FINAL REPORT

AUSTRALIAN MEAT PROCESSOR CORPORATION

Use of Paunch Waste as a Boiler Fuel

Project codes:	A.ENV.0110 A.ENV.0120 A.ENV.0121 A.ENV.0122 A.ENV.0123
Prepared by:	Trevor Bridle
Date Submitted:	August 2011

final report

Project code: A.ENV.0110
A.ENV.0120
A.ENV.0121
A.ENV.0122
A.ENV.0123

Prepared by: Trevor Bridle

Bridle Consulting

Date submitted: August 2011

Date published: August 2011

PUBLISHED BY
Meat & Livestock Australia Limited
Locked Bag 991
NORTH SYDNEY NSW 2059

Use of paunch waste as a boiler fuel

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Abstract

The prime objective of this project was to conduct a full-scale technical, commercial and environmental assessment of dewatered paunch waste co-combustion, using the existing sawdust-fired boiler at the Nippon Meat Packers abattoir in Wingham, NSW. The results from this paunch waste co-combustion trial strongly support this method for management of dewatered paunch waste at abattoirs that already have boilers suitable for co-combustion of dewatered paunch waste. Due to the significant economic advantages of dewatered paunch waste co-combustion it is very likely that many abattoirs with boilers suitable to co-combust dewatered paunch waste will proceed with this practise as soon as is practical. Even if boilers suitable for biomass-firing need to be installed, the economics of such a retrofit looks attractive. Only minor environmental impacts were noted during this paunch waste co-combustion trial.

Executive summary

Currently most abattoirs dispose of their paunch waste via either composting or land disposal. The current disposal methods can incur disposal fees, particularly if landfilling is practiced. Co-combustion of mechanically dewatered paunch waste in boilers, if proved to be technically practical, is most likely to demonstrate reduced disposal costs with potential GHG benefits to the industry. This project has been designed to provide this much needed information for the red meat industry. Consequently, the prime objective of this project was to conduct a full-scale technical, commercial and environmental assessment of dewatered paunch waste co-combustion, using the existing sawdust-fired boiler at the Nippon Meat Packers abattoir in Wingham, NSW.

This project was successful in achieving all of the objectives as outlined in the original scope of works. Both the control and co-combustion trials generated very good mass and energy balance data which allowed the process and environmental impacts of paunch waste co-combustion to be rigorously assessed. The cost benefit analysis was successfully completed and showed that co-combustion of dewatered paunch waste is an attractive commercial proposition.

Based on the outcomes of this full-scale dewatered paunch waste co-combustion trial the following conclusions are drawn:

1. There was no impact on boiler combustion performance when co-fired with 5% of its energy input as dewatered paunch waste, with a TS of 30%.
2. At this co-firing rate there were minor environmental impacts, the notable ones being increases in atmospheric emissions of CO, NOx and SOx. Whilst the mass emission rates for NOx and SOx doubled, the stack gas concentrations were still well within regulatory guidelines. The higher CO emission was a result of operating at higher than the design rating of the boiler, with the result that oxygen-limiting combustion occurred.
3. Co-firing with 5% of the boiler input energy being derived from dewatered paunch waste tripled the ash generation rate. There was no significant difference in ash quality when the boiler was co-fired with dewatered paunch waste.
4. The GHG impacts of co-combustion of dewatered paunch waste, were in this case neutral, since the paunch waste replaced another renewable energy fuel, namely sawdust. Had the boiler been fired with a fossil fuel, then GHG credits would apply. In addition, if the paunch waste was previously disposed via landfill, then additional GHG credits would likely apply due to avoided methane emissions from landfill operations. Calculation of potential GHG credits can only be done for specific operational scenarios.
5. Typical paunch waste generation rates at abattoirs indicate that up to 30% of boiler fuel requirements could be derived from the dewatered paunch waste. Co-firing of boilers at this rate could have more significant operational and environmental impacts.
6. Co-firing of dewatered paunch waste in existing boilers suitable for this duty offers a very attractive disposal option compared to existing methods such as landfilling or composting. It has been estimated that for a 600 to 700 head per day abattoir, the net economic benefit, over a 20-year period, is $1.58 million. In addition the payback period on the required capital investment is only 0.7 years.
7. Replacing existing coal-fired boilers with boilers suitable to co-fire biomass and paunch waste appears to offer long-term economic benefits. While the initial return on the capital investment does not meet the typical industry requirement of 3 years (it is 4 years), the net economic benefit, over a 20-year period, for a 600 to 700 head per day abattoir, is estimated at $2.85 million.

Since this co-combustion trial did not fire the boiler with dewatered paunch waste at a rate commensurate with its generation rate, it is recommended that the paunch waste plus DAF sludge co-combustion trial scheduled to take place later this financial year be conducted at a firing rate commensurate with the waste production rates. This will confirm if any adverse environmental impacts are evident at this waste firing rate.

It is also recommended that MLA explore in more detail the Build-Own-Operate project delivery method for contracts at abattoirs to supply of steam via privatised co-combustion systems. This may be particularly attractive when considering replacing coal-fired boilers with biomass-fired boilers which can co-fire dewatered paunch waste.

Contents

1 Background

MLA has undertaken numerous studies in the past to assess the potential for energy recovery from abattoir solid wastes via thermal processing such as co-combustion in boilers. A previous MLA project[1] confirmed that if paunch waste can be mechanically dewatered to a TS of 30% that it would combust autogenously in a boiler (that is, not require any external thermal energy for combustion). That study recommended full scale co-combustion trials be conducted to confirm the potential benefits offered via this waste disposal method. That study also indicated that processing of paunch waste via pyrolysis or gasification requires that the feedstock be thermally dried prior to thermal treatment and that the costs for these thermal disposal options are likely to range between $65 and $90 per dry tonne. Co-combustion in boilers is likely to provide a more attractive disposal option, based purely on cost considerations. Currently most abattoirs dispose of their paunch waste, after washing and screening, via either composting or land disposal. Typically the processed paunch waste has a TS of about 20%, or a water content of 80%. The current disposal methods can incur disposal fees, particularly if landfilling is practiced. Co-combustion of mechanically dewatered paunch waste in boilers, if proved to be technically practical, is most likely to demonstrate reduced disposal costs with potential GHG benefits to the industry. To further support this project it is known that the JBS Swift abattoir in Longford, Tasmania does co-combust paunch waste in their boiler but there is no documented evidence that this is cost effective and no data on the environmental impacts are available. This project has been designed to provide this much needed information for the red meat industry.

2 Project objectives

The prime objective of this project is to conduct a full-scale technical, commercial and environmental assessment of paunch waste co-combustion in the existing boiler at the Nippon Meat Packers abattoir in Wingham, NSW. This boiler is currently fired with sawdust as the primary fuel. The major objectives of this project are thus to develop a technically sound and robust assessment of the economic benefits and environmental impacts of co-combustion of dewatered paunch waste in boilers. Well controlled and monitored combustion trials will be undertaken when feeding only sawdust as the fuel and then co-combusting sawdust and paunch waste in the Wingham boiler. The project will deliver the following outputs:

- Engineering sound mass and energy balances for each of the two controlled combustion trials. This is designed to confirm that co-combustion of dewatered paunch waste delivers energy and GHG benefits to the industry.
- Confirmation that there are no operational issues with co-firing of dewatered paunch waste in boilers.
- Confirmation of the impact, if any, on flue-gas quality, as a result of co-firing of paunch waste in the boiler.
- Confirmation of the impact, if any, on the ash quality and quantity, as a result of co-firing paunch waste in the boiler.
- Development of a cost-benefit analysis of co-combustion of dewatered paunch waste in boilers.

[1] MLA, "Pilot Testing Pyrolysis Systems and Review of Solid Waste Use in Boilers", Project A.ENV.0111, 2011.

3 Methodology

The existing boiler at the Wingham Beef Exports (WBE) abattoir, supplied by Steam Systems Pty Ltd of Victoria, was used for this paunch waste co-combustion trial. This boiler can be described as a hydraulically fed sloping grate boiler and the design is proprietary to Steam Systems P/L. The primary fuel for this boiler is sawdust. WBE had recently installed a FAN screw press to mechanically dewater their paunch waste and they had reported that the TS of the dewatered paunch waste was about 50%. For this trial WBE installed a temporary dewatered paunch waste storage and feed system, which allowed co-firing of the boiler with the primary fuel, sawdust.

Steam Systems were contracted to supervise this co-firing combustion trial at WBE. The plan was to operate the boiler at as steady a firing rate as possible, close to the design steam output of 6 tph. The boiler operational parameters were to be monitored, via the CITECT SCADA system installed on the boiler, during the nominal 2-hour steady-state period when firing only sawdust and then when co-firing with dewatered paunch waste. Feed and ash characterisation was to be conducted by taking samples during these steady-state trials. Three samples of sawdust and ash from the boiler were collected during the first steady state trial and then for the co-firing trial, three samples of paunch waste and ash were again collected, for subsequent analysis by Australian Laboratory Services.

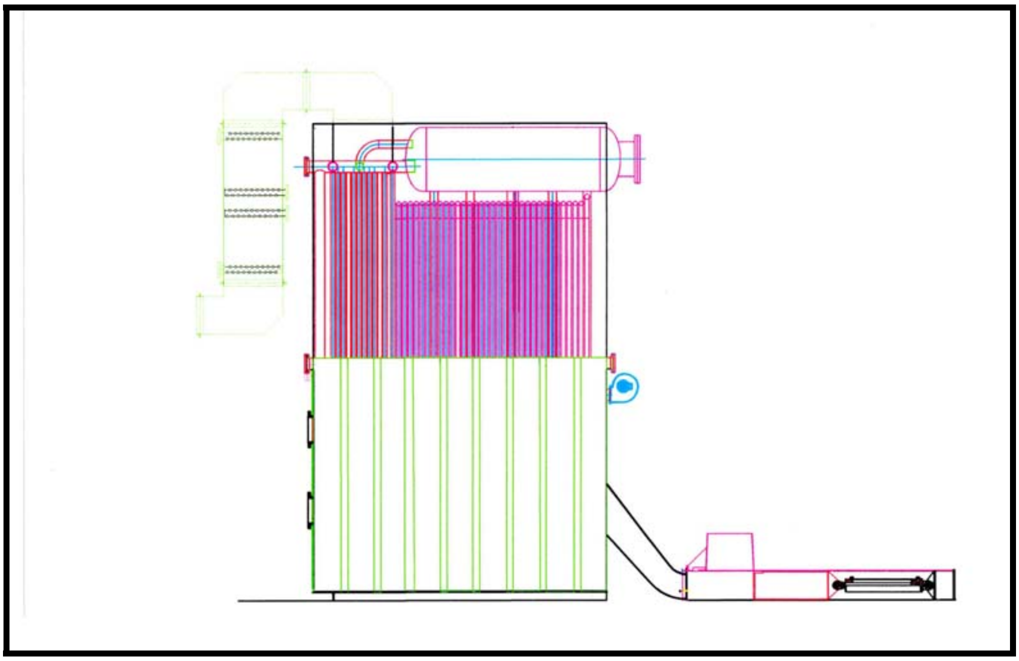
Stack emissions from the boiler were monitored and sampled by Emission Testing Consultants (ETC) Pty Ltd of Melbourne, Victoria. About 90 minutes was required during each steady-state trial to complete the stack sampling and analysis by ETC.

4 Results and discussion

4.1 Boiler details

The boiler at WBE was supplied by Steam Systems Pty Ltd of Victoria. It is designed to combust sawdust as its primary fuel and has a nominal steam output of 6 tph at a pressure of about 6 bar and temperature of about 160 ^{0}C. The boiler is fitted with two economisers to improve energy efficiency. Typically the boiler combusts about 2.5 tph of sawdust, at a nominal TS of 60%. Typically temperatures in the primary combustion zone (just above the grate) are about 650 ^{0}C and in the secondary combustion zone, where additional secondary air is provided, about 840 ^{0}C. Stack temperatures generally are between 115 and 125 ^{0}C. Ash is removed automatically from the bottom-end of the grate. Sawdust is fed automatically onto the grate, via a hydraulic ram feed system. The cycle-time of ram operations can be adjusted to provide the required fuel feed rate. A schematic of the boiler is shown in Figure 4.1.

Figure 4.1: Schematic of the Wingham boiler



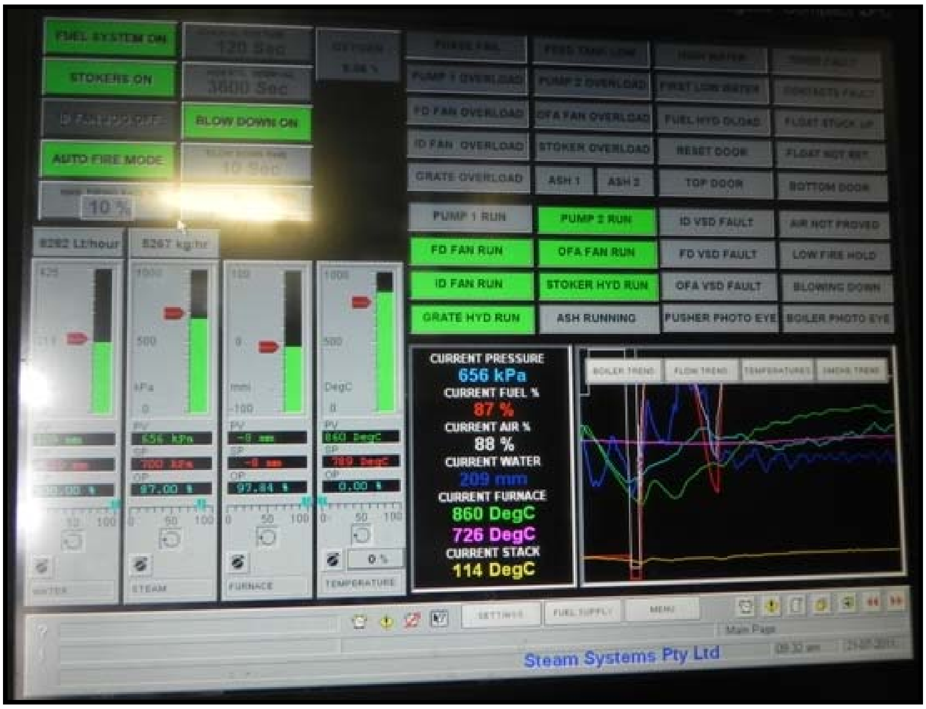
Pictures of the boiler are shown in Figures 4.2 and 4.3 below.

Figure 4.2: Wingham boiler pictures

Sawdust feed conveyor system

Boiler with inspection doors

Figure 4.3: Wingham boiler CITECT screen picture



The sawdust feed picture in Figure 4.2 shows the material being elevated into the small bin from which the hydraulic ram feeds the material onto the top of the grate, via the rectangular feed chute shown in the top-right of the picture. The second picture in Figure 4.2 shows the end of the boiler, at the ash discharge end of the furnace. The two inspection hatches can readily be seen in this picture. The lower inspection hatch has a sight glass from which one can view inside the furnace and see the fuel combusting on the grate. Figure 4.3 shows a snap-shot of the CITECT screen provided with the boiler. This was taken at 9:30 am on the day of the trial (July 21st, 2011), during the control sawdust combustion trial. As can be seen the boiler pressure was 656 kPa, fuel firing rate was 87% and the primary/secondary furnace temperatures were 726 and 860 ^{0}C respectively. Finally, the stack temperature was 114 ^{0}C.

4.2 Temporary paunch waste storage and feed system

WBE installed a temporary paunch waste storage and feed system for these trials. This included a steel hopper with an out loading screw conveyor and bin vibrator to minimise rat-holing in the hopper. A variable feed screw conveyor then transferred the paunch waste to the small feed bin, above the hydraulic ram which feeds the fuel into the furnace. A picture of the feed hopper and the variable speed feed screw conveyor, as well as one showing the small bin above the hydraulic ram, are shown in Figure 4.4.

Figure 4.4: Temporary paunch waste feed system pictures

Hopper and feed screw

Paunch waste and sawdust feed to boiler

The paunch waste feed screw was pre-calibrated by WBE and set to a feedrate commensurate with their dewatered paunch waste production rate. As can be seen from the picture on the right in Figure 4.4 the sawdust and dewatered paunch waste are delivered to a small hopper above the hydraulic ram feeder. Feed to this bin is controlled by a level indicator in the bin. The hydraulic ram feeds equal volume batches of material into the furnace, based on a timer system.

4.3 Fuel characteristics

Since feed control to the furnace is controlled volumetrically, it was important, for this set of trials, to know the bulk density of both the sawdust and the dewatered paunch waste. These were measured on the day of testing using a 1 L vessel and slightly tapping the contents to simulate the slight compression that the feed material undergoes in the ram. Four replicate values were obtained for each fuel and the average of these values used to calculate mass loadings to the boiler. The results of these bulk density measurements are shown in Table 4.1.

Table 4.1: Fuel bulk density values (kg/m^3)

Sample	Sawdust	Grass-fed Paunch Waste	Grain-fed Paunch Waste
1	379	261	282
2	391	224	303
3	378	270	257
4	390	307	248
AVERAGE	**385**	**266**	**273**

Due to test constraints only one type of paunch waste could be tested. In concert with WBE staff it was decided to use the grass-fed paunch waste as this is the predominate class of paunch waste produced by the red meat industry in Australia.

The sawdust and grass-fed paunch waste were analysed, in triplicate, by Australian Laboratory Services (ALS). The average value results of these analyses are shown in Table 4.2. The detailed analytical reports prepared by ALS are shown in Appendix 8.1.

Table 4.2: Fuel characteristics

Parameter	Units	Average Sawdust Value	Average Grass-fed Paunch Waste Value
TS	%	58.6	30.5
Ash	% of TS	0.4	7.7
Carbon	% of TS	50.6	47.25
Hydrogen	% of TS	5.51	5.4
Nitrogen	% of TS	0.09	1.28
Oxygen	% of TS	43.19	38.23
Sulphur	% of TS	0.06	0.21
Gross Calorific Value	GJ/dry tonne	16.1	15.6
Net Calorific Value	GJ/dry tonne	14.9	14.4
Aluminium	mg/kg	<50	160
Calcium	mg/kg	67	3801
Iron	mg/kg	113	577
Chromium	mg/kg	0.37	0.7
Copper	mg/kg	0.63	6.2
Lead	mg/kg	0.13	0.3
Zinc	mg/kg	1.43	57.3

The total solids values for the two fuels were lower than what were expected. It was expected that the saw dust TS value would be about 80% and the paunch waste TS would be at least 35%, since this is the value that would be expected from a well operated screw press. The ash contents of the two fuels were as expected, with the paunch waste ash content being about 20 times higher than the sawdust value. This will increase the amount of ash produced from the boiler when paunch waste is co-combusted. The paunch waste GCV value was lower than that measured for paunch waste from the Oakey abattoir[1]. As can be seen the paunch waste has higher levels of nitrogen and sulphur than the sawdust which could have an impact on NOx and SOx emissions from the boiler when co-combusting paunch waste. The triplicate calorific values for the fuels were consistent and the average values reported in Table 4.2 are considered reasonable, if somewhat lower than what were expected. It must be mentioned that the dewatered paunch waste had been stored in 1 m^3 bins for quite a few days prior to the combustion trial and it was noticed that composting was occurring in these bins (as evidenced by elevated material temperatures). This could have reduced the energy content of the paunch waste, but based on the high volatile solids content (92.3%) this appears not to be likely.

The paunch waste has significantly higher levels of metals such as aluminium, calcium and iron compared to sawdust. The levels of copper and zinc are also significantly higher in the paunch waste than the sawdust, up to 40 times higher. However, by other waste standards, such as sewage sludge and MSW, the levels of these heavy metals are very low.

4.4 Feed rate control system

As indicated previously, the feed rate into the boiler is controlled by a hydraulic ram, which pushes a constant volume of feed into the boiler at a controllable frequency rate. The volume of each hydraulic ram push is 0.1764 m^3 (1 metre by 360 mm by 490 mm). The frequency of ram pushes can be varied to control the feed rate, expressed as Feed Rate Percent. During these trials the Feed Rate varied from 87 % to 100 %. At a Feed Rate setting of 87%, there are 36 ram pushes per hour which increase to 48 pushes per hour at 100%. Four Feed Rate settings were used during the trials and the volumetric feed rates for these four settings are shown in Table 4.3.

Table 4.3: Feed rate setting data

Feed Rate Setting (%)	Pushes per hour	Volumetric Feed Rate (m^3/h)
87	36	6.350
92	40.7	7.179
97	45.5	8.026
100	48	8.467

4.5 Control combustion trial results

This trial was conducted as a control, feeding only sawdust as the fuel. The entire trial was done at a Feed Rate setting of 87%, which equates to a sawdust feed rate of 6.35 m^3/h. Based on the measured bulk density of the sawdust, the feed rate was 2.445 tonnes per hour. The trial commenced at 9:00 am and was completed at 10:30 am. Boiler operating conditions and performance data was averaged during this time frame, using the “averaging” function on the CITECT SCADA control panel.

4.5.1 Combustion performance

The combustion performance and thermal efficiency of the boiler was assessed by comparing the measured thermal input energy to the furnace to the steam output, as recorded on the CITECT SCADA system. The input thermal energy is based on the measured sawdust feedrate and its total solids and energy content, as measured by ALS. For energy input calculations the net calorific values were used. The steam enthalpy was sourced from standard steam tables, based on the steam pressure as recorded by the SCADA system. On this basis, the boiler combustion performance and efficiency based on the average values for the 1.5 h test are shown in Table 4.4.

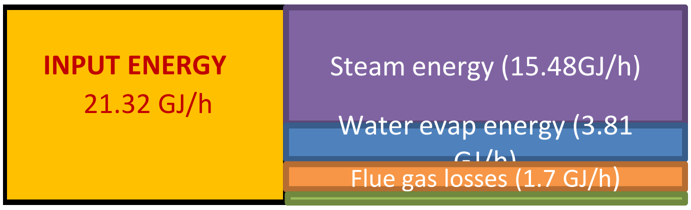
Table 4.4: Boiler performance during controlled sawdust combustion trial

Parameter	Units	Average Value
Wet sawdust fed	m^3/h	6.350
Wet sawdust fed	kg/h	2,445
Dry sawdust fed	kg/h	1,431
Water fed	kg/h	1,014
Energy input	GJ/h	21.32
Steam output	kg/h	5,430
Steam pressure	kPa	590
Steam enthalpy	GJ/t	2.85
Steam energy output	GJ/h	15.48
Energy use per tonne steam	GJ/t steam	3.93
Boiler efficiency	%	72.6
Primary combustion temperature	^{0}C	730
Secondary combustion temperature	^{0}C	850
Stack temperature	^{0}C	114
Ash output	kg/h	9.44

The measured wet sawdust feed rate during the trial was 2.445 tonnes per hour, which is consistent with the historical WBE data indicating they combust about 25 tpd of sawdust, over a 10 hour per day period. Based on the sawdust TS and NCV values it is calculated that the dry sawdust feedrate over the combustion trial was 1,431 kg/h and the energy input was 21.32 GJ/h. As can be seen just over 1 tph of water was fed to the boiler. Based on the measured steam output and its enthalpy value it can be seen that the energy output, as steam was 15.48 GJ/h. This gives an overall boiler efficiency of 72.6%, which is considered normal for this type of boiler. Also, the specific energy use per tonne of steam produced is calculated at 3.93 GJ/tonne. Finally, based on the measured ash content of the sawdust it is estimated that the ash generation rate was 5.72 kg/h. However, based on the measured loss on ignition of the ash (see section 4.5.3) the actual amount of ash produced is estimated at 9.44 kg/h

The major energy losses from this boiler are associated with the energy required to vaporise the feed water and raise the water vapour temperature to 850 ^{0}C, estimated at 3.81 GJ/h and that lost in the flue gas, estimated at 1.7 GJ/h. Note that the stack temperature of 150 ^{0}C, as measured by ETC, was used to calculate the energy lost in the flue gas (see data in Table 4.5). When these losses are subtracted from the input fuel energy value, there is a very good agreement between steam energy (15.48 GJ/h) and that available for use to generate steam (15.8 GJ/h), leaving only 0.32 GJ/h of energy unaccounted for, as other thermal losses from the boiler. Thus the energy balance around the boiler is regarded as being very good and is depicted as a Sankey energy diagram in Figure 4.5.

Figure 4.5: Sankey energy diagram for the control combustion trial



4.5.2 Stack emission data

Emission Testing Consultants Pty Ltd (ETC) of Melbourne conducted the stack emission testing for this combustion study. The boiler is equipped with sampling ports on the stack which were used by ETC to obtain the stack emission samples. These ports were not the required distance of 6 stack diameters upstream of a bend and hence obtaining iso-kinetic sampling conditions was compromised somewhat. Pictures of this stack emission testing are shown in Figure 4.6. The photo on the left shows the sampling equipment and the photo on the right shows the stack samplers on the platform inserting the sampling probes into the two 100 mm BSP ports on the stack to take the emission samples. Iso-kinetic emission samples were collected from 9:00 am to 10:30 am.

Figure 4.6: Stack emission testing photographs

Sampling equipment

Stack sampling

The detailed emissions report as prepared by ETC can be found in Appendix 8.2; however a summary of the pertinent results are shown in Table 4.5 and are discussed below.

The flow rate and concentration data in Table 4.5 are expressed on a dry weight basis and at standard conditions (100 kPa pressure and 0 ^{0}C). The actual flow rate of flue gas, at 150 ^{0}C, was 210 m3/min and included 14% by volume of water vapour. The concentration of total organic compounds or Volatile Organic Compounds (VOCs) is expressed as n-propane.

Table 4.5: Summary of stack emission testing results

Parameter	Emission value	Mass emission rate (g/min)
Temperature (^0C)	150	
Dry Flow rate (m^3/min)	120	
NOx (mg/m^3)	120	15
SOx (mg/m^3)	6.9	0.81
CO (mg/m^3)	320	38
Total particulates (mg/m^3)	24	2.8
Total organic compounds (mg/m^3)	11	1.3
PAHs ($\mu g/m^3$ as TEQ)	2.7	
CO_2 (%)	14	
O_2 (%)	7.1	

The SOx, NOx, particulate and VOC emission data as measured by ETC is regarded as being very good. The average CO value of 320 mg/m^3) is regarded as being higher than would be expected for good combustion conditions. A value of less than 100 mg/m^3 is what is regarded as a good emission level. However, the CO_2 and O_2 levels are regarded as indicating acceptable combustion conditions. The measured Polycyclic Aromatic Hydrocarbon (PAH) emission value of 2.7 $\mu g/m^3$, expressed as the Benzo-a-pyrene Toxicity Equivalence (TEQ) value, is regarded as good.

4.5.3 Ash quality data

The average quality of the ash, as analysed by ALS, is shown in Table 4.6. Detailed ash data from ALS is shown in Appendix 8.1.

Table 4.6: Average ash quality data

Parameter	Units	Average Value
TS	%	93.5
Loss on Ignition (LOI)	% of TS	39.4
SO_4	mg/kg dry ash	630
Chlorides	mg/kg dry ash	33
SiO_2	% of dry ash	61.44
CaO	% of dry ash	6.23
Al_2O_3	% of dry ash	9.39
Fe_2O_3	% of dry ash	8.86
MgO	% of dry ash	2.49
Na_2O	% of dry ash	4.4
K_2O	% of dry ash	4.91
P_2O_5	% of dry ash	1.00

The measured LOI value of the ash indicates that a significant amount of combustible material (unburnt carbon) is still present in the ash. This is estimated at 3.72 kg/h. The mineralogy data is shown on a dry combustible-free basis. This analysis of the ash shows relatively low values of alkali oxides (Na_2O and K_2O) and P_2O_5 and as such there would likely be an ash melting issue in the boiler. There is a good closure on the ash analysis with the sum of the constituents amounting to 98.73 %

4.6 Co-combustion trial results

This trial was conducted to assess the impact of co-combustion of dewatered paunch waste with the conventional sawdust fuel. To obtain steam outputs similar to those of the control trial, fuel feed rates had to be increased. This trial commenced at a Feed Rate setting of 87% but was increased during the trial in steps, ultimately operating at a Feed Rate setting of 100%. The feed rate settings during this trial are shown in Table 4.7. Based on the data shown in Table 4.7, the average feed rate during the co-combustion trial was 8.086 m^3/h.

Table 4.7: Co-combustion trial feed rate data

Time period	Feed Rate Setting (%)	Feed Rate (m^3/h)
10:30 to 10:50 am	87	6.350
10:50 to 11:10 am	92	7.179
11:10 to 11:20 am	97	8.026
11:20 am to 1:40 pm	100	8.467

The mass of dewatered paunch waste fed during the trial was measured by WBE personnel. Three skips of dewatered paunch waste were fed over the 3h trial, with a combined weight of 899 kg. Based on the measured bulk density, as shown in Table 4.1, this is equivalent to a volumetric feed of 3.386 m^3 over the trial. This paunch waste feed rate was lower than the typical paunch waste generation rate at the abattoir. The total volumetric feed during the trial was 25.607 m^3. Consequently there was 22.221 m^3 of sawdust fed during the trial.

The trial commenced at 10:30 am and was completed at 1:40 pm. Boiler operating conditions and performance data was averaged during this time frame, using the “averaging” function on the CITECT SCADA control panel. There were no boiler operational problems experienced during this co-combustion trial.

4.6.1 Combustion performance

The combustion performance and thermal efficiency of the boiler was assessed by comparing the measured thermal input energy to the furnace to the steam output, as recorded on the CITECT SCADA system. The input thermal energy is based on the measured sawdust and paunch waste feedrate data and their total solids and energy contents, as measured by ALS. For energy input calculations the net calorific values were used. The steam enthalpy was sourced from standard steam tables, based on the steam pressure as recorded by the SCADA system. On this basis, the boiler combustion performance and efficiency based on the average values for the 3h 10 minute test are shown in Table 4.8.

Table 4.8: Boiler performance during the co-combustion trial

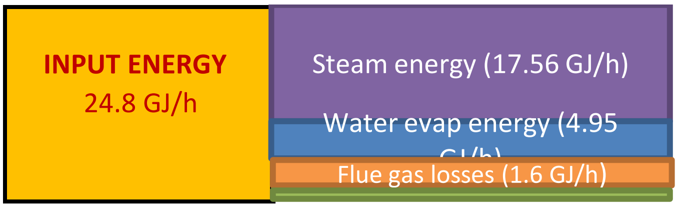
Parameter	Units	Average Value

Wet sawdust fed	m^3/h	7.016
Wet sawdust fed	kg/h	2,701
Dry sawdust fed	kg/h	1,581
Wet paunch waste fed	m3/h	1.069
Wet paunch waste fed	kg/h	283.87
Dry paunch waste fed	kg/h	86.6
Water fed	kg/h	1,317
Sawdust Energy Input	GJ/h	23.55
PW Energy Input	GJ/h	1.25
Total Energy input	GJ/h	24.8
Steam output	kg/h	6,387
Steam pressure	kPa	573
Steam enthalpy	GJ/t	2.75
Steam energy output	GJ/h	17.56
Energy use per tonne steam	GJ/t steam	3.88
Boiler efficiency	%	70.82
Primary combustion temperature	^0C	734
Secondary combustion temperature	^0C	832
Stack temperature	^0C	112
Ash output	kg/h	29.77

As indicated in Table 4.8, the co-combustion trial was run at a higher steam output value than the control combustion trial. This increase was in response to the abattoir steam requirements and resulted in the boiler operating above its design steam output of 6 tph. Consequently there was a higher fuel requirement for this co-combustion trial. The dry sawdust feedrate was increased to an average value of 1,581 kg/h compared to 1,431 kg/h during the control trial. The average dry paunch waste feed rate during the trial was 86.6 kg/h and the average water input increased to 1,317 kg/h compared to 1,014 kg/h for the control trial. Total energy input during the co-combustion trial averaged 24.8 GJ/h compared to 21.32 GJ/h for the control trial. The energy input from the paunch waste was only 1.25 GJ/h or 5% of the total energy input. Based on the measured steam output and its enthalpy value it can be seen that the energy output, as steam was 17.56 GJ/h. This gives an overall boiler efficiency of 70.8%, which is slightly lower than that measured for the control combustion trial. Also, the specific energy use per tonne of steam produced is calculated at 3.88 GJ/tonne, which surprisingly is slightly lower than that measured for the control combustion trial. Finally, based on the measured ash contents of the sawdust and the paunch waste the estimated ash generation rate was calculated to be 12.95 kg/h. However, based on the measured loss on ignition of the ash (see section 4.63) the actual amount of ash produced is estimated at 29.77 kg/h

The major energy losses from this boiler are associated with the energy required to vaporise the feed water and raise the water vapour temperature to 832 ^0C, estimated at 4.95 GJ/h and that lost in the flue gas, estimated at 1.6 GJ/h. Note that the stack temperature of 130 ^0C, as measured by ETC, was used to calculate the energy lost in the flue gas (see data in Table 4.9). When these losses are subtracted from the input fuel energy value, there is a very good agreement between steam energy (17.56 GJ/h) and that available for use to generate steam (18.25 GJ/h), leaving only 0.69 GJ/h of energy unaccounted for as other thermal losses from the system. Thus the energy balance around the boiler is regarded as being very good and is depicted as a Sankey energy diagram in Figure 4.7

Figure 4.7: Sankey energy diagram for the co-combustion trial



4.6.2 Stack emission data

Stack emission samples were collected between 11:45 am and 1:15 pm. Detailed results are shown in Appendix 8.2 and are summarised in Table 4.9 below.

The flow rate and concentration data in Table 4.9 are expressed on a dry weight basis and at standard conditions (100 kPa pressure and 0 ^{0}C). The actual flow rate of flue gas, at 130 ^{0}C, was 210 m3/min and included 14% by volume of water vapour. The concentration of total organic compounds or Volatile Organic Compounds (VOCs) is expressed as n-propane.

Table 4.9: Summary of stack emission testing results

Parameter	Emission value	Mass emission rate (g/min)
Temperature (^{0}C)	130	
Dry Flow rate (m^3/min)	120	
NOx (mg/m^3)	210	25
SOx (mg/m^3)	15.3	1.88
CO (mg/m^3)	950	120
Total particulates (mg/m^3)	23	2.8
Total organic compounds (mg/m^3)	9.5	1.2
PAHs (µg/m^3 as TEQ)	3.7	
CO_2 (%)	15.6	
O_2 (%)	5.3	

As can be seen the SOx and NOx emission values are about double those measured for the control combustion trial. This is most likely due to the significantly higher feed N and S values, associated with the paunch waste. Nonetheless these emission values are regarded as being acceptable from a regulatory viewpoint. The particulate and VOC emission data as measured by ETC are regarded as being very good and very similar to those measured for the control combustion trial. The measured Polycyclic Aromatic Hydrocarbon (PAH) emission value of 3.7 µg/m^3, expressed as the Benzo-a-pyrene Toxicity Equivalence (TEQ) value, is slightly higher than that measured for the control combustion trial. The average CO value of 950 mg/m^3 is regarded as being significantly higher than would be expected for good combustion conditions and this value is about three times higher than that measured for the control combustion trial. As can be seen the oxygen level at only 5.3% is significantly below that measured during the control combustion trial and indicates that during this co-combustion trial that combustion occurred under oxygen limiting conditions.

4.6.3 Ash quality data

The average quality of the ash, as analysed by ALS, is shown in Table 4.10.

Table 4.10: Average ash quality data

Parameter	Units	Average Value
TS	%	100
Loss on Ignition (LOI)	% of TS	56.5
SO_4	mg/kg dry ash	2007
Chlorides	mg/kg dry ash	69
SiO_2	% of dry ash	61.86
CaO	% of dry ash	5.89
Al_2O_3	% of dry ash	6.86
Fe_2O_3	% of dry ash	5.85
MgO	% of dry ash	2.05
Na_2O	% of dry ash	5.33
K_2O	% of dry ash	4.54
P_2O_5	% of dry ash	2.23

The measured LOI value of the ash indicates that a significant amount of combustible material (unburnt carbon) is still present in the ash. This is estimated at 16.82 kg/h. This is higher than that measured for the control combustion trial and supports the lower combustion efficiency measured in this co-combustion trial. The mineralogy data is shown on a dry combustible-free basis to make comparison with the controlled combustion ash easier. This analysis of the ash shows that it is similar to the controlled combustion ash (see Table 4.6) with the exception of higher concentrations of sulphate, chlorides and phosphates (P_2O_5). This is attributed to higher levels of these parameters in the paunch waste. There is a good closure on the ash analysis with the sum of the constituents amounting to 94.64 %

4.7 Impacts of co-combustion

These full-scale combustion trials demonstrated no operational impacts from paunch waste co-combustion when the boiler was operated with 5% of its input energy being derived from dewatered paunch waste. This paunch waste energy input was much lower than the typical paunch waste generation rate. Had the paunch waste been fed at a rate commensurate with its generation rate it is estimated the boiler would have been fired with about 30% of its energy being derived from paunch waste. It should be noted that these trials were conducted with a paunch waste TS value of 30.5%, which is regarded as at the lower end of what should be achieved by screw press dewatering operations. As such this trial can be considered as a “worst case” scenario for paunch waste co-combustion, notwithstanding that the firing rate was lower than it should have been.

Only some minor environmental impacts were observed with co-combustion of paunch waste when the boiler was operated with 5% of its input energy being derived from dewatered paunch waste. Under this level of paunch waste input to the boiler there was a doubling of NOx and SOx emission rates, but the emission concentrations were still well within regulatory guidelines. There was a minor deterioration in combustion efficiency when operating under co-combustion conditions but this may have been largely due to the fact that the co-combustion trial was conducted at above the boilers design steam output value. This is corroborated by the lower oxygen levels in the flue gas during the co-combustion trial. It is thus very likely that the levels of CO in the flue gas would have been be the same as the control combustion trial had the system been able to operate under the same levels of oxygen during the co-combustion trial. There was a slight increase in PAH emissions when co-combusting dewatered paunch waste.

Due to the higher ash content of the paunch waste, co-combustion of this material will increase ash generation rates. This was further increased by the higher proportion of combustible material in the ash from the co-combustion trial. Ash generation is expected to almost triple compared to control combustion conditions, when co-combustion with a 5% energy input from paunch waste is practised. Ash generation rates, for the same energy input scenarios (21.32 GJ/h) increased from 9.44 kg/h for the control combustion trial to 25.59 kg/h for the co-combustion trial. Co-combustion had only a minor impact on ash quality.

The above comments on the impacts of co-combustion only apply when 5% of the boiler energy input is derived from dewatered paunch waste. Had the paunch waste energy input been the expected 30%, the environmental impacts would likely have been more significant. It is very likely that under these firing conditions that the SOx emissions would increase proportionally, to an estimated value of about 45 mg/m^3, which is still within Australian regulatory requirements. NO_x would also likely increase but it is not possible to estimate what the increase is likely to be. Ash generation would also increase proportionally to the PW feed rate.

The GHG impacts of co-combustion of dewatered paunch waste, were in this case neutral, since the paunch waste replaced another renewable energy fuel, namely sawdust. Had the boiler been fired with a fossil fuel, then GHG credits would apply. In addition, if the paunch waste was previously disposed via landfill, then additional GHG credits would likely apply due to avoided methane emissions from landfill operations. Calculation of potential GHG credits can only be done for specific operational scenarios.

4.8 Co-combustion cost benefit analysis

4.8.1 No new boiler required

This section of the paunch waste co-combustion cost benefit analysis (CBA) is based on the assumption that the existing boiler is suitable for co-combustion. It is based on boilers at a 600 to 700 head per day abattoir, as per the WBE abattoir. Process inputs for this CBA are based on the results achieved from the co-combustion trial completed at WBE and reported in Section 4.6 of this report. The CBA is however conducted on the assumption that a 600 to 700 head/day abattoir produces about 25 wet tpd of paunch waste at a nominal TS of 20%, as identified in an earlier MLA report[1]. This CBA is also based on the assumption that the boiler's existing fuel is sawdust. Finally it is assumed that the boiler operates for 10 hours per day at a steam output of 6 tph and based on the combustion performance as monitored during these trials, that the boiler thermal input required for this steam output is 23.3 GJ/h.

Capital cost expenditures for this CBA are thus limited to supply and installation of a paunch waste screw press for dewatering and a dewatered paunch waste storage and feed systems to the existing boiler. These capital cost estimates have been supplied by WBE. Operating costs for the co-combustion facility are associated with maintenance of the new equipment and increased ash disposal costs. Credits are then applied for reductions in purchased fuel (sawdust) costs and avoided paunch waste disposal costs. A summary of the input data to the CBA are shown in Table 4.11.

As shown in Table 4.11, the co-combustion CBA is based on combusting 16.7 tpd of dewatered paunch waste at a TS of 30.5% and 18.42 tpd of sawdust at a TS of 58.6%. The control combustion is based on combusting only 26.69 tpd of sawdust. The costs for purchase of sawdust and disposal of paunch waste and ash are based on values that are deemed appropriate for the red meat industry. The NPV discount factor of 10.59 is based on a 7% discount rate and a term of 20 years.

Table 4.11: CBA input data

Parameter	Units	Control combustion value	Co-combustion value
Boiler steam output	tph	6	6
Boiler operating hours	hours/day	10	10
Boiler thermal input	GJ/h	23.3	23.3
Wet paunch waste mass	tpd	25	16.7
Dry paunch waste input	tph	0	0.5
Paunch waste energy input	GJ/h	0	7.22
Sawdust energy input	GJ/h	23.3	16.08
Dry sawdust input	tph	1.56	1.08
Wet sawdust input	tpd	26.69	18.42
Ash disposal mass	tpd	0.1	0.28
Ash disposal cost	$/tonne	20	20
Paunch waste disposal cost	$/tonne	15	
Sawdust cost	$/tonne	35	35
Operating days per year	number	250	250
Maintenance cost	% capex		4
NPV discount factor			10.59

Based on the data in Table 4.11 the CBA data for paunch waste co-combustion in existing boilers is shown in Table 4.12.

Table 4.12: CBA for paunch waste co-combustion in existing boilers

Parameter	Units	CBA value
Capital cost estimate	$	120,000
Increased maintenance cost	$/a	4,800
Increased ash disposal cost	$/a	881
Decreased paunch waste disposal cost	$/a	93,750
Decreased sawdust purchase cost	$/a	72,316
Net O&M cost	$/a	-160,358
Simple pay-back period	years	0.7
20-year NPV	$	-1,578,477

This CBA for dewatered paunch waste co-combustion in existing boilers indicates that the economics are very attractive, even for mid-size abattoirs processing 600 to 700 cattle per day. Based on the combustion data generated from these full-scale co-combustion trials and the input assumptions shown in Table 4.11, this CBA indicates that the costs associated with installation of the required infrastructure to permit co-combustion is recovered in less than a year, due to the significant operational savings realised via co-combustion. As can be seen the reductions in fuel costs amount to $72,316 per year and reductions in paunch waste disposal costs amount to $93,750 per year. The NPV value shows that over a 20 year period a positive cash flow of $1.58 million can be expected via adoption of co-combustion of dewatered paunch waste in existing boilers suitable for this duty. Or put another way, operating savings of $57.85/dry tonne of paunch waste combusted are achieved based on reduced sawdust costs and savings of $75/dry tonne of paunch combusted are achieved based on reductions in paunch disposal costs. When one takes into account the increased maintenance and ash disposal costs net operating savings of $128/dry tonne of paunch waste combusted are achieved via co-combustion.

The economics will likely be even more attractive for coal-fired boilers, since the cost of energy is higher than for sawdust. In addition, since coal is a non-renewable fossil fuel, this option would also attract credits once a carbon tax is introduced.

One other option to consider is privatising the boiler operations at abattoirs. Under this scenario a service provider will install and operate the required equipment for co-combustion systems and likely charge the abattoir a fee for the steam provided. This contractual arrangement is classified as a Build-Own-Operate (BOO) contract. This is already being done in New Zealand and is worthy of further consideration.

4.8.2 New boiler required

This scenario is based on the assumption that a 600 to 700 head per day abattoir currently combusting coal now wishes to switch to combust renewable fuels, namely sawdust and dewatered paunch waste. Thus a new boiler suitable to combust biomass is installed together with a paunch waste screw press installation. The capital cost for a new 6 tph steam output boiler is estimated at $1.9 million and the screw press installation cost is estimated at $75,000, bringing total capital expenditure to $1.975 million. Maintenance costs for this new co-combustion facility are based only on that associated with the new screw press, since it is assumed that boiler maintenance costs will not change. In this case credits apply due to reductions in ash disposal costs, avoided paunch waste disposal costs, reductions in fuel costs by changing from coal to sawdust and finally a carbon tax credit for avoided fossil fuel use. For this CBA the current proposed carbon tax rate of $23/tonne carbon dioxide has been assumed. A summary of the input data to this CBA are shown in Table 4.13. In this scenario it is assumed that the NCV of the coal is 20 GJ/t, the carbon content 75% and the ash content 7%.

Based on the data in Table 4.13 the CBA data for co-combustion of sawdust and dewatered paunch waste in a new boiler, compared to the combustion of coal, is shown in Table 4.14. Based on the estimated operational savings shown in Table 4.14 the simple payback period on the invested capital is 4 years. This is not that attractive; however the CBA does show that over a 20 year period cost savings of $2.85 million can be realised. Furthermore this scenario generates GHG credits of 7,645 tonnes per annum. This reduction may allow abattoirs to remain below the current NGERS reporting limit of 25,000 tonnes per annum of GHG emissions.

Table 4.13: CBA input data, new boiler (coal to sawdust plus PW)

Parameter	Units	Coal combustion value	Co-combustion value
Boiler steam output	tph	6	6

Boiler operating hours	hours/day	10	10
Boiler thermal input	GJ/h	23.3	23.3
Wet paunch waste mass	tpd	25	16.7
Dry paunch waste input	tph	0	0.5
Paunch waste energy input	GJ/h	0	7.22
Coal or sawdust energy input	GJ/h	23.3	16.08
Dry coal or sawdust input	tph	1.16	1.08
Wet sawdust input	tpd	0	18.42
Ash disposal mass	tpd	0.82	0.28
Ash disposal cost	$/tonne	20	20
Paunch waste disposal cost	$/tonne	15	
Sawdust or coal cost	$/tonne	120	35
Carbon tax	$/tonne C	23	
Operating days per year	number	250	250
Maintenance cost	% capex		4
NPV discount factor			10.59

Table 4.14: CBA for paunch waste co-combustion in a new boiler

Parameter	Units	CBA value
Capital cost estimate	$	1,975,000
Increased maintenance cost	$/a	4,800
Decreased ash disposal cost	$/a	2,680
Decreased paunch waste disposal cost	$/a	93,750
Cost credit, coal to sawdust	$/a	188,278
Carbon tax credit	$/a	175,833
Net O&M cost	$/a	-455,741
Simple pay-back period	years	4
20-year NPV	$	-2,851,298

5 Success in achieving objectives

This project was successful in achieving all of the objectives as outlined in the original scope of work for the combustion trials. Both the control and co-combustion trials generated very good mass and energy balance data which allowed the process and environmental impacts of paunch waste co-combustion to be rigorously assessed. The cost benefit analysis was successfully completed and showed that co-combustion of dewatered paunch waste is an attractive commercial proposition provided that existing boilers can be utilised. Even if new boilers that are currently combusting coal are decommissioned and new biomass-capable boilers are installed, the economics are quite appealing.

6 Impact on meat and livestock industry – Now and in five years time

The results from this full-scale paunch waste co-combustion trial strongly support this method for management of paunch waste at abattoirs that already have boilers suitable for co-combustion of dewatered paunch waste. Due to the significant economic advantages of dewatered paunch waste co-combustion it is very likely that many abattoirs with boilers suitable to co-combust dewatered paunch waste will proceed with this practise as soon as practical. Whilst there is no data base currently available to indicate how many abattoirs in Australia have boilers suitable for paunch waste co-combustion, it is conservatively estimated that 10 to 20 abattoirs would be able to co-combust dewatered paunch waste in their existing boilers. On this assumption it is conservatively estimated that if these abattoirs adopted paunch waste co-combustion that economic benefits of between $1.6 and $3.2 million per annum could be realised within the Australian red meat industry. This value would increase over time as older boilers not suitable to co-combust dewatered paunch waste are replaced with new boilers suitable for this duty. Replacement of coal-fired boilers with biomass-fired boilers which co-combust paunch waste looks relatively attractive and abattoirs should evaluate this boiler upgrade option in more detail.

7 Conclusions and recommendations

7.1 Conclusions

Based on the outcomes of this full-scale dewatered paunch waste co-combustion trial the following conclusions are drawn:

1. There was no impact on boiler combustion performance when co-fired with 5% of its energy input as dewatered paunch waste, with a TS of 30%.
2. At this co-firing rate there were minor environmental impacts, the notable ones being increases in atmospheric emissions of CO, NOx and SOx. Whilst the mass emission rates for NOx and SOx doubled, the stack gas concentrations were still well within regulatory guidelines. The higher CO emission was a result of operating at higher than the design rating of the boiler, with the result that oxygen-limiting combustion occurred.
3. Co-firing with 5% of the boiler input energy being derived from dewatered paunch waste tripled the ash generation rate. There was no significant difference in ash quality when the boiler was co-fired with dewatered paunch waste.
4. Typical paunch waste generation rates at abattoirs indicate that up to 30% of boiler fuel requirements could be derived from the dewatered paunch waste. Co-firing of boilers at this rate could have more significant operational and environmental impacts.
5. Co-firing of dewatered paunch waste in existing boilers suitable for this duty offers a very attractive disposal option compared to existing methods such as landfilling or composting. It has been estimated that for a 600 to 700 head per day abattoir, the net economic benefit, over a 20-year period, is $1.58 million.
6. Replacing existing coal-fired boilers with boilers suitable to co-fire biomass and paunch waste appears to offer long-term economic benefits. While the initial return on the capital investment does not meet the typical requirement of 3 years (it is 4 years), the net economic benefit, over a 20-year period, for a 600 to 700 head per day abattoir, is estimated at $2.85 million.

7.2 Recommendations

Since this co-combustion trial did not fire the boiler with dewatered paunch waste at a rate commensurate with its generation rate, it is recommended that the paunch waste plus DAF sludge co-combustion trial scheduled to take place later this financial year be conducted at a firing rate commensurate with the waste production rates. This will confirm if any adverse environmental impacts are evident at this waste firing rate.

It is also recommended that MLA explore in more detail the concept of BOO contracts at abattoirs for supply of steam via privatised co-combustion systems. This may be particularly attractive when considering replacing coal-fired boilers with biomass-fired boilers which can co-fire dewatered paunch waste.

8 Appendices

These appendices are the results of testing carried out under the following contracts for this project.

A.ENV.0120
A.ENV.0121
A.ENV.0122
A.ENV.0123

8.1 Appendix 1: ALS analytical reports

Page : 3 of 5
Work Order : EB1114545
Client : MEAT & LIVESTOCK AUSTRALIA
Project : A ENV 0110

Analytical Results

Sub-Matrix: SOLID

			Client sample ID	WW1	WW2	WW3	WWA1	WWA2
			Client sampling date / time	21-JUL-2011 09:00	21-JUL-2011 09:30	21-JUL-2011 10:00	21-JUL-2011 09:00	21-JUL-2011 09:40
Compound	CAS Number	LOR	Unit	EB1114545-001	EB1114545-002	EB1114545-003	EB1114545-004	EB1114545-005
EA030: Total Solids								
^ Total Solids	----	0.1	%	58.6	58.2	59.0	----	----
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	41.3	41.8	41.0	19.5	<1.0
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	----	----	----	390	190
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	10	mg/kg	----	----	----	20	<10
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	<50	<50	<50	----	----
Iron	7439-89-6	50	mg/kg	170	80	90	----	----
Calcium	7440-70-2	50	mg/kg	70	60	70	----	----
EG020T: Total Metals by ICP-MS								
Chromium	7440-47-3	0.1	mg/kg	0.3	0.4	0.4	----	----
Copper	7440-50-8	0.1	mg/kg	0.6	0.6	0.7	----	----
Nickel	7440-02-0	0.1	mg/kg	0.1	0.1	0.1	----	----
Lead	7439-92-1	0.1	mg/kg	<0.1	<0.1	0.3	----	----
Zinc	7440-66-6	0.1	mg/kg	1.6	1.3	1.4	----	----

Page : 4 of 5
Work Order : EB1114545
Client : MEAT & LIVESTOCK AUSTRALIA
Project : A ENV 0110

Analytical Results

Sub-Matrix: SOLID

			Client sample ID	WWA3	PW1	PW2	PW3	PWA1
			Client sampling date / time	21-JUL-2011 10:20	21-JUL-2011 10:30	21-JUL-2011 11:30	21-JUL-2011 12:45	21-JUL-2011 11:30
Compound	CAS Number	LOR	Unit	EB1114545-006	EB1114545-007	EB1114545-008	EB1114545-009	EB1114545-010
EA030: Total Solids								
^ Total Solids	----	0.1	%	----	29.8	28.9	32.8	----
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	<1.0	70.2	71.1	67.2	<1.0
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	570	----	----	----	680
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	10	mg/kg	20	----	----	----	30
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	----	240	100	140	----
Iron	7439-89-6	50	mg/kg	----	780	590	360	----
Calcium	7440-70-2	50	mg/kg	----	4990	3550	2870	----
EG020T: Total Metals by ICP-MS								
Chromium	7440-47-3	0.1	mg/kg	----	1.0	0.7	0.7	----
Copper	7440-50-8	0.1	mg/kg	----	5.8	5.3	7.6	----
Nickel	7440-02-0	0.1	mg/kg	----	0.6	0.5	0.5	----
Lead	7439-92-1	0.1	mg/kg	----	0.6	0.2	0.2	----
Zinc	7440-66-6	0.1	mg/kg	----	46.1	46.2	79.6	----

Page : 5 of 5
Work Order : EB1114545
Client : MEAT & LIVESTOCK AUSTRALIA
Project : A ENV 0110

Analytical Results

Sub-Matrix: SOLID

			Client sample ID	PWA2	PWA3	----	----	----
			Client sampling date / time	21-JUL-2011 12:30	21-JUL-2011 13:30	----	----	----
Compound	CAS Number	LOR	Unit	EB1114545-011	EB1114545-012	----	----	----
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1.0	%	<1.0	<1.0	----	----	----
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	800	1140	----	----	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	10	mg/kg	30	30	----	----	----

REPORT No: 21009391
Date: 10/08/11 Page 1

ANALYSIS AND TESTING REPORT

ALS STAFFORD

Sample Details	Purchase order 309823 EB1114545 Sample:1 - WW1	Purchase order 309823 EB1114545 Sample:2 - WW2	Purchase order 309823 EB1114545 Sample:3 - WW3
Moisture %	8.2	8.0	8.0
Ash %	0.5	0.4	0.4
Total Sulfur %	0.05	0.06	0.06
CALORIFIC VALUE (AD)			
Calorific Value MJ/kg	17.23	17.33	18.05
Calorific Value kcal/kg	4116	4140	4312
ULTIMATE ANALYSIS (d.a.f.)			
Carbon %	51.0	50.9	51.0
Hydrogen %	5.52	5.56	5.54
Nitrogen %	0.11	0.11	0.06
Sulfur %	0.06	0.06	0.06
Oxygen (By Difference) %	43.3	43.4	43.4

All results reported to air dried basis unless noted
d.a.f. = dry ash free basis

Sample Details	Purchase order 309823 EB1114545 Sample:7 - PW1	Purchase order 309823 EB1114545 Sample:8 - PW2	Purchase order 309823 EB1114545 Sample:9 - PW3
Moisture %	8.4	8.3	8.7
Ash %	10.1	7.8	7.2
Total Sulfur %	0.20	0.16	0.16
CALORIFIC VALUE (AD)			
Calorific Value MJ/kg	16.85	17.07	17.32
Calorific Value kcal/kg	4024	4076	4136
ULTIMATE ANALYSIS (d.a.f.)			
Carbon %	51.0	51.2	51.3
Hydrogen %	5.86	5.84	5.83
Nitrogen %	1.46	1.32	1.36
Sulfur %	0.25	0.19	0.19
Oxygen (By Difference) %	41.4	41.4	41.4

All results reported to air dried basis unless noted
d.a.f. = dry ash free basis

		Type	LEV-01	OA-GRA05	ME-ICP86	ME-ICP86	ME-ICP86	ME-ICP86	ME-ICP86	ME-ICP86	ME-ICP86	ME-ICP86
				LOI	CaO	MgO	Al2O3	Fe2O3	SiO2	Na2O	K2O	P2O5
				%	%	%	%	%	%	%	%	%
				0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.05
1	WW1	Pulp	*	99.6								
2	WW2	Pulp	*	99.7								
3	WW3	Pulp	*	99.7								
4	WWA1	Pulp		56.9	2.83	0.97	3.6	3.82	25.5	1.77	1.88	0.52
5	WWA2	Pulp		4.9	6.16	2.54	8.96	8.2	58.9	4.24	4.71	0.92
6	WWA3	Pulp		56.4	2.34	1.02	4.52	4.08	27.3	1.99	2.34	0.38
7	PW1	Pulp	*	89.2								
8	PW2	Pulp	*	91.8								
9	PW3	Pulp	*	92.4								
10	PWA1	Pulp		85	0.86	0.34	1.29	1.21	9.33	0.73	0.86	0.22
11	PWA2	Pulp		58	2.45	0.85	3.09	2.54	26.9	2.18	1.89	0.9
12	PWA3	Pulp		26.5	4.37	1.49	4.61	3.88	44.5	4.04	3.18	1.79

8.2 Appendix 2: ETC stack emissions report

etc
emissiontestingconsultants

MELBOURNE
Unit 2, 160 New Street,
Ringwood, VIC 3134
Phone +61 3 9870 2644
Freecall 1300 782 007
Fax +61 3 9870 4055

PERTH
Unit 3, 4 Monash Gate,
Jandakot, WA 6164
Phone +61 8 9417 9133
Freecall 1300 782 007

www.emission.com.au
ABN 74 474 273 172

Date: 18 August 2011

Report No: 110107r

Page: 1 of 8

Bridle Consulting
3/10-12 Pisa Court
Surfers Paradise QLD 4217

Emission Testing – August 2011

Boiler – Normal Fuel (Wood Chips) and Alternative Fuel (Paunch Waste and Wood Chips)

Dear Mr Trevor Bridle,

Tests were performed 21 July 2011 to determine emissions to air from the Boiler under normal fuel conditions (burning wood chips) and then with paunch waste added to the wood chips at the Wingham Abattoir, Wingham NSW.

Yours faithfully
Emission Testing Consultants

Harry Braun BSc
Operations Manager

hb@emission.com.au

Report prepared for:
Bridle Consulting

Date: 18 August 2011
Report No: 110107r
Page: 2 of 8

RESULTS

Boiler – Normal Fuel (Wood Chips)

21 July 2011

Flow Results	Measured MW	Boiler - Normal Fuel 110107	
Time of flow test		0900 & 1110	hrs
Stack dimensions at sampling plane		780	mm
Velocity at sampling plane		7.4	m/s
Average temperature		150	°C
Moisture content	Method4	14	% v/v
Flow rate at discharge conditions		210	m³/min
Flow rate at wet NTP conditions		140	m³/min
Flow rate at dry NTP conditions		120	m³/min

Continuous Analyser Results (Boiler - Normal Fuel 110107 120)	Sampling Times	Concentration at NTP		Mass rate	
Oxygen (dry basis)	0935-1035	7.1	% v/v	-	
Carbon dioxide (dry basis)	0935-1035	13.9	% v/v	1,900	kg/hour
Dry gas density	0935-1035	1.4	kg/m3	-	
Molecular weight of stack gas, dry basis	0935-1035	31	g/g-mole	-	
Nitrogen oxides as NO_2	0935-1035	120	mg/m3	15	g/min
Carbon monoxide as CO	0935-1035	320	mg/m3	38	g/min
Total organic compounds as n-propane	0935-1035	11	mg/m3	1.3	g/min

Report prepared for:
Bridle Consulting

Date: 18 August 2011
Report No: 110107r
Page: 3 of 8

Boiler – Normal Fuel (Wood Chips)

21 July 2011

Isokinetic Sampling Results	Sampling Times	Concentration at NTP		Mass rate	
Sulphur dioxide (as SO_2)	0925-1045	4.9	mg/m3	0.57	g/min
Sulphur trioxide (as SO_3)	0925-1045	2.0	mg/m3	0.24	g/min
Particulate matter	0925-1045	24	mg/m3	2.8	g/min
PAH's (total TEQ as BaP, mediumbound)	0925-1045	2.7	$\mu g/m^3$	0.32	mg/min

Polycyclic Aromatic Hydrocarbon (PAH) Results

Stack Identification : **Boiler - Normal fuel**

Sample time, hrs: **0925-1045 hrs , 21-Jul-11**

Compound name	Concentration at NTP ($\mu g/m^3$)	Mass Rate (mg/min)	TEF (BaP equivalents)	TEQ (BaP) at NTP ($\mu g/m^3$)	TEQ (BaP) (mg/min)
Naphthalene	300	36	-	-	-
2-Methylnaphthalene	7.1	0.84	-	-	-
Acenaphthylene	55	6.5	-	-	-
Acenaphthene	2.3	0.27	-	-	-
Fluorene	9.5	1.1	-	-	-
Phenanthrene	58	6.9	0.0005	0.029	0.0034
Anthracene	3.8	0.44	0.0005	0.0019	0.00022
Fluoranthene	23	2.7	0.05	1.1	0.14
Pyrene	19	2.2	0.001	0.019	0.0022
Benzo(a)anthracene	0.93	0.11	0.005	0.0046	0.00055
Chrysene	2.4	0.28	0.03	0.072	0.0085
Benzo(b)fluoranthene	2.5	0.30	0.1	0.25	0.030
Benzo(k)fluoranthene	0.84	0.100	0.05	0.042	0.0050
Benzo(e)pyrene	1.6	0.18	0.002	0.0031	0.00037
Benzo(a)pyrene	0.82	0.097	1.0	0.82	0.097
Perylene	< 0.1	< 0.01	-	-	-
Indeno(1,2,3-cd)pyrene	1.1	0.14	0.1	0.11	0.014
Dibenzo(a,h)anthracene	0.14	0.016	1.1	0.15	0.018
Benzo(g,h,i)perylene	2.0	0.23	0.02	0.040	0.0047
Total	**490** Lower* / **490** Medium*	**58** Lower* / **58** Medium*		**2.7** Lower* / **2.7** Medium*	**0.32** Lower* / **0.32** Medium*

*Lowerbound (Lower) results do not include any limit of detection values (< values)
*Mediumbound (Medium) results include half limit of detection values (< values)

(*) PAH's marked are out of the range of linearity.

The TEQ values (BaP equivalent) have been calculated using the toxicity equivalence factors (TEF's) relative to Benzo(a)pyrene (BaP), as reported by Larsen & Larsen (1998).

(TEF factors reported in the 2003 World Health Organisation (WHO) report E78963 - HEALTH RISKS OF PERSISTENT ORGANIC POLLUTANTS FROM LONG-RANGE TRANSBOUNDARY AIR POLLUTION)

Report prepared for: Date: 18 August 2011
Bridle Consulting Report No: 110107r
Page: 4 of 8

Boiler – Alternate Fuel (Paunch Waste and Wood Chips)

21 July 2011

Flow Results	Measured MW		Boiler - Alternative Fuel 110107
Time of flow test		1145 & 1340	hrs
Stack dimensions at sampling plane		780	mm
Velocity at sampling plane		7.3	m/s
Average temperature		130	°C
Moisture content	Method4	14	% v/v
Flow rate at discharge conditions		210	m³/min
Flow rate at wet NTP conditions		140	m³/min
Flow rate at dry NTP conditions		120	m³/min

Continuous Analyser Results (Boiler - Alternative Fuel 110107 120)	Sampling Times	Concentration at NTP		Mass rate	
Oxygen (dry basis)	1215-1315	5.3	% v/v	-	
Carbon dioxide (dry basis)	1215-1315	15.6	% v/v	2,200	kg/hour
Dry gas density	1215-1315	1.4	kg/m3	-	
Molecular weight of stack gas, dry basis	1215-1315	31	g/g-mole	-	
Nitrogen oxides as NO_2	1215-1315	210	mg/m3	25	g/min
Carbon monoxide as CO	1215-1315	950	mg/m3	120	g/min
Total organic compounds as n-propane	1215-1315	9.5	mg/m3	1.2	g/min

Report prepared for:
Bridle Consulting

Date: 18 August 2011
Report No: 110107r
Page: 5 of 8

Boiler – Alternate Fuel (Paunch Waste and Wood Chips)

21 July 2011

Isokinetic Sampling Results (Boiler - Alternative Fuel 110107 120)	Sampling Times	Concentration at NTP		Mass rate	
Sulphur dioxide (as SO2)	1210-1330	13	mg/m3	1.6	g/min
Sulphur trioxide (as SO3)	1210-1330	2.3	mg/m3	0.28	g/min
Particulate matter	1210-1330	23	mg/m3	2.8	g/min
PAH's (total TEQ as BaP, mediumbound)	1210-1330	3.7	µg/m³	0.45	mg/min

Polycyclic Aromatic Hydrocarbon (PAH) Results

Stack identification : **Boiler - Alternate fuel**

Sample time, hrs: **1210-1330 hrs , 21-Jul-11**

Compound name	Concentration at NTP (µg/m³)		Mass Rate (mg/min)		TEF (BaP equivalents)	TEQ (BaP) at NTP (µg/m³)		TEQ (BaP) (mg/min)	
Naphthalene		240		29	-		-		-
2-Methylnaphthalene		7.5		0.91	-		-		-
Acenaphthylene		49		6.0	-		-		-
Acenaphthene		3.2		0.39	-		-		-
Fluorene		10		1.3	-		-		-
Phenanthrene		63		7.7	0.0005		0.032		0.0038
Anthracene		4.0		0.48	0.0005		0.0020		0.00024
Fluoranthene		29		3.5	0.05		1.4		0.18
Pyrene		20		2.5	0.001		0.020		0.0025
Benzo(a)anthracene		1.5		0.18	0.005		0.0075		0.00091
Chrysene		4.0		0.48	0.03		0.12		0.014
Benzo(b)fluoranthene		4.9		0.60	0.1		0.49		0.060
Benzo(k)fluoranthene		1.5		0.18	0.05		0.075		0.0091
Benzo(e)pyrene		2.8		0.34	0.002		0.0056		0.00068
Benzo(a)pyrene		1.0		0.13	1.0		1.0		0.13
Perylene		0.14		0.017	-		-		-
Indeno(1,2,3-cd)pyrene		1.9		0.23	0.1		0.19		0.023
Dibenzo(a,h)anthracene		0.21		0.026	1.1		0.24		0.029
Benzo(g,h,i)perylene		2.6		0.31	0.02		0.051		0.0063
Total	**440**	**440**	**54**	**54**		**3.7**	**3.7**	**0.45**	**0.45**
	Lower*	Medium*	Lower*	Medium*		Lower*	Medium*	Lower*	Medium*

*Lowerbound (Lower) results do not include any limit of detection values (< values)
*Mediumbound (Medium) results include half limit of detection values (< values)

(*) PAH's marked are out of the range of linearity.

The TEQ values (BaP equivalent) have been calculated using the toxicity equivalence factors (TEF's) relative to Benzo(a)pyrene (BaP), as reported by Larsen & Larsen (1998).

(TEF factors reported in the 2003 World Health Organisation (WHO) report E78963 - HEALTH RISKS OF PERSISTENT ORGANIC POLLUTANTS FROM LONG-RANGE TRANSBOUNDARY AIR POLLUTION)

SAMPLING PLANE OBSERVATIONS

The sampling plane had 2 x 4 inch flanged ports.

The location was determined to be "non-ideal" as per AS4323.1.

It was 2 duct diameters less than the required 6 duct diameters downstream from a connection but it was more than the required 2 duct diameters upstream from the exit.

The number of sampling points was increased as per AS4323.1.

The sampling plane did pass the flow assessment (items (a) to (f) of AS4323.1) for all parameters except the sulphur oxides sampling.

For sulphur oxides sampling the sampling plane did not pass the flow assessment (items (a) to (f) of AS4323.1) and was therefore "non-compliant". The following item of (a) to (f) was not met:

(e) For isokinetic testing with the use of impingers, the gas velocity ratio across the sampling plane shall not exceed 1.6:1. The actual ratio was 2.0:1

PLANT OPERATING CONDITIONS

Plant operating conditions were noted as follows.

Normal Fuel: Woodchips

Alternate Fuel: Paunch waste and Woodchips

Please refer to observations taken by Trevor Bridle of Bridle Consulting for detailed plant operating conditions.

Report prepared for:
Bridle Consulting

Date: 18 August 2011
Report No: 110107r
Page: 7 of 8

TEST METHODS

The following methods are accredited with the National Association of Testing Authorities (NATA) and are approved for the sampling and analysis of gases. Specific details of the methods are available on request.

All sampling and analysis conducted in accordance with test methods (TM) prescribed for the purposes of the New South Wales Protection of the Environment Operations (Clean Air) Regulation 2002, or other approved methods (OM).

All parameters are reported adjusted to dry NTP conditions unless otherwise stated.

Parameter	NSW TM Method	NATA	Analytical Laboratory	Analytical Laboratory NATA accreditaion	Analytical Laboratory Report Number(s)	Analytical Laboratory Report Date(s)
Selection of sampling positions	TM-1	Yes	Emission Testing Consultants	14601	NA	NA
Flow rate	TM-2	Yes	Emission Testing Consultants	14601	NA	NA
Velocity	TM-2	Yes	Emission Testing Consultants	14601	NA	NA
Temperature	TM-2	Yes	Emission Testing Consultants	14601	NA	NA
Moisture	TM-22	Yes	Emission Testing Consultants	14601	NA	NA
Particulate matter	TM-15	Yes	Emission Testing Consultants	14601	NA	NA
Dry gas Density	TM-23	Yes	Emission Testing Consultants	14601	NA	NA
Molecular weight	TM-23	Yes	Emission Testing Consultants	14601	NA	NA
Carbon dioxide (CO_2)	TM-24	Yes	Emission Testing Consultants	14601	NA	NA
Oxygen (O_2)	TM-25	Yes	Emission Testing Consultants	14601	NA	NA
Carbon monoxide (CO)	TM-32	Yes	Emission Testing Consultants	14601	NA	NA
Nitrogen oxides (NO_x) as NO_2	TM-11	Yes	Emission Testing Consultants	14601	NA	NA
Sulphur dioxide (SO_2)	TM-3	Yes	SGS Australia Pty Ltd	2562	SE89080	5/08/2011
Sulphur trioxide (SO_3) and sulphuric acid mist (H_2SO_4)	TM-3	Yes	SGS Australia Pty Ltd	2562	SE89080	5/08/2011
Total organic compounds (TOC) as n-propane	TM-34	Yes	Emission Testing Consultants	14601	NA	NA
Polycyclic aromatic hydrocarbons (TEQ)	OM-6	Yes	National Measurement Institute (NMI)	198	#ORG11_062	17/08/2011

Report prepared for:	Date: 18 August 2011
Bridle Consulting	Report No: 110107r
	Page: 8 of 8

DEFINITIONS

The following symbols and abbreviations are used in this test report:

NTP	Normal temperature and pressure. Gas volumes and concentrations are expressed on a dry basis at 0°C, at discharge oxygen concentration and an absolute pressure of 101.325 kPa, unless otherwise specified.
Disturbance	A flow obstruction or instability in the direction of the flow that may impede accurate flow determination. This includes centrifugal fans, axial fans, partially closed or closed dampers, louvres, bends, connections, junctions, direction changes or changes in pipe diameter.
BSP	British standard pipe.
TOC	Total Organic Compounds. Total gaseous organic concentration of vapours consisting primarily of alkanes, alkenes, and/or arenes (aromatic hydrocarbons) The concentration can be expressed in terms of propane, hexane (or other appropriate organic calibration gas) or in terms of methane.
<	Less than the minimum limit of detection using the specified method.
~	Approximately
NA	Not applicable
PAH's	Polycyclic aromatic hydrocarbons
PAH's TEQ values	The TEQ values have been calculated using the toxicity equivalence factors (TEF's) relative to Benzo(a)pyrene, as reported by Larsen & Larsen (1998) (TEF factors reported in the 2003 World Health Organisation (WHO) report E78963 - HEALTH RISKS OF PERSISTENT ORGANIC POLLUTANTS FROM LONG-RANGE TRANSBOUNDARY AIR POLLUTION)
Lowerbound	(Lower) results do not include any limit of detection values (< values)
Mediumbound	(Medium) results include half limit of detection values (< values)