Essential	Process	Information Required	Uploaded 03-11-17 and 27-11-17	27-Nov-17		Closed	Daily kill numbers provided 27/11/17 No imported waste volumes
RFI-007	Request for Information (RFI)	GHD	NCMC	16-Oct-17	20-Oct-17	Tannery fleshed masses (last 2 -4 years)	Essential	Process	Information Required	Uploaded 03-11-17	03-Nov-17		Closed	Tannery fleshed values by the week. Sufficient to commence analysis.

RFI-008	Request for Information (RFI)	GHD	NCMC	16-Oct-17	20-Oct-17	Vendor proposals provided to NCMC	Essential	Process	Information Required	Uploaded 03-11-17	03-Nov-17		Closed	Sufficient to commence analysis.
RFI-009	Request for Information (RFI)	GHD	NCMC	16-Oct-17	20-Oct-17	Most recent abattoir and tannery wastewater treatment process flow diagrams and piping & instrumentation diagrams where available	Essential	Process	Information Required	Uploaded 03-11-17	03-Nov-17		Closed	Sufficient to commence analysis.
RFI-010	Request for Information (RFI)	GHD	NCMC	16-Oct-17	20-Oct-17	Most recent site plans for abattoir and tannery water, wastewater and stormwater infrastructure	Essential	Process	Information Required	Uploaded 03-11-17	03-Nov-17		Closed	Irrigation and dam location shown. Sufficient to commence analysis.
RFI-011	Request for Information (RFI)	GHD	NCMC	16-Oct-17	20-Oct-17	Applicable licensing requirements, EPA permits	Essential	Process	Information Required	Uploaded 27-10-17	27-Oct-17		Closed	Sufficient to commence analysis.
RFI-012	Request for Information (RFI)	GHD	NCMC	16-Oct-17	20-Oct-17	Most recent plant layout drawing, aerial photos of factory and irrigation areas	Essential	Process	Information Required	Uploaded 03-11-17	03-Nov-17		Closed	Irrigation and dam location shown. Sufficient to commence analysis.
RFI-013	Request for Information (RFI)	GHD	NCMC	16-Oct-17	20-Oct-17	Indicative daily and weekly operating schedule for abattoir, tannery and wastewater treatment	Not Critical	Process	Information Required	Uploaded 03-11-17	03-Nov-17		Closed	Sufficient to commence analysis.
RFI-014	Request for Information (RFI)	GHD	NCMC	16-Oct-17	20-Oct-17	Any previous and relevant studies conducted on the abattoir, tannery, wastewater treatment plant, and irrigation sites	Essential	Process	Information Required	Uploaded 03-11-17	03-Nov-17		Closed	Sufficient to commence analysis.
RFI-015	Request for Information (RFI)	GHD	NCMC	16-Oct-17	20-Oct-17	List of equipment changes/upgrades and date of change	Essential	Process	Information Required	Uploaded 03-11-17	03-Nov-17		Closed	Sufficient to commence analysis.

RFI-016	Request for Information (RFI)	GHD	NCMC	16-Oct-17	20-Oct-17	Any process constraints, including: - Operating and capital budget - Footprint - Product quality requirements - Corporate environmental, quality, food safety legislations and safety policies	Essential	Process	Information Required	Refer to RFI -012& RFI -014 (These files have been uploaded to RFI-016.) 03-11-17	03-Nov-17		Closed	Sufficient to commence analysis.
RFI-017	Request for Information (RFI)	GHD	NCMC	16-Oct-17	20-Oct-17	Relevant information on current and proposed irrigated areas, including reports and irrigation practice	Not Critical	Process	Information Required	Refer RFI-012 (File has been uploaded to RFI-017) 03-11-17	03-Nov-17		Closed	Sufficient to commence analysis.
RFI-018	Request for Information (RFI)	GHD	NCMC	16-Oct-17	20-Oct-17	Irrigation modelling	Not Critical	Process	Information Required	Refer RFI-012 (File has been uploaded to RFI-018) -03-11-17	03-Nov-17		Closed	Sufficient to commence analysis.
RFI-019	Request for Information (RFI)	GHD	NCMC	16-Oct-17	20-Oct-17	Any data for current soil condition and contours	Not Critical	Process	Information Required	Uploaded 03-11-17	03-Nov-17		Closed	Sufficient to commence analysis.
RFI-020	Request for Information (RFI)	GHD	NCMC	16-Oct-17	20-Oct-17	Abattoir and tannery power consumption data (meter/monthly bills)	Essential	Power and Electrical	Information Required	Uploaded 27-10-17	27-Oct-17		Closed	Sufficient to commence analysis.
RFI-021	Request for Information (RFI)	GHD	NCMC	16-Oct-17	20-Oct-17	Current fuel prices and consumption	Essential	Power and Electrical	Information Required	Uploaded 03-11-17	03-Nov-17		Closed	Sufficient to commence analysis.
RFI-022	Request for Information (RFI)	GHD	NCMC	16-Oct-17	20-Oct-17	Electricity prices (rate/tariffs, timing of different rates (if applicable))	Essential	Power and Electrical	Information Required	Uploaded 27-10-17	27-Oct-17		Closed	Sufficient to commence analysis.
RFI-023	Request for Information (RFI)	GHD	NCMC	16-Oct-17	20-Oct-17	Electricity load profile (hour-by-hour over a typical year is preferable)	Essential	Power and Electrical	Information Required	Uploaded 03-11-17	03-Nov-17		Closed	Sufficient to commence analysis.

RFI-024	Request for Information (RFI)	GHD	NCMC	16-Oct-17	20-Oct-17	Heat/steam/chilling and freezing demand	Essential	Power and Electrical	Information Required	Uploaded 10-11-17	10-Nov-17	Closed	Sufficient to commence analysis.
RFI-025	Request for Information (RFI)	GHD	NCMC	16-Oct-17	20-Oct-17	Existing system arrangement (boiler, heat/steam flows, biomass/biogas flow rates)	Essential	Power and Electrical	Information Required	Uploaded 10-11-17	10-Nov-17	Closed	Sufficient to commence analysis.
RFI-026	Request for Information (RFI)	GHD	NCMC	16-Oct-17	20-Oct-17	Discount rate to be used for economic comparison (Homer software determines lowest NPC option)	Essential	Power and Electrical	Information Required	Advised that Chris Hertle - GHD was obtaining data.		Closed	GHD will nominate a discount rate. Rate can be changed to suit during NPV analysis.
RFI-027	Request for Information (RFI)	GHD	NCMC	16-Oct-17	20-Oct-17	Any previous and relevant studies conducted on renewable energy generation on the site	Essential	Power and Electrical	Information Required	Uploaded 03-11-17	03-Nov-17	Closed	Sufficient to commence analysis.
RFI-028	Request for Information (RFI)	GHD	NCMC	16-Nov-17	23-Nov-17	Single Line Drawings (SLD) of the entire plant	Essential	Power and Electrical	Information Required		28-Nov-17	Closed	Sufficient to commence analysis.

8.2 Mass Flows

8.2.1 Abattoir Stream Compositions and Daily Mass Flows

Table 12 Abattoir Stream Composition

Stream ID		2	3		4	5	6	7	8	9	10	11	13	14	15	17	18	19	20	21	22	23	24
Stream Name		**Paunch Screw Press Inlet**	**Paunch Screened Effluent**		**Paunch Dewatered Solids**	**Rendering Waste**	**Veal Room Waste**	**Slaughter and Offal Waste**	**Combined Red Stream (upstream of rotating drum)**	**Saveall Inlet**	**Saveall Outlet**	**Saveall Float (rendering)**	**Cattle Wash Inlet**	**Cattle Wash Effluent**	**Manure**	**Mix Pit Effluent**	**Dam 3 Effluent**	**Dam 1 Effluent**	**Dam 2 Effluent**	**Storage Dam 4 Effluent**	**Storage Dam 5 Effluent**	**Storage Dam 6 Effluent**	**Storage Dam 7 Effluent**
Source of data		a	a		a	a	a	a	a	a	a	b	a	a	a	b	c	c	c	c	c	c	c
Flow	kL/day	549	516		33.3	1,092	1,316	1,984	4,392	4,392	4,228	164	1,098	1,029	69.2	5,903							
Temp	deg C	33	34			39 - 46	31	37	38		36		21	19		31							
pH																							
TCOD	mg/L	12,190	5,420		12,190	35,560	14,120	2,210	14,072	12,790	8,020	127,613	11,070	1,800	89,530	6,531	131	195	212	211	219	122	99
SCOD	mg/L	920	850			12,108	2,270	1,220	4,242	2,790	3,010		400	250		2,274							
O&G	mg/L	142	194		1,095	7,631	4	325	2,045	3,300	978	62,121	82	10	380	719	10	11	11	5	3	3	6
VS	mg/L	12,897	4,370		236,615	20,954	8,942	2,245	8,904	7,830	3,439	117,474	7,940	1,361	136,101	3,082							
TS	mg/L	15,123	4,753		249,383	24,176	9,335	2,630	9,997	9,264	4,031	140,000	9,828	1,979	155,983	3,647	762	139	18	63	74	44	52
TKN	mg/L	266	243		776	1,598	294	154	555	420	402	482	356	129	1,922	332	382	226	200	141	97	143	119
NH3-N	mg/L	18	13			143	26	5	46	27	38	-294	86	87		44							
TP	mg/L	99	88			69	15	3	23	19	33	-375	29	9		33	21	21	20	11	11	11	10
Conductivity	mS/cm																						
Sodium	mg/L										131				5773								
Calcium	mg/L																						
Magnesium	mg/L																						
Chloride	mg/L																						
Chromium	mg/L																						

Notes:

a MLA, NGERS and Wastewater Management – mapping waste streams and quantifying the impacts (A.ENV.0151)

b Calculated value

c Calculated from dam water quality data provided by NCMC

Table 13 Abattoir Mass Flow

Stream ID		2	3	4	5	6	7	8	9	10	11	13	14	15	17	18	19	20	21	22	23	24
Stream Name		**Paunch Screw Press Inlet**	**Paunch Screened Effluent**	**Paunch Dewatered Solids**	**Rendering Waste**	**Veal Room Waste**	**Slaughter and Offal Waste**	**Combined Red Stream (upstream of rotating drum)**	**Saveall Inlet**	**Saveall Outlet**	**Saveall Float (rendering)**	**Cattle Wash Inlet**	**Cattle Wash Effluent**	**Manure**	**Mix Pit Effluent**	**Dam 3 Effluent**	**Dam 1 Effluent**	**Dam 2 Effluent**	**Storage Dam 4 Effluent**	**Storage Dam 5 Effluent**	**Storage Dam 6 Effluent**	**Storage Dam 7 Effluent**
Source of data		a	a	a	a	a	a	a	a	a	b	a	a	a	b	c	c	c	c	c	c	c
TCOD	kg/d	6,693	2,795	406	38,836	18,589	4,384	61,809	56,176	33,909	20,951	12,155	1,852	6,194	38,556	48						
SCOD	kg/d	505	438		13,224	2,988	2,420	18,632	12,254	12,726		439	257		13,422							
O&G	kg/d	78	100	36	8,334	5	645	8,984	14,494	4,135	10,199	90	10	26	4,245	4						
VS	kg/d	7,081	2,254	7,878	22,885	11,772	4,453	39,110	34,391	14,540	19,286	8,718	1,400	9,416	18,194							
TS	kg/d	8,303	2,451	8,303	26,403	12,289	5,217	43,909	40,689	17,043	22,984	10,792	2,036	10,792	21,530	278						
TKN	kg/d	146	125	26	17,46	387	305	2,438	1,845	1,700	79	391	133	133	1,958	139						
NH3-N	kg/d	10	7		156	34	10	200	119	161	-48	94	90		257							
TP	kg/d	54	45		75	20	6	101	83	140	-61	32	9		194	8						
Sodium	kg/d									72				3,169								
Calcium	kg/d																					
Magnesium	kg/d									553			135									
Chloride	kg/d																					
Chromium	kg/d																					

Notes:

a MLA, NGERS and Wastewater Management – mapping waste streams and quantifying the impacts (A.ENV.0151)

b Calculated value

c Calculated from dam water quality data provided by NCMC

8.2.2 Tannery Stream Compositions and Daily Mass Flows

Table 14 Tannery Steam Composition

Stream ID		34	37	42	43/44	45	46	48
Stream Name		**Tannery wastewater**	**EC Influent**	**EC Effluent**	**EC Sludge**	**Effluent after V-Fold**	**V-fold sludge**	**Hair sludge**
Source of data		a	a	a	a	b	a	c
Flow	kL/day	1,000	1,111	1,000				
Temp	deg C							
pH		7.5	9.4	8.92	7.5			
TCOD	mg/L	28,755	9,600	3,600				
SCOD	mg/L							
O&G	mg/L	2,778	923	8				
VS	mg/L	5,763	5,763					
TS	mg/L	6,403	6,403	55				
TKN	mg/L		809	407				
NH3-N	mg/L		281	226	150	120		
TP	mg/L	64	11.8	1.5				
Conductivity	mS/cm	13,100	15.4	19				
Sodium	mg/L		2,721	3,806				
Calcium	mg/L		330	181				
Magnesium	mg/L		115	61				
Chloride	mg/L		2,339	3,917				
Chromium	mg/L		3.2	0.016	1,200	960		59

Notes:

a Inovin data

b Calculated by assuming 20% removal rate across V-fold

c Data provided by NCMC

Table 15 Tannery Mass Flow

Stream ID		34	37	42	43/44	45	46	48
Stream Name		**Tannery wastewater**	**EC Influent**	**EC Effluent**	**EC Sludge**	**Effluent after V-Fold**	**V-fold sludge**	**Hair sludge**
Source of data		a	a	a	a	b	a	c
TCOD	kg/d	28,755	10,667	3,600				
SCOD	kg/d							
O&G	kg/d	2,778	1026	8				
VS	kg/d	5,763	6,403				4,613	652
TS	kg/d	6,403	7,114	55			5,125	725
TKN	kg/d		899	407				
NH3-N	kg/d		312	226				
TP	kg/d	64	13	1.5				
Sodium	kg/d	13,100	3,023	3,806				
Calcium	kg/d		367	181				
Magnesium	kg/d		128	61				
Chloride	kg/d		2,599	3,917				
Chromium	kg/d		3.6	0.02				

Notes:

a Inovin data

b Calculated by assuming 20% removal rate across V-fold

c Data provided by NCMC