final report

Project code: A.ENV.0106

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Date published: June 2012

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

Use of dewatered paunch waste and DAF sludge as a boiler fuel

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

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Abstract

The prime objective of this project was to conduct a full-scale technical, commercial and environmental assessment of dewatered paunch waste plus DAF sludge co-combustion, using the existing wood-waste fired boiler at the JBS Australia P/L abattoir in Longford, Tasmania. The results from this paunch waste co-combustion trial strongly support this method for management of dewatered paunch waste and DAF sludge at abattoirs that already have boilers suitable for co-combustion of dewatered paunch waste. Due to the significant economic advantages of dewatered paunch waste and DAF sludge co-combustion it is very likely that many abattoirs with boilers suitable to co-combust these 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, particularly for large abattoirs. Only minor environmental impacts were noted during this paunch waste and DAF sludge co-combustion trial.

Executive summary

Currently most abattoirs dispose of their paunch waste and DAF sludge via either composting or land disposal. The current disposal methods can incur disposal fees, particularly if landfilling is practiced. A previous MLA study confirmed the technical and economic viability of co-combusting dewatered PW in a wood waste fired boiler. If a co-dewatered stream of PW and DAF sludge can be successfully co-combusted in boilers waste disposal costs will be further reduced and energy recovery maximised. This project has been designed to provide this much needed information for the red meat industry.

The prime objectives of this project are to conduct a co-dewatering trial of PW and DAF sludge on a screw press and conduct a technical, commercial and environmental assessment of PW and DAF sludge co-combustion in the existing boiler at the JBS Australia P/L abattoir at Longford, Tasmania.

With the exception of the co-dewatering trial 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 and DAF sludge co-combustion to be rigorously assessed. The cost benefit analysis was successfully completed and showed that co-combustion of dewatered paunch waste and DAF sludge is an attractive commercial proposition.

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

1. Due to equipment issues the PW and DAF sludge co-dewatering trial at Longford was not successful. Consequently the co-combustion trial was conducted with separately dewatered PW and DAF sludge.
2. There was no impact on boiler combustion performance when co-fired with 7.5% of its energy input as dewatered PW+DAF, with a TS of 26%. This firing rate is 23% higher than the daily average waste generation rate at the abattoir.
3. At this co-firing rate there were minor environmental impacts, the notable ones being increases in atmospheric emissions of NOx and SOx. Whilst the mass emission rates for NOx doubled and SOx increased 40-fold, the stack gas concentrations were still well within regulatory guidelines.
4. Co-firing with 7.5% of the boiler input energy being derived from dewatered PW+DAF tripled the ash generation rate. There was no significant difference in ash quality when the boiler was co-fired with dewatered PW+DAF.
5. Co-firing of dewatered PW+DAF 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 300 head of cattle and 900 head of sheep per day abattoir, the net economic benefit, over a 20-year period, is $450,000.
6. Replacing existing coal-fired boilers with boilers suitable to co-fire biomass and PW+DAF offer long-term economic benefits. The return on the capital investment meets the typical industry requirement of 3 years if carbon tax credits are available and the net economic benefit, over a 20-year period, for a 300 head of cattle and 900 head of sheep per day abattoir, is estimated at $5.39 million. If carbon tax credits are not available the payback period increases to 6 years and the net economic benefit over a 20 year period is reduced to $1.38 million.

It is recommended that MLA support additional paunch waste and DAF sludge co-dewatering studies to identify suitable dewatering equipment which maximises dewatered product solids content. Such improved dewatering operations will have a major positive impact on co-combustion economics.

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 and DAF sludge.

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 (PW) 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). A subsequent MLA study[2] confirmed the technical and economic viability of co-combusting dewatered PW in a wood waste fired boiler. That study also confirmed that the environmental impacts of PW co-combustion were acceptable. Most abattoirs also produce Dissolved Air Flotation (DAF) sludge which like paunch waste is normally disposed via composting or landfilling. If a co-dewatered stream of PW and DAF sludge can be successfully co-combusted in boilers waste disposal costs will be further reduced and energy recovery maximised. This project has been designed to provide this much needed information for the red meat industry.

[1] MLA, "Pilot Testing Pyrolysis Systems and Review of Solid Waste Use in Boilers", Project A.ENV.0111, 2011.
[2] MLA, "Use of Dewatered Paunch Waste as a Boiler Fuel", Project A.ENV.0110, 2011.

2. Project objectives

The prime objectives of this project are to conduct a co-dewatering trial of PW and DAF sludge on a screw press and conduct a technical, commercial and environmental assessment of PW and DAF sludge co-combustion in the existing boiler at the JBS Australia P/L abattoir at Longford, Tasmania. This boiler is currently fired with wood waste as the primary fuel and is sometimes co-fired with dewatered PW. Well controlled and monitored combustion trials will be undertaken when feeding only wood waste as the fuel and then co-combusting wood waste and the dewatered PW plus DAF sludge in the Longford boiler. The project will deliver the following outputs:

- An assessment of the efficacy of co-dewatering of PW and DAF sludge on the existing FAN screw press at Longford.
- Engineering sound mass and energy balances for each of the two controlled combustion trials. This is designed to confirm that co-combustion of dewatered PW and DAF sludge delivers energy and GHG benefits to the industry.
- Confirmation that there are no operational issues with co-firing of dewatered PW and DAF sludge in boilers.
- Confirmation of the impact, if any, on flue-gas quality, as a result of co-firing of PW and DAF sludge in the boiler.
- Confirmation of the impact, if any, on the ash quality and quantity, as a result of co-firing dewatered PW and DAF sludge in the boiler.
- Development of a cost-benefit analysis of co-combustion of dewatered PW and DAF sludge in boilers.

3. Methodology

The existing FAN screw press at the Longford abattoir was used for the co-dewatering trials. A temporary feed line was set up to transfer DAF sludge to the screw press. The plan was to feed all the paunch waste and DAF sludge generated at the time to the screw press and monitor dewatered cake TS and filtrate quality during the co-dewatering trial. It was agreed with MLA that if the co-dewatering trial was unsuccessful, separately dewatered PW and DAF sludge would be co-fired in the boiler.

The existing wood waste fired boiler at the Longford abattoir, supplied by Steam Systems Pty Ltd of Victoria, was used for this paunch waste and DAF sludge 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 wood waste, although Longford do sometimes co-fire dewatered PW which is fed to the boiler via the wood waste feed bin. For this trial Longford installed a temporary dewatered PW plus DAF sludge storage and feed system, which allowed co-firing of the boiler with the primary fuel, wood waste.

Steam Systems were contracted to supervise this co-firing combustion trial at Longford. The plan was to operate the boiler at as steady a firing rate as possible, close to the design steam output of 5 tph. The boiler operational parameters were monitored, via the CITECT SCADA system installed on the boiler, during the nominal 1-hour steady-state period when firing only wood waste and then when co-firing with dewatered paunch waste and DAF sludge. Feed and ash characterisation was conducted by taking samples during these steady-state trials. Three samples of wood waste and ash from the boiler were collected during the first steady state trial and then for the co-firing trial, three samples of dewatered PW and DAF sludge 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 60 minutes was required during each steady-state trial to complete the stack sampling and analysis by ETC.

4. Results and discussion

4.1 Co- dewatering trial results

Longford had just commissioned their new FAN screw press when the co-dewatering trials were undertaken on 13th March 2012. Typically only the PW is dewatered on the screw press with the DAF sludge being dewatered on a centrifuge with the feed pre-heated using steam to enhance feed coagulation. A picture of the new screw press is shown in Figure 4.1 and the DAF centrifuge in Figure 4.2.

The co-dewatering trial was unsuccessful due almost entirely to the method used to feed the DAF sludge into the screw press. Normally the DAF sludge is pumped to the centrifuge at a rate higher than its generation rate and this same pump was used to feed the screw press. Thus an abnormally high DAF sludge feed rate was fed to the screw press. In addition the DAF sludge was fed into the inclined screw conveyor feeding the PW the screw press. Since the DAF sludge has the consistency of water, it could not be fed up an incline via a screw conveyor. To make matters worse the temporary DAF feed pipe was oriented backwards down the inclined screw conveyor. With this feed system it was not possible to feed DAF sludge to the screw press.

Figure 4.1: Picture of the FAN screw press

Figure 4.2: Picture of the DAF centrifuge

It was thus decided that for the co-combustion trial separately dewatered PW and DAF sludge would be used.

During the site visit on 13th March samples of individually dewatered PW (ex the screw press) and DAF sludge (ex the centrifuge) were taken and analysed for TS and VS by Tasmanian Laboratory Services in Launceston and bulk densities were measured on site using a 1 L graduated beaker. Results of these analyses are shown in Table 4.1. The results from these analyses are consistent with the results from the actual combustion trials conducted a week later.

Table 4.1: Dewatered PW and DAF sludge data

Solid Waste	Sample details	TS (%)	VS (% of TS)	BD (kg/m3)
PW	Sample 1	21.6	98.4	
	Sample 2	20.9	98.4	302
	Average Value	21.3	98.4	
DAF sludge	Sample 1	40.6	96.9	
	Sample 2	31.3	96.6	540
	Average Value	36.0	96.8	

The higher TS of the dewatered DAF sludge is attributed to the pre-treatment with steam and more likely the significant amount of fibrous material in the sludge. This is due to the poor solids capture in the PW screw press which results in a lot of fine paunch waste entering the abattoir wastewater stream which ends up in the DAF unit. A close-up picture (Figure 4.3) of the dewatered DAF sludge clearly shows this fine fibrous material. The bulk density (BD) of the dewatered PW was measured at 302 kg/m^3 which is very similar to that measured for the Wingham dewatered PW[2]. The dewatered DAF sludge BD is higher due to the lack of long fibres present in the dewatered PW.

Figure 4.3: Picture of dewatered DAF sludge

Temporary dewatered PW and DAF sludge storage and feed system

Longford installed a temporary dewatered PW and DAF sludge storage and feed system for these co-combustion trials. This comprised a 0.8 m^3 galvanised iron hopper mounted on top of the out-loading screw conveyor which was fitted with a variable speed drive (VSD). This variable feed screw conveyor then transferred the PW and DAF sludge mixture to the conveyor which feeds the fuel into the furnace via the ram feeder. A picture of the feed hopper and the variable speed feed screw conveyor is shown in Figure 4.4

The paunch waste feed screw was pre-calibrated and set to a feedrate commensurate with the dewatered paunch waste and DAF sludge production rates (that is a combined feed rate of 0.65 m^3/h).

Figure 4.4: Picture of temporary PW+DAF sludge feed system

Boiler details

The boiler at Longford was supplied by Steam Systems Pty Ltd of Victoria. It is designed to combust wood waste as its primary fuel and has a nominal steam output of 5 tph at a pressure of about 8 bar and temperature of about 170 ^{0}C. Typically the boiler combusts about 2.5 tph of wood waste, at a nominal TS of 50%. Typically temperatures in the combustion zone (just above the grate) are between 650 and 750 ^{0}C. Stack temperatures are generally between 300 and 340 ^{0}C. Furnace temperatures in the combustion zone are lower than what would be expected (about 800 ^{0}C) and stack temperatures are much higher than what would be expected (130 to 150 ^{0}C). Most of the ash is removed via the flue gas and is scrubbed from the gas stream by a wet scrubber. Bottom ash is removed from the furnace manually about once per week. Wood waste 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 4.5 and pictures of the boiler in Figure 4.6.

The first picture in Figure 4.6 shows the material being elevated into the small bin from which the hydraulic ram feeds the material onto the top of the grate. The second picture in Figure 4.6 shows the front of the boiler, at the start of the sloping grate.

Figure 4.5: Schematic of the Longford boiler

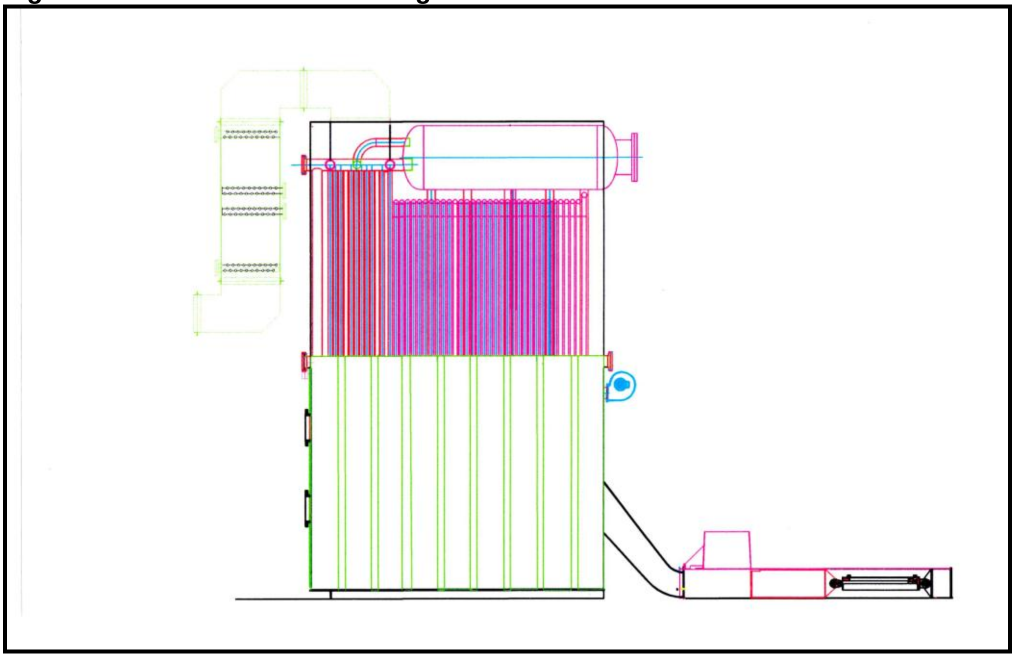


Figure 4.6: Longford boiler pictures

Inclined feed conveyor and ram feeder

Boiler showing sloping grate

Fuel characteristics

As indicated previously, the co-combustion trial was conducted using separately dewatered PW and DAF sludges. For the trial these were mixed in the same proportion as their generation rates (0.56 m^3 of DAF sludge per m^3 of PW). For the trial 1.6 m^3 of PW was mixed with 0.90 m3 of DAF sludge, using a bobcat to produce a homogeneous mixture. Two types of DAF sludge are produced at the abattoir, namely “black” and “green”, which are generated primarily from cattle and sheep processing respectively. For this trial 0.8 m^3 of “black” DAF and 0.1 m^3 of “green” DAF sludge were used. Pictures of the un-mixed material and mixed material are shown in Figure 4.7.

Figure 4.7: PW and DAF sludge pictures

Unmixed PW and DAF sludge

Mixed PW and DAF sludge

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 wood waste and the combined dewatered paunch waste and DAF sludge. 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. Three 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 4.2.

Table 4.2: Fuel bulk density values (kg/m3)

Sample	Wood waste	Paunch waste plus DAF sludge
1	395	426
2	392	468
3	417	442
AVERAGE	401	445

It should be noted that the measured BD of the mixed PW and DAF sludge is different to the calculated value based on the individual BDs and volumetric fractions. The calculated BD of the mixture is 410 kg/m^3. The higher measured BD of the mixture is attributed to the fact that the DAF sludge "binds" the long fibres in the PW (which cause the lower BD of this material) into a denser matrix and thus produces a higher BD of the mixture.

The wood waste and PW + DAF sludge were analysed, in triplicate, by Australian Laboratory Services (ALS). The average value results of these analyses are shown in Table 4.3. The detailed analytical reports prepared by ALS are shown in Appendix 8.1.

Table 4.3: Fuel characteristics

Parameter	Units	Average Wood waste Value	Average PW + DAF Value
TS	%	46.8	26
Ash	% of TS	0.3	8
Carbon	% of TS	49.7	50.1
Hydrogen	% of TS	5.5	6.1
Nitrogen	% of TS	<0.1	2.6
Oxygen	% of TS	44.6	33.3
Sulphur	% of TS	0.1	0.2
Gross Calorific Value	GJ/dry tonne	19.4	20.9
Net Calorific Value	GJ/dry tonne	18	19.5
Aluminium	mg/kg	<50	477
Calcium	mg/kg	193	5990
Iron	mg/kg	177	1617
SiO_2	mg/kg	2,433	38,600
Chromium	mg/kg	0.4	6.5
Copper	mg/kg	0.6	44
Nickel	mg/kg	0.2	4
Lead	mg/kg	0.2	1
Zinc	mg/kg	5.5	167

The total solids values for the two fuels were lower than what were expected. It was expected that the wood waste TS value would be above 50% and the PW+DAF TS would be at least 35%, since this is the value that would be expected from well operated screw presses and centrifuges.

Duplicate samples of separate PW and DAF sludge were collected on the 19th March 2012, the day before the combustion trials and were also analysed for the parameters as identified in Table 4.3. The average values of these analyses are shown in Table 4.4.

Table 4.4: PW and DAF sludge characteristics

Parameter	Units	Average PW Value	Average DAF sludge Value
TS	%	20.4	31.9
Ash	% of TS	5.9	8.4
Carbon	% of TS	48.6	53.1
Hydrogen	% of TS	5.5	6.7
Nitrogen	% of TS	0.7	3.9
Oxygen	% of TS	39.5	27.1
Sulphur	% of TS	0.1	0.2
Gross Calorific Value	GJ/dry tonne	18.9	23.5
Net Calorific Value	GJ/dry tonne	17.5	22.1
Aluminium	mg/kg	125	700
Calcium	mg/kg	2405	5925
Iron	mg/kg	615	2295
SiO_2	mg/kg	51,300	57,700
Chromium	mg/kg	7.8	8.4
Copper	mg/kg	29.2	66.7
Nickel	mg/kg	3	5.7
Lead	mg/kg	0.3	2.5
Zinc	mg/kg	93	153

The average PW TS was only 20.4%, which is significantly lower than what would be expected to be achieved from a well operated screw press. The DAF sludge TS of 31.9% is deemed reasonable. The theoretical TS of the PW and DAF sludge blend, based on the individual waste TS data is calculated to be 26.9%, close to the measured value of 26%. The value of the other measured parameters for the blended PW and DAF mix are generally consistent with the measured parameters for the individual waste streams. The exceptions are for zinc, where the theoretical value is 115 compared to a measured value of 167 mg/L for the blended waste stream and silica, where the theoretical value is 53,600 compared to the measured value of 38,600 mg/L.

The ash contents of the two fuels were as expected, with the PW+DAF ash content being about 26 times higher than the wood waste value. This will increase the amount of ash produced from the boiler when PW+DAF is co-combusted. The high ash in the PW+DAF is composed primarily of sand (silica). The PW+DAF GCV value was higher than that of the wood waste primarily due to the higher GCV of the DAF sludge. It should be noted that the DAF sludge GCV is lower than that typically measured for DAF sludge (about 35 GJ/dry tonne) due primarily to the high content of PW in the DAF sludge at Longford. The PW+DAF has much higher levels of nitrogen and slightly higher levels of sulphur than the wood waste which could have an impact on NOx and SOx emissions from the boiler when co-combusting PW+DAF. These nitrogen and sulphur levels are however not likely to cause any increased corrosion in the boiler (see results of emissions testing in section 4.7.2). The triplicate calorific values for the fuels were consistent and the average values reported in Table 4.3 are considered reasonable.

The PW+DAF sludge has significantly higher levels of metals such as aluminium, calcium and iron compared to wood waste. These again reflect the higher ash content of the PW+DAF. The levels of copper and zinc are also significantly higher in the PW+DAF sludge than the wood waste, 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 and do not pose a problem, from a regulatory viewpoint.

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 0.1763 m^3 (950 mm by 290 mm by 640 mm). The frequency of ram pushes can be varied to control the feed rate, expressed as Feed Rate Percent. Since there was no counter on the ram at Longford, the number of ram pushes for each trial was monitored manually. For the control combustion trial, there were 41 pushes per hour resulting in a feed rate of 7.229 m^3/h and 43 pushes per hour for the co-combustion trial, resulting in a feed rate of 7.405 m^3/h.

Control combustion trial results

This trial was conducted as the control, feeding only wood waste as the fuel. The trial was done at a wood waste feed rate of 7.229 m^3/h, which based on the measured bulk density of the wood waste, equates to a mass feed rate of 2.904 tonnes per hour. The trial commenced at 11.30 am and was completed at 12:30 pm. Boiler operating conditions and performance data was averaged during this time frame, using the “averaging” function on the CITECT SCADA control panel.

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 wood waste 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 1.0 h test are shown in Table 4.5.

Table 4.5: Boiler performance during controlled wood waste combustion trial

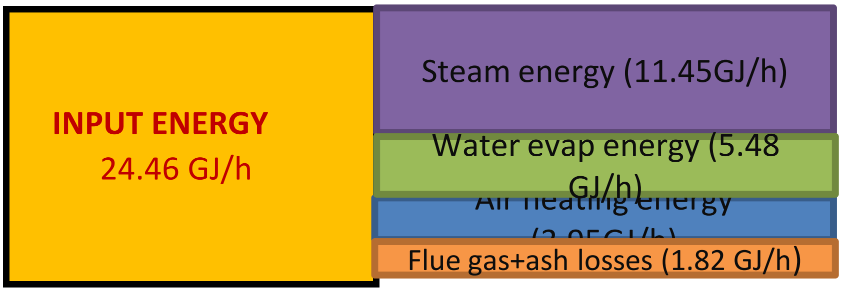
Parameter	Units	Average Value
Wet sawdust fed	m^3/h	7.229
Wet sawdust fed	kg/h	2,904
Dry sawdust fed	kg/h	1,359
Water fed	kg/h	1,545
Energy input	GJ/h	24.46
Steam output	kg/h	4,143
Steam pressure	kPa	780
Steam enthalpy	GJ/t	2.763
Steam energy output	GJ/h	11.45
Energy use per tonne steam	GJ/t steam	5.90
Boiler efficiency	%	46.8
Combustion temperature	^0C	746
Stack temperature	^0C	221
Ash output	kg/h	16.1

Based on the sawdust TS and NCV values it is calculated that the dry sawdust feedrate over the combustion trial was 1,359 kg/h and the energy input was 24.46 GJ/h. The water feed to the boiler was 1,545 kg/h. Based on the measured steam output and its enthalpy value it is calculated that the energy output, as steam, was 11.45 GJ/h. This gives an overall boiler efficiency of only 46.8%, which is considered low for this type of boiler; however, it must be remembered that there is no air pre-heater or economiser on this boiler. Also, the specific energy use per tonne of steam produced is calculated at 5.90 GJ/tonne. Finally, based on the measured ash content of the sawdust it is estimated that the ash generation rate was 3.62 kg/h. However, based on the measured loss on ignition of the ash (see section 4.6.3) the actual amount of ash produced is estimated at 16.1 kg/h.

The major energy losses from this boiler are associated with the energy required to heat the combustion air, to vaporise and heat the feed water, and that lost in the flue gas and ash. The combustion air mass is calculated based on the ETC stack dry gas mass flow rate minus the wood waste feed rate. Note that the stack temperature of 221 ^0C, as measured by ETC, rather than the boiler SCADA value of 327 ^0C, was used to calculate the energy lost in the flue gas (see data in Table 4.5). Based on the ash VS value of 77.43%, its energy content has been estimated at 18.7GJ/t. When these known losses are subtracted from the input fuel energy value, there is only a small difference between the actual steam energy (11.45 GJ/h) and that available for use to generate steam (13.21 GJ/h), leaving 1.76 GJ/h of energy unaccounted for. This is shown schematically as a Sankey energy diagram in Figure 4.8.

It must be emphasised that the low boiler temperature (only 746 ^0C) together with the high unburnt carbon in the ash and the low oxygen level in the flue gas strongly indicates that this combustion test was conducted under oxygen limiting conditions. This may well have been due to a replacement ID fan being installed prior to the combustion trial (for more on this see section 4.6.2 below).

Figure 4.8: Sankey energy diagram for the control combustion trial



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. A picture of this stack emission testing is shown in Figure 4.9. The photo shows the sampling equipment inserted into the two ports on the stack. Iso-kinetic emission samples were collected from 11:30 am to 12:30 pm.

Figure 4.9: Stack emission testing photograph

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 4.6 and are discussed below.

The flow rate and concentration data in Table 4.6 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 221 ^{0}C, was 220 m3/min and included 21% by volume of water vapour. The concentration of total organic compounds or Volatile Organic Compounds (VOCs) is expressed as n-propane.

Table 4.6: Summary of stack emission testing results

Parameter	Emission value	Mass emission rate (g/min)
Temperature (^{0}C)	221	
Dry Flow rate (m^3/min)	94	
NOx (mg/m^3)	130	12
SOx (mg/m^3)	<0.9	<0.09
CO (mg/m^3)	1400	130
Total particulates (mg/m^3)	580	55
Total organic compounds (mg/m^3)	37	3.5
PAHs (µg/m^3 as TEQ)	0.84	
CO_2 (%)	14	
O_2 (%)	6.5	

The average CO value of 1400 mg/m^3 is regarded as being higher than would be expected for good combustion conditions. This is corroborated by the relatively low oxygen content of only 6.5%, which may also explain the relatively low combustion temperature of only 746 ^{0}C. A CO value of less than 100 mg/m^3 is what is regarded as a good emission level. The boiler may have been operating with a limited air supply, since the main ID fan malfunctioned the night before this trial and was replaced with a stand-by fan. Similarly the total particulate emission of 580 mg/m^3 is regarded as being higher than would be expected for good combustion conditions. This value exceeds the current EPA licence conditions for the boiler. The SOx, NOx, and VOC emission data as measured by ETC is regarded as being very good. The measured Polycyclic Aromatic Hydrocarbon (PAH) emission value of 2.7 µg/m^3, expressed as the Benzo-a-pyrene Toxicity Equivalence (TEQ) value, is regarded as good.

Ash quality data

As mentioned previously, the ash collected is fly ash which is removed from the flue gas by a water scrubber and shaker sieve system. This is shown in the photograph in Figure 4.10. The fly ash was completely black indicating a significant amount of unburnt carbon being present, again supporting the view that the boiler was operating under oxygen limited conditions.

The average quality of the ash, as analysed by ALS, is shown in Table 4.7. Detailed ash data from ALS is shown in Appendix 8.1.

Figure 4.10: Photograph of wet fly ash recovery system

Table 4.7: Average ash quality data

Parameter	Units	Average Value
TS	%	20.1
Loss on Ignition (LOI)	% of TS	77.43
SO_4	mg/kg dry ash	1727
Chlorides	mg/kg dry ash	187
SiO_2	% of dry ash	6.7
CaO	% of dry ash	NM
Al_2O_3	% of dry ash	3.5
Fe_2O_3	% of dry ash	1.9
MgO	% of dry ash	0.77
Na_2O	% of dry ash	0.35
K_2O	% of dry ash	0.8
P_2O_5	% of dry ash	0.56

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 12.48 kg/h. The mineralogy data is shown on a dry ash 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 not be an ash melting issue in the boiler. Even without the CaO analysis there is a good closure on the ash analysis with the sum of the constituents amounting to 92 %. A silica balance across the combustor shows that 33% is recovered in the ash.

Co-combustion trial results

This trial was conducted to assess the impact of co-combustion of dewatered paunch waste and DAF sludge (PW+DAF) with the conventional wood waste fuel. To obtain steam outputs similar to those of the control trial, fuel feed rates had to be increased slightly from 41 to 42 ram pushes per hour, giving an average feed rate during the co-combustion trial of 7.405 m^3/h. The volume of dewatered PW+DAF fed during the one-hour trial was 0.8 m^3, or one full feed hopper (see figure

4.5). This PW+DAF feed rate was slightly higher than the average 24h/d abattoir production figure of 0.65 m^3/h.

The trial commenced at 1:30 pm and was completed at 2:30 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.

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 wood waste and PW+DAF 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 60 minute test are shown in Table 4.8.

Table 4.8: Boiler performance during the co-combustion trial

Parameter	Units	Average Value
Wet wood waste fed	m^3/h	6.605
Wet wood waste fed	kg/h	2,653
Dry wood waste fed	kg/h	1,242
Wet PW+DAF fed	m3/h	0.8
Wet PW+DAF fed	kg/h	356.27
Dry PW+DAF fed	kg/h	92.51
Water fed	kg/h	1,675
Wood waste Energy Input	GJ/h	22.35
PW+DAF Energy Input	GJ/h	1.8
Total Energy input	GJ/h	24.15
Steam output	kg/h	3,809
Steam pressure	kPa	831
Steam enthalpy	GJ/t	2.768
Steam energy output	GJ/h	10.54
Energy use per tonne steam	GJ/t steam	6.34
Boiler efficiency	%	43.65
Combustion temperature	^{0}C	701
Stack temperature	^{0}C	246
Ash output	kg/h	45.2

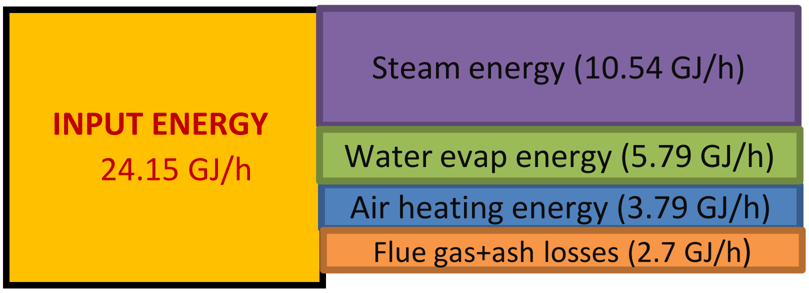
As indicated in Table 4.8, the co-combustion trial was run at a lower steam output value than the control combustion trial. The dry wood waste feedrate was decreased to an average value of 1,242 kg/h compared to 1,359 kg/h during the control trial. The average dry PW+DAF feed rate during the trial was 92.5 kg/h and the average water input increased to 1,675 kg/h compared to 1,545 kg/h for the control trial. Total energy input during the co-combustion trial averaged 24.15 GJ/h compared to 24.46 GJ/h for the control trial. The energy input from the paunch waste was 1.8 GJ/h or 7.5% 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 10.54 GJ/h. This gives an overall boiler efficiency of only 43.65%, 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 6.34

GJ/tonne, which is slightly higher than that measured for the control combustion trial. Finally, based on the measured ash contents of the sawdust and the PW+DAF the estimated ash generation rate was calculated to be 11.13 kg/h. However, based on the measured loss on ignition of the ash (see section 4.7.3) the actual amount of ash produced is estimated at 45.2 kg/h.

The major energy losses from this boiler are associated with the energy required to heat the combustion air, to vaporise and heat the feed water, and that lost in the flue gas and ash. The combustion air mass is calculated based on the ETC stack dry gas mass flow rate minus the wood waste and PW+DAF feed rate. Note that the stack temperature of 246 ^{0}C, as measured by ETC, rather than the boiler SCADA value of 320 ^{0}C, was used to calculate the energy lost in the flue gas (see data in Table 4.9). Based on the ash VS value of 76.2%, its energy content has been estimated at 18.4 GJ/t. When these known losses are subtracted from the input fuel energy value, there is only a small difference between the actual steam energy (10.54 GJ/h) and that available for use to generate steam (11.89 GJ/h), leaving 1.35 GJ/h of energy unaccounted for. This is shown schematically as a Sankey energy diagram in Figure 4.11.

It must be emphasised that the low boiler temperature (only 701 ^{0}C) together with the high unburnt carbon in the ash and the low oxygen level in the flue gas strongly indicates that this combustion test was conducted under oxygen limiting conditions. This may well have been due to a replacement ID fan being installed prior to the combustion trial (for more on this see section 4.7.2 below).

Figure 4.11: Sankey energy diagram for the co-combustion trial



Based on the PW+DAF characteristics used in this co-combustion trial, it is calculated that one tonne of dewatered PW+DAF (at a TS of 26%) generates 0.94 tonnes of steam at a pressure of 831 kPa. This is calculated by dividing the usable energy in the paunch waste (2.55 GJ/wet tonne) by the steam energy (2.7688 GJ/t). The usable paunch waste energy is the NCV value (5.07 GJ/wet tonne) minus that used to evaporate the water and raise the temperature to 701 ^{0}C (2.52 GJ/wet tonne).

Stack emission data

Stack emission samples were collected between 1:30 pm and 2:30 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 246 ^{0}C, was 320 m^3/min and included 22% 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 (^0C)	246	
Dry Flow rate (m^3/min)	130	
NOx (mg/m^3)	290	38
SOx (mg/m^3)	40.8	5.4
CO (mg/m^3)	880	110
Total particulates (mg/m^3)	56	7.3
Total organic compounds (mg/m^3)	30	4
PAHs ($\mu g/m^3$ as TEQ)	0.77	
CO_2 (%)	13.1	
O_2 (%)	7.1	

The average CO value of 880 mg/m^3, while lower than that measured in the control combustion trial, is regarded as being higher than would be expected for good combustion conditions. This is corroborated by the relatively low oxygen content of only 7.1%, which may also explain the relatively low combustion temperature of only 701 ^0C. A CO value of less than 100 mg/m^3 is what is regarded as a good emission level. As indicated previously, the boiler may have been operating with a limited air supply, since the main ID fan malfunctioned the night before this trial and was replaced with a stand-by fan. The total particulate emission of 56 mg/m^3 is regarded as being very good for this combustor. The NOx emission value of 290 mg/m^3 is roughly twice that measured for the control combustion trial and the SOx emission value of 40.8 mg/m^3 is about 40 times higher than that measured during the control combustion trial. This is most likely due to the significantly higher feed N and S values, associated with the PW+DAF fed to the boiler. Nonetheless these emission values are regarded as being acceptable from a regulatory viewpoint. The PAH and VOC emission data as measured by ETC are regarded as being very good and are slightly lower than the values measured in the control combustion trial.

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	%	17.8
Loss on Ignition (LOI)	% of TS	76.2
SO_4	mg/kg dry ash	1987
Chlorides	mg/kg dry ash	183
SiO_2	% of dry ash	8.4
CaO	% of dry ash	NM
Al_2O_3	% of dry ash	3.6
Fe_2O_3	% of dry ash	1.9
MgO	% of dry ash	0.8
Na_2O	% of dry ash	0.5
K_2O	% of dry ash	0.8
P_2O_5	% of dry ash	1

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 34.1 kg/h. The mineralogy data is shown on a dry ash basis. This analysis of the ash shows that it is similar to the controlled combustion ash (see Table 4.7) with the exception of higher concentrations of silica and phosphates (P_2O_5). This is attributed to higher levels of these parameters in the paunch waste. Even without the CaO analysis, there is a good closure on the ash analysis with the sum of the constituents amounting to 93%. A silica balance across the combustor shows that 57% is recovered in the ash.

Impacts of co-combustion

These full-scale combustion trials demonstrated no operational impacts from PW+DAF co-combustion when the boiler was operated with 7.5% of its input energy being derived from dewatered PW+DAF. This PW+DAF energy input was higher than the typical waste generation rate at the Longford abattoir. It should be noted that these trials were conducted with a PW+DAF TS value of 26%, which is regarded as at the lower end of what should be achieved by optimised screw press and centrifuge dewatering operations. As such this trial can be considered as a "worst case" scenario for PW+DAF co-combustion, especially when taking into account that the PW+DAF firing rate was about 23% higher than it should have been.

Only some minor environmental impacts were observed with co-combustion of PW+DAF when the boiler was operated with 7.5% of its input energy being derived from dewatered PW+DAF. Under this level of waste input to the boiler there was a doubling of NOx and a forty-fold increase in SOx emission rates, but the emission concentrations were still well within regulatory guidelines. Whilst there was a minor deterioration in combustion efficiency when operating under co-combustion conditions, emissions of CO, particulates, PAHs and organic compounds were much lower than for the control combustion conditions. The reason(s) for this are unknown but it was stated by the boiler operator that they were having difficulty controlling the boiler during the control combustion test.

Due to the higher ash content of the PW and DAF sludge, co-combustion of this material will increase ash generation rates. Ash generation is expected to almost triple compared to control combustion conditions, when co-combustion with a 7.5% energy input from PW+DAF is practised. Ash generation rates, for the same energy input scenarios (~24 GJ/h) increased from 16 kg/h for the control combustion trial to 45 kg/h for the co-combustion trial. Co-combustion had only a minor impact on ash quality.

The GHG impacts of co-combustion of dewatered PW+DAF were in this case neutral, since the waste replaced another renewable energy fuel, namely wood waste. Had the boiler been fired with a fossil fuel, then GHG credits could apply, depending on the total GHG emissions from the abattoir 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.

Co-combustion cost benefit analysis

This cost benefit analysis (CBA) is based on an abattoir similar to one at Longford. That is, an abattoir with a typical kill rate of 300 cattle and 900 sheep per day. Such an abattoir generates about 10 m^3/d of dewatered paunch waste and 5.6 m^3/d of dewatered DAF sludge. For the purposes of this CBA it is assumed the two wastes are co-dewatered and the resulting dewatered product has a TS of 30%. It is assumed that the boiler operates 24 hours per day, 5 days per week, has a steam output of 5 tph and the primary fuel is wood waste. It is also assumed, that unlike the results achieved in the Longford combustion trials, the boiler efficiency is 70%, which is typical of well operated boilers burning wood waste as the primary fuel. Thus for a 5 tph steam output, the input fuel requirement is 19.97 GJ/h. In addition it is assumed that the ash produced from combustion has a loss on ignition of 5%, again representing good combustion conditions.

No new boiler required

This section of the PW+DAF co-combustion CBA is based on the assumption that the existing boiler is suitable for co-combustion of a combined dewatered stream of PW plus DAF sludge, as was demonstrated using the Longford boiler.

Capital cost expenditures for this CBA are thus limited to supply and installation of a PW+DAF screw press for dewatering and a dewatered PW+DAF storage and feed systems to the existing boiler. These capital cost estimates have been estimated by Bridle Consulting but are based heavily on the costs provided by Wingham Beef Exports for their system recently installed at the Wingham abattoir. 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 (wood waste) costs and avoided paunch waste and DAF sludge disposal costs. A summary of the input data to the CBA are shown in Table 4.11. To be consistent with the CBA conducted for the earlier PW co-combustion trial[2], the costs for waste disposal and fuel purchases are the same as were used in that previous study.

As shown in Table 4.11, the co-combustion CBA is based on combusting 6.94 tpd of dewatered paunch waste at a TS of 30 % and 48.74 tpd of wood waste at a TS of 50 %. The control combustion is based on combusting only 53.25 tpd of wood waste. The costs for purchase of wood waste and disposal of PW+DAF 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	5	5
Boiler operating hours	hours/day	24	24
Boiler thermal input	GJ/h	19.97	19.97
Wet PW+DAF mass	tpd	6.94	6.94
Dry PW+DAF input	tph	0	0.087
PW+DAF energy input	GJ/h	0	1.69
Wood waste energy input	GJ/h	19.97	18.28
Dry wood waste input	tph	1.11	1.02
Wet wood waste input	tpd	53.25	48.74
Ash disposal mass	tpd	0.084	0.252
Ash disposal cost	$/tonne	20	20
PW+DAF disposal cost	$/tonne	15	
Wood waste 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 PW+DAF co-combustion in existing boilers is shown in Table 4.12.

Table 4.12: CBA for PW+DAF co-combustion in existing boilers

Parameter	Units	CBA value
Capital cost estimate	$	165,000
Increased maintenance cost	$/a	6,600
Increased ash disposal cost	$/a	839
Decreased PW+DAF disposal cost	$/a	26,033
Decreased wood waste purchase cost	$/a	39,483
Net O&M cost	$/a	-58,076
Simple pay-back period	years	2.8
20-year NPV	$	-450,024

This CBA for dewatered PW+DAF co-combustion in existing boilers indicates that the economics are attractive, even for mid-size abattoirs processing a mix of cattle and sheep. 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 3 years, due to the operational savings realised via co-combustion. As can be seen the reductions in fuel costs amount to $39,483 per year and reductions in PW+DAF disposal costs amount to $26,033 per year. The NPV value shows that over a 20 year period a positive cash flow of $450,024 can be expected via adoption of co-combustion of dewatered PW+DAF in existing boilers suitable for this duty. Or put another way, operating savings of $75.63/dry tonne of PW+DAF combusted are achieved based on reduced wood waste costs and savings of $49.87/dry tonne of PW+DAF combusted are achieved based on reductions in PW+DAF disposal costs. When one takes into account the increased maintenance and ash disposal costs, net operating savings of $111/dry tonne of PW+DAF combusted are achieved via co-combustion. This is very similar to the value achieved by co-combustion of PW alone ($128/dry tonne PW) as reported in the previous co-combustion trial[2].

The economics will likely be even more attractive for coal-fired boilers, since the cost of energy is higher than for wood waste. In addition, since coal is a non-renewable fossil fuel, this option would also likely attract credits once the 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 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 by the red meat industry in Australia.

New boiler required

This scenario is based on the assumption that an abattoir processing 300 cattle and 900 sheep per day currently combusting coal now wishes to switch to combust renewable fuels, namely wood waste and dewatered PW+DAF. Thus a new boiler suitable to combust biomass is installed together with a PW+DAF dewatering screw press installation. The capital cost for a new 5 tph steam output boiler is estimated at $1.9 million and the screw press installation cost is estimated at $100,000, bringing total capital expenditure to $2 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 PW+DAF disposal costs, reductions in fuel costs by changing from coal to wood waste and finally, potentially a carbon tax credit for avoided fossil fuel use. Note that in this scenario the CO_2 emissions from coal combustion alone amount to 16,500 tpa and thus the carbon tax threshold value of 25,000 tpa would probably be met for such an abattoir. For this CBA the current 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 wood waste and dewatered PW+DAF 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 3 years, which is attractive. In addition the CBA shows that over a 20 year period cost savings of $5.39 million can be realised. Furthermore this scenario generates GHG credits of 16,475 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. Should the abattoir not be eligible for carbon tax credits then the payback period increases to 6 years and the 20 year cost savings are reduced to $1,378,182.

Table 4.13: CBA input data, new boiler (coal to wood waste plus PW+DAF)

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	19.97	19.97
Wet PW+DAF mass	tpd	6.94	6.94
Dry PW+DAF input	tph	0	0.087
PW+DAF energy input	GJ/h	0	1.69
Coal/wood waste energy input	GJ/h	19.97	18.28
Dry coal or wood waste input	tph	1	1.02
Wet wood waste input	tpd	0	48.74
Ash disposal mass	tpd	1.68	0.25
Ash disposal cost	$/tonne	20	20
PW+DAF disposal cost	$/tonne	15	
Wood waste or coal cost	$/tonne	120	35
Carbon tax	$/tonne CO_2	23	
Operating days per year	number	250	250
Maintenance cost	% capex		4
NPV discount factor			10.59

Table 4.14: CBA for PW+DAF co-combustion in a new boiler

Parameter	Units	CBA value
Capital cost estimate	$	2,000,000
Increased maintenance cost	$/a	6,600
Decreased ash disposal cost	$/a	7,129
Decreased PW+DAF disposal cost	$/a	26,063
Cost credit, coal to wood waste	$/a	292,436
Carbon tax credit	$/a	378,931
Net O&M cost	$/a	-697,928
Simple pay-back period	years	3
20-year NPV	$	-5,391,058

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 PW+DAF co-combustion to be rigorously assessed. The cost benefit analysis was successfully completed and showed that co-combustion of dewatered PW+DAF 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 appealing, provided that carbon credits apply.

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

The results from this full-scale paunch waste plus DAF sludge co-combustion trial strongly support this method for management these wastes at abattoirs that already have boilers suitable for co-combustion. Due to the significant economic advantages of dewatered PW+DAF co-combustion it is very likely that many abattoirs with boilers suitable to co-combust these wastes will proceed with this practise as soon as practical. This is particularly true for abattoirs with cattle kill rates of 600 head per day or more or larger abattoirs that co-process cattle and sheep. Whilst there is no data base currently available to indicate how many abattoirs in Australia have boilers suitable for PW+DAF co-combustion, it is conservatively estimated that 10 to 20 abattoirs would be able to co-combust these wastes in their existing boilers. On this assumption it is conservatively estimated that if these abattoirs adopted PW+DAF co-combustion that economic benefits of between $1.1 and $2.2 million per annum could be realised within the Australian red meat industry, assuming an equal split between cattle only and cattle plus sheep abattoirs. This value would increase over time as older boilers not suitable to co-combust dewatered PW+DAF are replaced with new boilers suitable for this duty. Replacement of coal-fired boilers with biomass-fired boilers which co-combust PW+DAF looks relatively attractive and abattoirs should evaluate this boiler upgrade option in more detail.

7. Conclusions and recommendations

Conclusions

Based on the outcomes of this full-scale dewatered PW plus DAF sludge co-combustion trial the following conclusions are drawn:

1. Due to equipment issues the PW and DAF sludge co-dewatering trial at Longford was not successful. Consequently the co-combustion trial was conducted with separately dewatered PW and DAF sludge.
2. There was no impact on boiler combustion performance when co-fired with 7.5% of its energy input as dewatered PW+DAF, with a TS of 26%. This firing rate is 23% higher than the daily average waste generation rate at the abattoir.
3. At this co-firing rate there were minor environmental impacts, the notable ones being increases in atmospheric emissions of NOx and SOx. Whilst the mass emission rates for NOx doubled and SOx increased 40-fold, the stack gas concentrations were still well within regulatory guidelines.
4. Co-firing with 7.5% of the boiler input energy being derived from dewatered PW+DAF tripled the ash generation rate.
5. Co-firing of dewatered PW+DAF 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 300 head of cattle and 900 head of sheep per day abattoir, the net economic benefit, over a 20-year period, is $450,000.
6. Replacing existing coal-fired boilers with boilers suitable to co-fire biomass and PW+DAF offer long-term economic benefits. The return on the capital investment meets the typical industry requirement of 3 years if carbon tax credits are available and the net economic benefit, over a 20-year period, for a 300 head of cattle and 900 head of sheep per day abattoir, is estimated at $5.39 million. If carbon tax credits are not available the payback period increases to 6 years and the net economic benefit over a 20 year period is reduced to $1.38 million.

Recommendations

It is recommended that MLA support additional paunch waste and DAF sludge co-dewatering studies to identify suitable dewatering equipment which maximises dewatered product solids content. Such improved dewatering operations will have a major positive impact on co-combustion economics.

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 and DAF sludge.

8. Appendices

Appendix 1: ALS analytical reports

Page : 3 of 6
Work Order : EB1208184
Client : MEAT & LIVESTOCK AUSTRALIA
Project : A ENV 0 0126

Analytical Results

Sub-Matrix: SOIL			Client sample ID	PW1	PW2	DAF1	DAF2	WW1
			Client sampling date / time	19-MAR-2012 15:00	19-MAR-2012 15:00	19-MAR-2012 16:00	19-MAR-2012 16:00	20-MAR-2012 11:30
Compound	CAS Number	LOR	Unit	EB1208184-001	EB1208184-002	EB1208184-003	EB1208184-004	EB1208184-005
EA030: Total Solids								
Total Solids	----	0.1	%	21.4	19.3	35.8	28.0	47.0
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	78.6	80.7	64.1	72.0	53.0
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	90	160	710	690	<50
Iron	7439-89-6	50	mg/kg	240	990	2520	2070	200
Calcium	7440-70-2	50	mg/kg	2750	2060	6930	4920	220
EG020T: Total Metals by ICP-MS								
Chromium	7440-47-3	0.1	mg/kg	5.5	10.0	6.5	10.3	0.4
Copper	7440-50-8	0.1	mg/kg	5.0	8.3	76.4	56.9	0.7
Nickel	7440-02-0	0.1	mg/kg	1.2	4.8	5.5	5.9	0.2
Lead	7439-92-1	0.1	mg/kg	0.2	0.3	1.3	3.7	0.1
Zinc	7440-66-6	0.1	mg/kg	36.5	149	138	168	5.3

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Work Order : EB1208184
Client : MEAT & LIVESTOCK AUSTRALIA
Project : A ENV 0 0126

Analytical Results

Sub-Matrix: SOIL			Client sample ID	WW2	WW3	WWA1	WWA2	WWA3
			Client sampling date / time	20-MAR-2012 12:00	20-MAR-2012 12:30	20-MAR-2012 11:30	20-MAR-2012 12:00	20-MAR-2012 12:30
Compound	CAS Number	LOR	Unit	EB1208184-006	EB1208184-007	EB1208184-008	EB1208184-009	EB1208184-010
EA030: Total Solids								
Total Solids	----	0.1	%	46.2	47.2	----	----	----
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	53.8	52.8	75.8	82.0	81.9
ED040: Sulfur as SO4 2-								
Sulfate as SO4 2-	14808-79-8	100	mg/kg	----	----	1840	1650	1690
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	10	mg/kg	----	----	160	200	200
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	<50	<50	----	----	----
Iron	7439-89-6	50	mg/kg	180	150	----	----	----
Calcium	7440-70-2	50	mg/kg	190	170	----	----	----
EG020T: Total Metals by ICP-MS								
Chromium	7440-47-3	0.1	mg/kg	0.5	0.4	----	----	----
Copper	7440-50-8	0.1	mg/kg	0.6	0.6	----	----	----
Nickel	7440-02-0	0.1	mg/kg	0.2	0.2	----	----	----
Lead	7439-92-1	0.1	mg/kg	0.4	0.1	----	----	----
Zinc	7440-66-6	0.1	mg/kg	5.1	6.1	----	----	----

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Work Order : EB1208184
Client : MEAT & LIVESTOCK AUSTRALIA
Project : A ENV 0 0126

Analytical Results

Sub-Matrix: SOIL			Client sample ID	PD1	PD2	PD3	PDA1	PDA2
			Client sampling date / time	20-MAR-2012 13:30	20-MAR-2012 14:00	20-MAR-2012 14:00	20-MAR-2012 13:30	20-MAR-2012 14:00
Compound	CAS Number	LOR	Unit	EB1208184-011	EB1208184-012	EB1208184-013	EB1208184-014	EB1208184-015
EA030: Total Solids								
Total Solids	----	0.1	%	25.5	25.8	26.6	----	----
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	74.5	74.2	73.4	84.4	79.3
ED040: Sulfur as SO4 2-								
Sulfate as SO4 2-	14808-79-8	100	mg/kg	----	----	----	1750	2400
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	10	mg/kg	----	----	----	50	280
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	480	490	460	----	----
Iron	7439-89-6	50	mg/kg	1560	1710	1580	----	----
Calcium	7440-70-2	50	mg/kg	6210	6000	5760	----	----
EG020T: Total Metals by ICP-MS								
Chromium	7440-47-3	0.1	mg/kg	5.6	5.1	8.8	----	----
Copper	7440-50-8	0.1	mg/kg	44.4	47.8	39.1	----	----
Nickel	7440-02-0	0.1	mg/kg	3.7	3.4	5.1	----	----
Lead	7439-92-1	0.1	mg/kg	1.0	1.2	1.0	----	----
Zinc	7440-66-6	0.1	mg/kg	173	175	153	----	----

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Work Order : EB1208184
Client : MEAT & LIVESTOCK AUSTRALIA
Project : A ENV 0 0126

Analytical Results

Sub-Matrix: SOIL			Client sample ID	PDA3	----	----	----	----
			Client sampling date / time	20-MAR-2012 14:30	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	EB1208184-016	----	----	----	----
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	82.8	----	----	----	----
ED040: Sulfur as SO4 2-								
Sulfate as SO4 2-	14808-79-8	100	mg/kg	1810	----	----	----	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	10	mg/kg	220	----	----	----	----

Table 1. Proximate, Ultimate, Calorific Value Results

HRL Sample ID	Sample Description	Moist (%ar)	Ash,815°C %db	Ash,550°C %db	Carbon %db	Hydrogen %db	Nitrogen %db	Total Sulphur %db	Oxygen (by difference 815°C) %db	Gross Dry Calorific Value	Gross Wet Calorific Value	Net Wet Calorific Value
CMM/12/0365-01	PW1	10.8	5.2	5.6	49.1	5.4	0.79	0.10	39.4	18.8	16.8	15.5
CMM/12/0365-02	PW2	10.7	6.0	6.2	48.0	5.6	0.70	0.08	39.6	19.0	17.0	15.7
CMM/12/0365-03	DAF1	8.1	8.6	8.8	55.6	7.1	5.53	0.27	22.9	25.3	23.2	21.7
CMM/12/0365-04	DAF2	8.7	9.5	10.0	50.5	6.3	2.30	0.17	31.3	21.6	19.7	18.4
CMM/12/0365-05	WW1	10.4	0.2	0.4	49.8	5.6	<0.01	0.01	44.4	19.4	17.4	16.1
CMM/12/0365-06	WW2	10.2	0.3	0.2	49.5	5.5	<0.01	0.01	44.7	19.4	17.4	16.2
CMM/12/0365-07	WW3	10.1	0.2	0.2	49.7	5.5	<0.01	0.01	44.6	19.4	17.5	16.2
CMM/12/0365-08	PD1	9.1	7.9	8.0	50.4	6.2	2.68	0.16	32.7	21.7	19.7	18.4
CMM/12/0365-09	PD2	9.6	7.8	8.0	49.8	6.0	2.69	0.15	33.6	20.9	18.9	17.6
CMM/12/0365-10	PD3	9.3	7.9	8.1	50.1	6.0	2.54	0.17	33.3	20.2	18.4	17.0

SAMPLE DESCRIPTION	ME-ICP86 MgO %	ME-ICP86 Al2O3 %	ME-ICP86 Fe2O3 %	ME-ICP86 SiO2 %	ME-ICP86 Na2O %	ME-ICP86 K2O %	ME-ICP86 P2O5 %	ME-GRA05 LOI %
WWA1	1.14	3.7	2.85	10.35	0.53	1.12	0.81	73.79
WWA2	0.57	3.65	1.45	4.94	0.25	0.6	0.42	81.02
WWA3	0.59	3.14	1.41	4.82	0.27	0.67	0.44	77.49
PDA1	1.24	2.02	3	12.9	0.69	1.2	1.25	70.23
PDA2	0.62	4.75	1.61	7.31	0.45	0.66	0.85	76.63
PDA3	0.46	3.88	1.18	4.91	0.37	0.52	0.76	81.83
PW1	0.07	0.27	0.82	5.56	1.13	0.29	0.63	90.61
PW2	0.06	0.12	0.37	4.7	0.79	0.24	0.5	92.77
DAF1	0.14	0.4	0.87	4.55	0.16	0.11	1.14	91.24
DAF2	0.1	0.48	0.85	6.99	0.14	0.12	0.33	89.9
WW1	0.01	0.03	0.22	0.52	<0.01	0.03	<0.05	99.13
WW2	0.01	0.01	0.08	0.17	<0.01	0.02	<0.05	99.68
WW3	0.01	0.01	0.05	0.04	<0.01	<0.01	<0.05	99.87
PD1	0.13	0.33	0.75	3.84	0.52	0.15	0.84	92.25
PD2	0.14	0.2	0.6	3.34	0.63	0.18	0.78	93.27
PD3	0.13	0.36	0.75	4.4	0.44	0.19	1.06	91.22

Appendix 2: ETC stack emissions report

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: 24 April 2012

Report No: 120082r

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

Emission Testing – March 2012
Alternative Fuel Trials – Longford Abattoir

Dear Mr Trevor Bridle,

Tests were performed 20 March 2012 to determine emissions to air from the Boiler at the Longford Abattoir, Tasmania, under two different operating conditions.

Yours faithfully
Emission Testing Consultants

Ben Minchinton BSc
Field Consultant

bm@emission.com.au

Report prepared for:
Bridle Consulting

Date: 24 April 2012
Report No: 120082r
Page: 3 of 9

RESULTS

Boiler – Normal Fuel

20 March 2012

Flow Results	Measured MW		Boiler - Normal Op 120082
Time of flow test		1100 & 1235	hrs
Stack dimensions at sampling plane		945	mm
Velocity at sampling plane		5.2	m/s
Average temperature		221	°C
Moisture content	Method4	21	% v/v
Flow rate at discharge conditions		220	m³/min
Flow rate at wet NTP conditions		120	m³/min
Flow rate at dry NTP conditions		94	m³/min

Continuous Analyser Results (Boiler - Normal Op 120082 94)	Sampling Times	Concentration at NTP		Mass rate	
Oxygen (dry basis)	1140-1240	6.5	% v/v	-	
Carbon dioxide (dry basis)	1140-1240	14.0	% v/v	1,500	kg/hour
Dry gas density	1140-1240	1.4	kg/m3	-	
Molecular weight of stack gas, dry basis	1140-1240	31	g/g-mole	-	
Nitrogen oxides as NO_2	1140-1240	130	mg/m3	12	g/min
Carbon monoxide as CO	1140-1240	1,400	mg/m3	130	g/min
Total organic compounds as n-hexane	1135-1235	37	mg/m3	3.5	g/min

Boiler – Normal Fuel

20 March 2012

Isokinetic Sampling Results (Boiler - Normal Fuel 120082 94)	Sampling Times	Concentration at NTP			Mass rate		
Sulphur dioxide (as SO_2)	1135-1235	<	0.2	mg/m3	<	0.02	g/min
Sulphur trioxide (as SO_3)	1135-1235	<	0.7	mg/m3	<	0.07	g/min
Particulate matter	1135-1235		580	mg/m3		55	g/min
PAH's (total TEQ as BaP, mediumbound)	1135-1235		0.84	$\mu g/m^3$		0.079	mg/min

Polycyclic Aromatic Hydrocarbon (PAH) Results (Boiler - Normal Fuel 120)

Stack Identification : **Boiler - Normal Fuel - Test 1**

Sample time, hrs: **1135-1235 hrs , 20/Mar/12**

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	130	12	-	-	-
2-Methylnaphthalene	9.1	0.86	-	-	-
Acenaphthylene	9.9	0.93	-	-	-
Acenaphthene	1.3	0.12	-	-	-
Fluorene	2.4	0.22	-	-	-
Phenanthrene	17	1.6	0.0005	0.0085	0.00080
Anthracene	1.1	0.10	0.0005	0.00055	0.000052
Fluoranthene	5.8	0.55	0.05	0.29	0.027
Pyrene	3.5	0.33	0.001	0.0035	0.00033
Benzo(a)anthracene	0.26	0.024	0.005	0.0013	0.00012
Chrysene	1.1	0.11	0.03	0.034	0.0032
Benzo(b)fluoranthene	0.33	0.031	0.1	0.033	0.0031
Benzo(k)fluoranthene	0.24	0.022	0.05	0.012	0.0011
Benzo(e)pyrene	0.27	0.026	0.002	0.00055	0.000052
Benzo(a)pyrene	0.42	0.040	1.0	0.42	0.040
Perylene	< 0.04	< 0.003	-	-	-
Indeno(1,2,3-cd)pyrene	0.088	0.0082	0.1	0.0088	0.00082
Dibenzo(a,h)anthracene	< 0.04	< 0.003	1.1	< 0.04	< 0.004
Benzo(g,h,i)perylene	0.13	0.012	0.02	0.0025	0.00024
Total	**180** Lower* / **180** Medium*	**17** Lower* / **17** Medium*		**0.82** Lower* / **0.84** Medium*	**0.077** Lower* / **0.079** 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)

Boiler – Alternative Fuel

20 March 2012


Flow Results	Measured MW		Boiler - Alternative Fuel 120082
Time of flow test		1315 & 1445	hrs
Stack dimensions at sampling plane		945	mm
Velocity at sampling plane		7.6	m/s
Average temperature		246	°C
Moisture content	Method4	22	% v/v
Flow rate at discharge conditions		320	m³/min
Flow rate at wet NTP conditions		170	m³/min
Flow rate at dry NTP conditions		130	m³/min

Continuous Analyser Results (Boiler - Alternative Fuel 120082 130)	Sampling Times	Concentration at NTP		Mass rate	
Oxygen (dry basis)	1332-1432	7.1	% v/v	-	
Carbon dioxide (dry basis)	1332-1432	13.1	% v/v	2,000	kg/hour
Dry gas density	1332-1432	1.3	kg/m3	-	
Molecular weight of stack gas, dry basis	1332-1432	30	g/g-mole	-	
Nitrogen oxides as NO_2	1332-1432	290	mg/m3	38	g/min
Carbon monoxide as CO	1332-1432	880	mg/m3	110	g/min
Total organic compounds as n-hexane	1340-1440	30	mg/m3	4.0	g/min

Boiler – Alternative Fuel

20 March 2012

Isokinetic Sampling Results (Boiler - Alternative Fuel 120082 130)	Sampling Times	Concentration at NTP		Mass rate	
Sulphur dioxide (as SO2)	1340-1440	35	mg/m3	4.6	g/min
Sulphur trioxide (as SO3)	1340-1440	5.8	mg/m3	0.75	g/min
Particulate matter	1340-1440	56	mg/m3	7.3	g/min
PAH's (total TEQ as BaP, mediumbound)	1340-1440	0.77	µg/m³	0.100	mg/min

Polycyclic Aromatic Hydrocarbon (PAH) Results (Boiler - Alternative Fuel)

Stack Identification : **Boiler - Alternative Fuel - Test 1**

Sample time, hrs: **1340-1440 hrs , 20/Mar/12**

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		72		9.4	-		-		-
2-Methylnaphthalene		6.0		0.78	-		-		-
Acenaphthylene		4.9		0.64	-		-		-
Acenaphthene		0.65		0.085	-		-		-
Fluorene		1.5		0.20	-		-		-
Phenanthrene		11		1.4	0.0005		0.0054		0.00071
Anthracene		0.68		0.089	0.0005		0.00034		0.000044
Fluoranthene		5.2		0.67	0.05		0.26		0.034
Pyrene		3.0		0.39	0.001		0.0030		0.00039
Benzo(a)anthracene		0.37		0.048	0.005		0.0018		0.00024
Chrysene		1.1		0.15	0.03		0.033		0.0044
Benzo(b)fluoranthene		0.44		0.057	0.1		0.044		0.0057
Benzo(k)fluoranthene		0.27		0.035	0.05		0.014		0.0018
Benzo(e)pyrene		0.46		0.060	0.002		0.00093		0.00012
Benzo(a)pyrene		0.38		0.050	1.0		0.38		0.050
Perylene		< 0.03		< 0.004	-		-		-
Indeno(1,2,3-cd)pyrene		0.064		0.0083	0.1		0.0064		0.00083
Dibenzo(a,h)anthracene		< 0.03		< 0.004	1.1		< 0.03		< 0.004
Benzo(g,h,i)perylene		0.080		0.010	0.02		0.0016		0.00021
Total	**110**	**110**	**14**	**14**		**0.75**	**0.77**	**0.098**	**0.100**
	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)