AUSTRALIAN MEAT PROCESSOR CORPORATION

Evaluation of greenhouse gas mitigation activities undertaken by the red meat processing industry

FINAL REPORT

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Prepared by:	SG Heilbron Economic Policy & Consulting
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Table of Contents

1.0 Introduction

The Australian Meat Processor Corporation (AMPC) commissioned a study evaluating greenhouse gas (GHG) mitigation activities undertaken by the red meat processing industry. Direct GHG emissions in the red meat processing sector are primarily derived from wastewater and the consumption of stationery fuel, mainly used in operating boilers. Secondary emissions are also generated by the consumption of purchased electricity.

The Australian red meat processing industry has developed a range of research and development strategies to address climate change, reduce GHG emissions and adopt clean technology. These strategies have been formalised in the Red Meat Processing Industry Climate Change Strategy 2012 prepared by AMPC and AMIC.

Determining the most cost effective solutions and technologies is difficult and often varies between individual plants, depending upon their particular operating processes, cost structure and previous investment. The key objectives of this study are as follows:

- Document the range of GHG abatement technologies currently available to the meat processing industry in Australia, or with the potential to be implemented in the sector.
- Quantify the costs and benefits associated with the various options that have been implemented utilising CTIP grant funding. These projects include the following technologies:
  - Covered anaerobic lagoons;
  - In-vessel anaerobic digesters;
  - Co-generation / tri-generation;
  - Biomass as boiler fuel;
  - Direct and co-firing of boilers using biogas;
  - Energy efficient refrigeration technologies / processes; and
  - Other energy efficiency or renewable energy applications.
- Validate the costs and benefits of related AMPC investment either via AMPC's Core Environmental Program or the Plant Initiated Project (PIP) Program;
- Report on the cost benefit analysis of individual projects and, through economic modelling, provide an extrapolation of the site-based results to the broader industry;
- Undertake a series of case studies within the industry examining a range of key environmental technology options that have been implemented; and
- Provide advice on current barriers to implementation of key environmental technology solutions and areas of future research in this field and recommendations for the adoption of commercially available technologies, processes and practices.

This is the final report for Project 2013-1014.

2.0 Greenhouse Gas Emissions from the red meat processing industry

The main sources of direct greenhouse gas (GHG) emissions from the red meat processing industry are derived from wastewater, burning fuel to fire boilers and waste disposal. Indirect GHG emissions are derived from the purchase of electricity from the grid, with the industry using significant amounts of electricity primarily for refrigeration and freezing plants.

Anaerobic lagoons, a key component of wastewater treatment at many red meat processing plants, generally contribute the largest component of CO_2-e emissions. Emissions from anaerobic lagoons are estimated to equate to approximately 0.177 tonnes of CO_2-e per tonne of hot standard carcase weight (HSCW), using Method 1[1] from the National Greenhouse and Energy Reporting Scheme (NGERS). Applying this across the entire red meat processing industry nationally would suggest total GHG emissions from wastewater treatment in the order of more than 520 kilotonnes of CO_2-e per annum, although this does not make allowance for those plants which have already installed new Covered Anaerobic Lagoons (CALs) or adapted existing anaerobic lagoons with the installation of covers. Emissions from anaerobic lagoons primarily comprise methane and carbon dioxide in varying ratios, with traces of other compounds such as hydrogen sulphide and water. The percentage of methane in the biogas generated from anaerobic lagoons ranges from 55% to 70% and methane contributes 21 times more than carbon dioxide to GHG emissions.

The level of emissions from boiler fuel is influenced by the type of fuel utilised and the operating parameters of the individual plant. Data from NGERS adopts the CO_2-e emissions factors for the main types of boiler fuel as outlined in Table 1.

Table 1: Emissions factors for key boiler fuels used

Fuel type	Kg CO_2-e / GJ			
	CO_2	CH_4	N_2O	Total
Black coal	88.2	0.03	0.2	88.43
Brown coal	92.7	0.01	0.4	93.11
Natural gas	51.2	0.10	0.03	51.33
Fuel oil	68.8	0.02	0.2	69.02
Methane	0.0	4.80	0.03	4.83
Dry wood	0.0	0.08	1.2	1.28
Biomass	0.0	0.60	1.2	1.80

Of the main fossil fuels utilised to fire a boiler, natural gas has the lowest emissions per GJ. However, the average cost per GJ for natural gas is generally substantially higher than for either black or brown coal. Renewable fuels such as methane derived from biogas, wood or biomass have negligible CO_2-e emissions

[1] Method 1 for the measurement of methane released from wastewater handling incorporates the following formula:
$E_j = [CH_4^* - y(Q_{cap} + Q_{flared} + Q_{tr})]$ where: E_j is the emissions of methane released by the plant during the year measured in CO_2-e tonnes; CH_4^* is the estimated quantity of methane in sludge biogas released by the plant during the year measured in CO_2-e tonnes; y is the factor $6.784 \times 10^{-4} \times 21$ converting cubic metres of methane at standard conditions to CO_2-e tonnes; Q_{cap} is the quantity of methane captured for combustion for use by the plant; Q_{flared} is the quantity of methane flared by the plant; and Q_{tr} is the quantity of methane transferred out of the plant during the year.

by comparison.

The emissions derived from electricity purchased from the grid vary depending upon the location of the facility and the source of electricity. Data from NGERS adopts the CO_2-e emissions factors for grid electricity produced by State or Territory as outlined in Table 2.

Table 2: Emissions factors for purchased electricity from the grid

State or Territory	Kg CO_2-e / kWh
New South Wales and Australian Capital Territory	0.87
Victoria	1.17
Queensland	0.82
South Australia	0.62
South West Interconnected System in Western Australia	0.78
Tasmania	0.20
Northern Territory	0.69

These factors are influenced by the sources of fuel used to generate electricity with Tasmania being the lowest through the widespread use of hydro-electric plants. Victoria, on the other hand, relies heavily on brown coal for electricity generation and consequently has a significantly higher level of emissions per kWh. This impacts on the relative level of reduction in GHG emissions when replacing purchased electricity by cogeneration or simply reducing purchased electricity usage through improved efficiencies.

3.0 Mitigation of Greenhouse Gas Emissions from the red meat processing industry

The following section summarises the results of the six Case Studies undertaken as part of this project, as well as previous work undertaken for Milestone 1 of this project examining CTFFIP applications. The six Cast Studies undertaken were:

- CALs and biogas as boiler fuel – Plant A;
- CALs and biogas as boiler fuel – Plant B;
- CALs and biogas in cogeneration;
- Biomass as boiler fuel;
- Anaerobic digestion of paunch waste; and
- Refrigeration technologies.

Where relevant, the individual components of the various mitigation activities are addressed separately. The potential industry-wide benefits have been extrapolated from the results of the Case Studies.

3.1 Covered Anaerobic Lagoons

Wastewater from abattoirs is generally the principle source of greenhouse gas emissions. Anaerobic systems are generally regarded as the main biological treatment system as a result of the high biological oxygen demand (BOD) and oil/grease content in abattoir waste water. Anaerobic digestion is a natural process of degradation of organic compounds into methane and carbon dioxide. Anaerobic lagoons are commonly used for the treatment of abattoir effluent but odours and greenhouse gas emissions are an issue with uncovered ponds. Covering a lagoon gives increased temperatures and performance, particularly in cold climates and traps the odours and biogas.

Covered anaerobic lagoons (CALs) can be loaded at up to 6 times the rate of uncovered lagoons. However, it is reported that in addition to satisfying the design criteria related to uncovered ponds, including those relating to depth, length to breadth ratio, internal slope and minimum freeboard, the cover of a CAL presents some potential issues[2]. These include:

- Stormwater /rainfall ponding on the cover;
- Effects of wind and other natural disturbances;
- Build-up of sludge blanket underneath the cover;
- Accumulation of scum, fats, oils and grease under the cover;
- A need to de-sludge the lagoon; and
- Sizing of the biogas off take system.

The main benefits of CALs when compared with uncovered anaerobic lagoons are:

- Reduced odour emissions;
- Lower hydraulic retention times;

[2] A.ENV.0135 – Covered Anaerobic Lagoons. July 2012.

- Higher possible organic loading rates;
- Recovery of biogas for generation of energy; and
- Use of biogas for boilers allowing CALs to operate in colder climates.

The capital cost of installing a CAL is obviously influenced by a range of factors, some of which are site specific. A broad range of the generic costs associated with the capital cost of CAL systems are summarised in Table 3 overleaf. The initial construction costs include the costs of earthworks involved in excavation, the costs of the synthetic cover for the lagoon, the biogas system and any pumping and piping requirements. The size of the CAL is governed by the volume of wastewater flow.

Table 3: Estimated cost of CAL construction

	Small Plant	Low-medium Plant	High-medium Plant	Large Plant
Size of CAL (ML)	**7.5ML**	**22ML**	**60ML**	**90ML**
Lagoon excavation	$250,000	$380,000	$750,000	$1,500,000
Lagoon liner	$80,000	$150,000	$300,000	$520,000
Inlet/outlet structures	$20,000	$20,000	$35,000	$40,000
CAL cover	$150,000	$200,000	$400,000	$600,000
Biogas Flare	$100,000	$100,000	$150,000	$140,000
Ancillaries	$380,000	$670,000	$1,320,000	$1,950,000
Contingencies (30%)	$294,000	$456,000	$887,000	$1,425,000
Total	**$1,274,000**	**$1,976,000**	**$3,842,000**	**$6,175,000**

Source: A.ENV.0135 (excludes costs associated with electrical generator, sulphide scrubber)

Flaring of the biogas produced in CALs reduces total CO_2-e emissions by 98.7% of what the level would have been without CAL and flare. Clearly this has a major impact on GHG emissions but previous analysis suggests that this alone may not be a cost-effective measure for processors, particularly in the absence of a price on carbon. Previous analysis[3] of CAL and flare incorporated savings resulting from a reduction in the requirement to purchase carbon permits, priced at $23 per tonne of CO_2-e emitted over and above the threshold of 25,000 tonnes per annum. The estimated average simple pay-back period from the installation of a CAL and flare system was 5.9 years, considerably in excess of that generally required by a commercial enterprise.

The installation of CAL and flare incurs capital and operating costs without generating any financial benefit to the plant. Utilising the biogas to provide energy, either through direct firing in a boiler or in a cogeneration plant can serve to reduce expenditure on boiler fuel and / or electricity. However, the biogas captured from a CAL must be treated prior to use.

[3] Australian Red Meat Industry Carbon Tax Modelling. SG Heilbron Pty Ltd. February 2012.

3.2 Treatment of biogas

There are a number of issues to be addressed in the successful utilisation of biogas as either a boiler fuel or in a cogeneration plant including:

- Consistency of biogas production;
- Quality of biogas produced; and
- Contaminants in the biogas.

A number of studies have examined the range of issues associated with the utilisation of biogas as a source of energy in the red meat processing industry. Biogas, whilst comprising mainly methane and carbon dioxide, also contains a number of other constituents which potentially have adverse effects on equipment and downstream uses[4]. Hydrogen sulphide in particular is very corrosive and when combined with water increases the impact by leading to the production of sulphurous and sulphuric acids. This can cause corrosion of process equipment. Removal of water and hydrogen sulphide from the biogas is required, to varying degrees, when considering the final process equipment.

Free water and condensate can be removed using knock-out pots and drip traps if the biogas is either to be flared or used to fire a boiler. However, reciprocating gas engines or microturbines used in co-generation require further water removal which can be achieved through refrigeration of the gas.

It is recommended that biogas quality should be considered at the initial stages of concept development and that biogas sampling should be undertaken to identify the concentrations of constituents with potentially adverse process and mechanical effects. It has also been suggested that the additional costs associated with engine operations and maintenance should be weighed against the costs of hydrogen sulphide removal, as it may potentially be more economical to manage these issues than installing removal technologies.

Pond efficiency, pond configuration and operational practices can reportedly have a significant impact on the quantity of biogas generated, with tenfold variations reported at the tests at one plant examined. That assessment recommended a number of actions to maximise pond efficiency and biogas production including:

- Routine removal of crust and sludge to optimise the effective volume of the pond and therefore maximise biogas production. In addition other studies have noted that crust build-up causes mechanical failure and degradation of the pond cover;
- The addition of a clarifier to the system to recycle the activated sludge leaving the system or the addition of baffles to increase solids retention time; and
- The installation of fat removal systems such as a dissolved air flotation (DAF) unit to pre-treat the effluent and thus reduce the organic loading into the ponds.

[4] A.ENV.0098 – Review of biogas cleaning. June 2012.

3.3 Biogas as boiler fuel

Case studies examining the use of biogas as boiler fuel have primarily incorporated a requirement to construct new CALs but have also included modifications to existing natural gas boilers rather than a need to purchase a new boiler suitable for combusting biogas. Consequently, the investment costs are influenced by the comparative cost of constructing CALs contrasted with the relatively minimal cost of modifying an existing boiler rather than purchasing and installing a new boiler. The costs for a plant which already has CALs and existing natural gas-fired boilers would obviously be reduced whereas the costs for plants without CALs and operating on solid fossil fuel-fired boilers would increase. In assessing the returns on investment, the following capital costs were incorporated:

- Construction of new CALs;
- Associated biogas pipeline;
- Flaring equipment required for emergency release or at times when the biogas cannot be combusted in the boiler;
- Biogas scrubber;
- Modifications to existing natural gas fired boiler; and
- Commissioning.

Analysis of the costs and benefits of using biogas captured from CALs to co-fire an existing natural gas-fired boiler incorporated the following:

- Capital costs associated with construction of CALs and associated equipment, modifications to the existing boiler and commissioning;
- Savings resulting from reduced expenditure on non-renewable fossil fuels to fire the boiler; and
- Company expectations relating to future real price increases in either coal or natural gas.

It was found that the results were significantly influenced by the type of fossil fuel currently used as boiler fuel, with natural gas generally being substantially more expensive per GJ than coal. Therefore replacing energy consumption from natural gas with methane generates greater savings or benefits per GJ than replacing coal consumption which in turn can have a significant impact on the pay-back period and return on investment. The impact of the project on CO_2-e emissions from boiler fuel is an estimated reduction of between 63% and 74% depending upon the type of non-renewable fossil fuel being replaced. As noted earlier, black coal has an emissions factor, measured in kg of CO_2-e per GJ, which is more than 70% higher than natural gas.

3.4 Biogas and cogeneration

Combined heat and power generation is viewed as being one of the most practical and cost effective methods for utilising biogas and one of the most economical renewable energy options for a site. When biogas is converted to electricity via a biogas powered electric generator, approximately 35% of the total energy is converted to electricity due to the efficiency of the generator. The remainder of the energy is converted into heat, some of which can be recovered for heating applications.

The economic viability of cogeneration plants is maximised when the electrical power and heating / cooling is required at the same time and when this occurs during peak electricity tariffs. Cogeneration is ideally suited to the red meat processing industry as it uses heat and electricity at the same time and generally requires only low pressure steam (800 – 1,200 kPa) for rendering. In addition, the red meat processing industry is a significant user of electricity, primarily for refrigeration and / or freezing plants, which, in turn, contributes a major proportion of its operating cost structure.

Analysis of the costs and benefits of adopting a cogeneration system using biogas captured from CALs incorporated the following, under an ideal scenario whereby maximum chemical oxygen demand (COD) reduction (85%) is achieved:

- The capital cost of the generating equipment, including design, planning and project management;
- Costs associated with the construction of CALs;
- Generator requirement was based on 100kW per 40m3 per hour of biogas;
- Operation and maintenance costs were assessed at half of the initial capital cost of the project over its lifetime, assumed to be 10 years;
- Savings in electricity costs; and
- Savings in black coal costs.

The estimated impact of the project was a reduction in purchased electricity from the grid of 45% and a reduction in black coal consumption for boiler fuel of almost 12%. Reductions in GHG emissions from energy usage were estimated at 26%, excluding the reduction in CO_2-e emissions from wastewater as a result of installing CALs.

3.5 Biomass as boiler fuel

Co-combustion of abattoir waste has the potential to impact on the operations in terms of:

- Reducing waste disposal fees, particularly if disposed by land fill;
- Minimising GHG emissions; and
- Reducing purchased energy costs.

Currently most abattoirs dispose of their paunch waste, after washing and screening, either via composting or land disposal. Current methods of disposal can incur costs, particularly if landfilling is practiced. Studies have indicated that if paunch waste can be mechanically dewatered to a total solids (TS) ratio of 30% it would combust autogenously in a boiler i.e. it would not require any external thermal energy for combustion. Typical processed paunch waste has a TS of 20% and a water content of 80%.

The initial reports suggested that the total solids (TS) of the dewatered paunch waste were expected to be around 50%, the findings in the trials generated TS of just over 30%. The co-combustion trials were undertaken with the boiler operating with 5% of its energy input derived from dewatered paunch waste with the balance being supplied by the normal fuel, in this case sawdust. At that level, there were reportedly increased emissions of NO_2 and SO_2 although these emissions remained well within regulatory guidelines.

It should be noted that utilising 5% of the boiler energy input derived from paunch waste is considerably lower than the paunch waste generation rate. Had that level been adopted, it would have represented approximately 30% of the boiler energy input. That would have resulted in increased emissions with a potentially more significant environmental impact. Co-combustion of paunch waste tripled the ash generation rates although there was only a minor impact on ash quality. However, the cost effectiveness of dewatering paunch waste to suitable TS levels requires further examination, particularly given the variability of the make-up of the waste.

3.6 Anaerobic Digesters

Anaerobic digestion is being actively investigated as another method of dealing with paunch waste, generating biogas. In addition, anaerobic co-digestion of paunch waste and DAF sludge is also being examined. The Advanced Water Management Centre at the University of Queensland has operated a pilot paunch digester since 2010. Initial setup was based on paunch liquor with the digester operating on paunch solids in 2011-12. Results from the demonstration plant indicated that an average size processor (600 head per day) could reduce paunch waste from 15 tonnes of wet solid per day to around 5 tonnes per day using anaerobic digestion[5]. It was noted that at feed concentrations above 3% solids, the demonstration plant had significant problems with materials handling as a result of engineering limitations rather than biological limitations. Re-engineering the mixing systems was expected to improve the loading rates.

In addition to generating renewable energy, anaerobic digestion will significantly reduce the volume of paunch requiring transport for disposal. It was estimated that converting approximately 50% of solids to methane will reduce the solids transport load to around one-third of the load from paunch without treatment. Further outcomes of the study indicated that co-digestion is a promising strategy to improve process performance. Anaerobic co-digestion of paunch and DAF sludge resulted in higher methane levels. However, as the inclusion of DAF sludge also resulted in process inhibition, determination of the optimal mixture is required. Clearly this process offers considerable potential to reduce disposal costs and generate renewable energy, although it would appear that more investigation is required to make the technology more attractive and increase its utility to processors.

3.7 Refrigeration Technologies

The red meat processing industry is a significant user of electricity which, in turn, contributes a major proportion of its operating cost structure. Industrial refrigeration plants are substantial users of energy and frequently contribute a significant amount of a facility's total electrical usage. It has been estimated that refrigeration costs approximate between 40% and 70% of total electricity consumption in abattoirs with chillers and/or freezers[6]. Given the increasing cost of electricity, any savings in consumption will have a direct impact on the operation's bottom line and can also impact on the level of CO_2-e emissions. Improved energy efficiency and performance in refrigeration plants offers potential savings in both energy and carbon intensity in the red meat processing sector.

A number of technologies have been identified which can improve efficiency and performance in refrigeration plants, reducing electricity consumption and associated GHG emissions. These include:

- Variable head pressure and condenser fan speed control – the head pressure of a refrigeration plant is the pressure at which the compressors discharge and the refrigerant condenses. With conventional refrigeration plants, the head pressure is fixed and the plant control system attempts to maintain that pressure. With variable head pressure control (VHPC), the aim is to optimise the head pressure at any given time taking into account minimum compression ratios and oil separation as well as variables such as ambient temperature and plant load.
- Compressor staging and capacity control – the engineering consultants7 noted that considerable

[5] A.ENV.155 – Anaerobic co-digestion of paunch and DAF sludge. October 2013.
[6] A.ENV.0129 – Saving Electrical Energy and Cost Phase Changing Materials, June 2012
[7] A.ENV.0129 – MINUS 40 Pty Ltd

energy savings can be made by adopting variable speed controls on screw compressors in industrial refrigeration plants, particularly during part load conditions.

- Condensate sub-cooling by screw compressor economiser – the engineering consultants noted that this process was only applicable at the plant examined if the previously mentioned compressor staging and capacity control was installed. This may not necessarily be the case at other facilities depending upon the slide valve position of the compressor.
- Evaporator fan speed control – fan-coil evaporators are used in most industrial freezing, chilling and cold storage applications. They tend to run at full speed even when the load is low. Varying fan speeds to suit the load enables energy savings as lower fan speed translates into less heat being produced with the resultant decrease in load on the refrigeration system.
- Converting blast freezers to plate freezers – air-blast freezers are widely used in the industry for freezing cartons of meat but plate freezers have significant advantages including a higher heat transfer rate which reduces the time to reach the required temperature and the absence of high powered fans which contribute directly to direct energy consumption as well as increasing the refrigeration load, contributing to indirect electricity consumption.

There are also a number of absorption refrigeration technologies available for converting waste heat into cooling that could be applicable in the red meat processing industry. One approach is to utilise the biogas captured from CALs and use this to power a gas engine which in turn drives a generator to produce electricity with the exhaust heat used for absorption refrigeration. This technology incurs high capital and maintenance costs and, in the absence of a price on carbon, is unlikely to be a financially viable option. Another alternative is direct firing the absorption chiller using the biogas. Whilst this has lower capital and operating costs than cogeneration, it does not produce any electricity. However, the lower initial investment means that the pay-back period is more attractive than the former option.

3.8 Summary of impact of GHG Mitigation projects

The analysis of the impacts of the various technologies discussed is summarised in Table 4. It should be noted that these are site-specific results which may not necessarily translate to the same impact on other plants for a number of reasons including:

- Operating parameters including throughput, hours of operation and location;
- Methane content of biogas produced; and
- Relative distribution of expenditure on stationary fuel end electricity.

Table 4 summarises the results of each project in terms of key financial variables (simple pay-back period and benefit-cost ratio of the investment) assessed at a real discount rate of 7%. The impact on GHG emissions for each project is presented measured as a reduction in emissions measured in tonnes per annum and the investment (capital) cost measured as a dollar value per tonne of CO_2-e emissions saved over the life of the project.

The author should provide a description of how the project was conducted, including experimental design(s), measurements, and statistical analysis.

Table 4: Summary of impact of GHG mitigation projects in the red meat industry

Technology type	Simple pay-back period (years)	Benefit-cost ratio	Impact on CO_2-e Emissions (tonnes per annum)	Cost per Tonne CO_2-e Emissions saved (project life)
1. CAL & boiler fuel				
Project 1.A	6.1	1.37	60,300	$20.51
Project 1.B	7.7	1.41	48,150	$12.56
Project 1.C	5.6	6.20	31,770	$9.15
Project 1.D	16.1	0.80	30,620	$12.26
Project 1.E	2.8	2.40	26,300	$7.19
2. CAL & cogeneration				
Project 2.A[1]	5.5	1.25	15,700	$13.10
Project 2.B[2]	3.5	2.07	3,000	$28.10
3. Co-combustion of biomass				
Project 3.A[3]	1.0	7.95	0	N.A.
Project 3.B[4]	5.6	1.27	5,514	$35.82
4. Anaerobic digesters				
Project 4.A[5]	4.5	1.31	1,800	$29.65
Project 4.B[6]	6.7	1.03	1,800	$29.65
Project 4.C[7]	0.6	2.85	1,800	$30.89
Project 4.D[8]	0.8	2.25	1,800	$30.89
5. Refrigeration				
Project 5.A	4.3	1.58	1,350	$136.49
Project 5.B[9]	11.1	0.60	3,560	$159.10
Project 5.C	1.4	4.87	1,930	$41.19

Notes to Table: 1 – Includes estimated impact and cost of CAL

2 – Excludes impact and cost of CAL

3 – Assumes use in existing boiler

4 – Assumes replacement of coal-fired boiler

5 – Capital cost of $1,000 per m^3 and cost of disposal of paunch waste at $20 per tonne

6 – Capital cost of $1,000 per m^3 and cost of disposal of paunch waste at $0 per tonne

7 – Capital cost of $125 per m^3 and cost of disposal of paunch waste at $20 per tonne

8 – Capital cost of $125 per m^3 and cost of disposal of paunch waste at $0 per tonne

9 – The project involved significant investment in new equipment rather than an upgrade to existing plant

Some key points illustrated by the table include:

- The construction of CALs is the most cost-effective method of reducing GHG emissions, although as noted previously, CALs alone do not provide a financial return to the processor;
- The results suggest that there is little difference between CALs and using the resultant biogas as boiler fuel and CALs and using the biogas in a cogeneration plant. However, it should be noted that there could be a significant difference in results if a plant had to install a new boiler to utilise the biogas; and
- Anaerobic digestion of abattoir waste appears to be a more cost-effective method of dealing with paunch waste, particularly if the capital cost associated with digesters can be reduced.

Extrapolating the findings outlined above, on an industry-wide basis, suggests the potential reduction in GHG emissions and energy sourced from non-renewable fossil fuels described in Table 5. It should be noted that each of the Case Studies reflected plants which processed cattle only and the industry-wide impacts have only been measured for the beef processing sector, with the exception of co-generation and upgrades to refrigeration plant. Obviously, some of the other technologies would be equally applicable to plants processing sheep but it is likely that the relevant ratios would differ. An average value for each of the projects outlined above has been incorporated and the estimated coverage of the beef processing sector is outlined in footnotes to the table.

Table 5: Potential industry-wide impacts of GHG mitigation projects in the red meat industry

Technology type	**Reduction in CO_2-e emissions per annum (tonnes)**	**Reduction in CO_2-e Emissions - kg per tonne HSCW**	**Reduction in energy consumption from fossil fuel per annum (GJ)**	**Reduction in energy consumption from fossil fuel - MJ per tonne HSCW**
1a. CAL & boiler fuel[1]	150,000	321	285,000	623
1a. CAL & boiler fuel[2]	22,000	47	285,000[1]	623[1]
2. CAL & cogeneration[3]	155,000	51	924,000	307
3. Co-combustion of biomass[4]	N.A.	N.A.	N.A.	N.A.
4. Anaerobic digesters[5]	42,000	18	820,000	359
5. Refrigeration[6]	60,000	21	250,000	82

Notes to Table: 1 – Includes estimated impact of CAL and applied to 20% of beef production
2 – Excludes estimated impact of CAL and applied to 20% of beef production
3 – Excludes estimated impact of CAL and applied across all red meat processing
4 – Assumed to apply to 10 abattoirs with existing capacity to co-combust paunch waste
5 – Assumed to apply to all beef processing
6 – Assumed to apply to all red meat processing

Some key points illustrated by the above table include:

- After removing the impact of the CAL on GHG emissions, there is little difference between using biogas as boiler fuel or using it to fire a cogeneration plant;
- Anaerobic digestion of abattoir waste appears to offer significant impacts on reducing energy consumption derived from fossil fuels, although whether this would be a cost-effective technology for plants using existing coal-fired boilers has not been examined; and
- Refrigeration technologies can reduce energy consumption from electricity purchased from the grid which, in turn, serves to reduce GHG emissions.

Further investigation of the suitability of the various technologies across the industry, and particularly for sheep meat processing is warranted to determine the most cost-effective solutions to reducing both GHG emissions and energy consumption derived from fossil fuels.

4.0 Investment in Mitigation

4.1 Clean Technology Food and Foundries Investment Program

The Clean Technology Food and Foundries Investment Program (CTFFIP) was established by the Federal Government in February 2012 as part of the Clean Technology Investment Program (CTIP). It was designed to assist Australian food and foundry manufacturers to invest in energy-efficient capital equipment and low-emission technologies, processes and products. The program was competitive whereby applications were assessed against a range of eligibility criteria including the potential to improve the carbon and energy efficiency of the applicant's operations. Merit criteria examined varied depending upon the size of the grant application and included the extent to which the project reduced carbon emissions intensity of the operation.

Applicants with facilities that are liable under the Carbon Pricing Mechanism i.e. those with CO_2-e emissions of 25,000 tonnes or more, could apply for grant funding on a dollar for dollar basis provided emissions do not exceed 100,000 tonnes. Applications where the facility is not directly liable under the Carbon Pricing Mechanism could apply for grants with a government to private sector funding ration of 1:2 or 1:3 depending upon the size of the project and the applicant's turnover in the most recent financial year. However, applicants seeking a grant of less than $500,000 could also be eligible for funding at a 1:1 ratio, provided their turnover was less than $100 million.

The CTFFIP ceased to be operational in October 2013 following the Federal election. At the time of cessation of the program, a total of $122 million in grants had been approved reflecting total project investment of almost $346 million in energy-efficient equipment and low emissions technologies. Of this, more than $34 million in grants had been allocated to the meat, poultry and smallgoods manufacturing sector, equating to total project investment of almost $82 million.

A total of 44 projects were approved in the meat, poultry and smallgoods manufacturing sector and these are summarised in Table 6 overleaf.

The installation of solar photovoltaic panels received the largest number of grants across the sector at an average project cost of just over $150,000. Based on the limited data publicly available, these projects were generally expected to reduce carbon emissions intensity by between 13% and 25% through reduced purchase of electricity from the grid as well as reducing the applicant's expenditure on electricity.

Table 6: Summary of CTFFIP grants approved in the meat, poultry and smallgoods manufacturing sector at October 2013

Energy efficiency or emissions reduction	No. of projects	Total value of grants	Total value of investment	Average investment per project	Average ratio of grant : applicant contribution
Solar PV Installation	13	$988,148	$1,976,701	$152,054	1:1.0
Replacement Equipment	11	$5,666,341	$16,572,311	$1,506,574	1:1.9
Refrigeration Upgrade	8	$4,044,622	$12,009,629	$1,501,204	1:2.0
Switching to Biogas	7	$18,624,350	$39,142,700	$5,591,814	1:1.0
Other	2	$3,616,432	$7,232,864	$3,616,432	1:1.0
Insulation	1	$59,416	$118,832	$118,832	1:1.0
Pump/ Compressor/Motor Upgrade	1	$227,052	$681,837	$681,837	1:2.0
Switching to Natural Gas	1	$1,053,500	$4,123,000	$4,123,000	1:2.9
Total	44	$34,279,861	$81,857,874	$1,860,406	1:1.4

Grants for replacement equipment accounted for 25% of grants approved in the sector. These projects, with an average total investment cost of $1.5 million generally focused on replacing boilers to improve efficiency of operation and reduce CO_2-e emissions. Reductions in emissions of between 12% and 43% were anticipated.

Upgrades to refrigeration plants accounted for 8 of the approved grants at an average total investment cost of $1.5 million. Projects designed to improve the efficiency of refrigeration systems varied significantly in investment cost depending upon the nature of the upgrade and were expected to reduce emissions primarily through reduced usage of electricity purchased from the grid.

Projects relating to switching to biogas accounted for 7 of the grants approved with an average project value of $5.6 million, significantly above the average. These projects generally incorporated either the construction of new CALs or modifying and covering existing anaerobic lagoons and using the captured biogas as boiler fuel in either modified existing natural gas-fired boilers or a new boiler. The installation of the CALs clearly has a significant impact on reducing CO_2-e emissions and, when combined with reduction in emissions from using fossil fuels to fire boilers, equated to an estimated average investment cost of $13.68 per tonne of CO_2-e saved over the life of the project.

Other projects partially funded by a CTFFIP grant have related to the installation of a tri-generation plant operating on natural gas to minimise the purchase of electricity from the grid, resulting in significant cost savings and a major reduction in CO_2-e emissions. However, it should be noted that the project is located in Victoria and that the reduction in GHG emissions from purchased electricity would be likely to be lower in other parts of Australia.

Overall, the average investment cost for projects in the meat, poultry and smallgoods manufacturing sector was $1.86 million with an average grant to applicant contribution of 1:1.4. It would appear from the data available that these projects were successful in both reducing GHG emissions and reducing operating costs at the plant through reducing reliance on purchased fuels and exposure to future price rises in these. However, it must be remembered that the financial viability of these projects in terms of pay-back and return on investment was influenced by obtaining the grant and, for larger plants, removing their liability for a price on carbon. Whilst it is possible that some of the projects would have been implemented in the absence of CTFFIP grants, that is by no means certain based on the assessed return on investment. Competing demands for investment, combined with a finite source of capital, may have resulted in other opportunities being more attractive, particularly in the absence of a price on carbon.

4.2 AMPC and Meat & Livestock Australia funding

A large number of environmental projects have been funded by AMPC and Meat & Livestock Australia (MLA) over the past three years, some of which were undertaken under Plant Initiated Project (PIP) funding whereby the plant also makes a contribution to funding the project.

The Consultants have classified the project list provided, shown at Appendix A, into the following approximate categories:

- Energy and emissions management – encompassing general projects relating to energy management, energy efficiency and measurement;
- Wastewater – encompassing studies relating to treatment, measurement and verification;
- Biogas – encompassing studies relating to recovery, production (including anaerobic digesters), monitoring, cleaning and safety;
- Biomass – encompassing studies relating to use as boiler fuel after various processes;
- Refrigeration – including improvements to efficiency and optimisation; and
- Electricity – including solar power and cogeneration.

Expenditure on the projects listed totalled approximately $6.4 million. Table 7 provides an approximate breakdown of expenditure by project category.

Table 7: Summary of AMPC, MLA and PIP funded projects 2011-12 to 2013-14

Project Category	Proportion of Project Expenditure
Wastewater	50.6%
Biogas	17.3%
Energy and emissions management	17.0%
Biomass	9.3%
Refrigeration	4.7%
Electricity	1.1%
Total	100.0%

Whilst there are obvious overlaps between the categories, it appears that half of total expenditure has been devoted to studies related to the management and treatment of wastewater. It is not possible in the scope of this study to assess the returns on investment from project expenditure. However, as wastewater from red meat processing facilities is responsible for the largest proportion of GHG emissions from the industry, the allocation of a significant proportion of project funds to studies which inform the industry about its treatment would appear to be an efficient and effective allocation of funds. Similarly, the proportion of funding directed to investigations regarding the production and utilisation of biogas reflects the potentially greater returns to the industry, in reducing both CO_2-e emissions and operating costs, than that likely to accrue from utilising biomass directly, at least with the technology currently available.

5.0 Gaps in take-up of mitigation technologies

Barriers to the take-up of GHG mitigation activities primarily relate to investment cost, length of pay-back period and overall return on investment. Whilst the industry is committed to reducing its GHG emissions, commercial reality must prevail in a sector characterised by high volumes and low margins.

In the absence of a price on carbon or the availability of grant funding, the key motivator for reducing CO_2-e emissions is an associated reduction in operating costs. Projects which can significantly reduce energy costs, either through replacement with renewable energy sources such as biogas or solar power, or through increased efficiency of energy utilisation are likely to be viewed more favourably than projects which are primarily aimed at reducing GHG emissions. A project that successfully reduces operating costs, with an acceptable pay-back period, and also reduces emissions could therefore be viewed as the best possible outcome.

For smaller processing facilities, it is likely that lower economies of scale may prohibit the implementation of some technologies. For example, previously cited estimates of the costs of constructing a CAL suggest that smaller lagoons may cost more per ML of volume than larger lagoons. Similarly, cogeneration plants are reportedly less expensive per kW when they are of a larger size.

6.0 Conclusions and Recommendations

Clearly, the single biggest source of GHG emissions from red meat processing plants is derived from wastewater treatment when uncovered anaerobic lagoons are used as part of the process. Whilst covering the lagoons and flaring the resultant captured biogas reduces CO2-e emissions by 98.7%, this process can incur significant capital outlay with no financial return. Consequently, if CALs are to be installed it is preferable to treat and use the biogas as either boiler fuel or in cogeneration.

The most cost-effective method of utilising the biogas will be influenced by a number of factors including:

- Capital expenditure including:
  - Cost of constructing new CALs or modifying existing uncovered anaerobic lagoons, which may be site specific;
  - Costs associated with modifying an existing natural-gas boiler or purchasing a new boiler;
  - Costs associated with biogas treatment; and
  - Costs associated with the purchase, installation and operation of a cogeneration system.
- Type of boiler fuel currently used and associated magnitude of financial savings from reduced purchases;
- Relative price of purchased electricity;
- Ability to utilise electricity generated and / or return to the grid; and
- Ability to utilise heat generated from the system.

In general it would appear that with technology currently available and with current price differentials for purchased energy, utilising the biogas as boiler fuel is the most cost-effective option, particularly if replacing existing natural gas usage. However, any future increase in the price of electricity could impact on that analysis.

The use of biomass in the form of paunch waste and / or DAF sludge either in dewatered form as boiler fuel or to generate biogas in anaerobic digesters serves to reduce disposal costs and GHG emissions associated with the various methods of disposal. Dewatering the biomass appears to offer some potential, although currently there are difficulties in achieving a suitable level of TS at a cost-effective level. Further investigations into improving the technology associated with dewatering paunch waste and thereby increasing the percentage of total solids could serve to make this a more attractive technology for the red meat processing industry in the longer term.

However, even assuming that dewatering to an appropriate level can be achieved, this only generates a commercially viable pay-back for plants already using renewable fuels such as sawdust and incurring costs associated with disposal of the paunch waste. Anaerobic digestion appears to offer greater potential although again the pay-back period is influenced by relatively high initial capital outlay and again, the stream of benefits is impacted by the disposal costs experienced by individual sites. However, further development of technologies which reduce the initial capital cost, even at the expense of a reduced project life, could serve to make this an attractive option for many processing plants.

Implementation of the various refrigeration technologies are likely to be driven by a desire to reduce costs associated with the purchase of electricity, with reductions in GHG emissions being a by-product. As refrigeration plants in red meat processing facilities are upgraded because of ageing equipment, it would be expected that more energy efficient equipment would be installed.

The key factor influencing the pay-back period and return on investment in the technologies examined is the initial capital outlay rather than the magnitude of the stream of benefits. Grants or other instruments which help to minimise the initial capital expenditure are more likely to assist in wider take-up of technologies aimed at mitigating GHG emissions, particularly with a reduced or non-existent price on carbon.

7.0 Appendices

7.1 Appendix A - Environmental Projects funded by AMPC and MLA

Year/Category	Project code	Project Name
Environmental Projects 2013/14	2013_4004	Energy management planning
	2013_3010	Renewable Energy Options for Off-Grid Red Meat Processing Facilities
	2013_4006	High rate aerobic treatment with AD & anammox Yr 3
	2013_4007	Nutrient recovery from paunch and CAL lagoon effluent (Yr2)
	2013_4005	Water and Energy Efficiency Program
	2013_4008	AWMC Fellowship
	2013_3009	Torrefaction
	2013_5015	Torrefaction CBA
	2013_5018	Integrated agroindustrial wastewater treatment & nutrient recovery (Yr 3) – (OMNI code not allocated at this stage)
	3000_5086	QCMPA Energy Efficiency Program
	2013.4003	Review of renewable energy and energy storage options
	2013.5011	Examining options to maximize process heat recovery
Environmental Projects 2012/13	A.ENV.0138	Dry Cleaning of Chillers
	A.ENV.0149	Integrated agri-industrial WWT & NR
	A.ENV.0150	High rate aerobic treatment with AD & anammox Yr 2
	A.ENV.0151	NGERS and wastewater management
	A.ENV.0152	Effect of rendering on waste & emissions
	A.ENV.0153	Paunch value adding, energy, nutrient
	A.ENV.0154	Nutrient recovery from PW & DAF sludge
	A.ENV.0155	AD of paunch & DAF sludge
	A.ENV.0157	Carbon emissions measurement, reporting & implications
	A.ENV.0160	Biogas Safety Guideline & Manual
	A.ENV.0162	Review & evaluation of AAR (UQ)
	A.ENV.0164	AAR feasibility (ETS)
AMPC funded projects (no matching MLA funds)	AM12-5053	Development of a Waste Water Management kit for meat industry practitioners
	AM12-5065	Integrated solar PV & CHP at abattoirs
	AM12-5066	Domestic Processors Energy Efficiency Program
	AM12-156	Evaluation of Energy Efficiency Opportunities
	AM13-5072	Energy Efficiency Information Program
Environmental projects 2011/12	A.ENV.0055 & A.ENV.0058	Energy savings calculator & energy allocation tool
	A.ENV.0093	Biogas Quality Study
	A.ENV.0098	Biogas Cleaning Review
	A.ENV.0100	Review contaminant emissions
	A.ENV.0106	DAF Sludge as Boiler Fuel
	A.ENV.0110	Nippon PW as boiler fuel (also A.ENV.0120, A.ENV.0121, A.ENV.0122, A.ENV.0123)
	A.ENV.0107	Using CALs to Treat Wastewater, Reduce GHGs & Generate Bioenergy
	A.ENV.0129	Saving electrical energy and cost phase changing materials
	A.ENV.0131	Energy & nutrient analysis of individual waste streams
	A.ENV.0132	High rate aerobic treatment combined with AD & anammox Yr 1
	A.ENV.0133/0149	Integrated agroindustrial wastewater treatment & nutrient recovery
	A.ENV.0135	Global CAL Review
PIP's 2012	P.PIP.0141	Churchill Abattoir large scale demonstration of a WWT system
	P.PIP.0204	Fletchers comparison of environment implications of various treatments of abattoir wastewater
	P.PIP.0290	JBS demonstration of CAL Technology
	P.PIP.0293	T&R design & optimisation of a purpose built CAL - Stage 1
	P.PIP.0308	Teys remote optimisation systems for ammonia refrigeration plant
	P.PIP.0318	Rocky Creek feasibility study into in-vessel high rate fixed film AD

	P.PIP.0319	Abattoir site energy balance
	P.PIP.0328	KPC refrigeration efficiency improvements
	P.PIP.0333	Churchill demonstration & monitoring of in-vessel AD
	P.PIP.0335	Teys generating biodiesel from Tallow (Stage 1)
	P.PIP.0340	T&R manipulation of the newly constructed WWT System to maximize bio-gas production
	P.PIP.0347	T&R gas consumption reduction
	P.PIP.0348	Teys characterisation of pre-treated effluent
	P.PIP.0350	Nippon refrigeration efficiency advances in new technology
	P.PIP.0351	MC Herd pilot AD plant
	P.PIP.0353	John Dee baseline energy consumption analysis
	P.PIP.0363	JBS Dinmore Screw Compressor degradation tests
PIP's 2013	P.PIP.0348	Teys design, measurement and verification of wastewater
	P.PIP.0379	Investigation into refrigeration system optimisation
	P.PIP.0386	Ryans Wholesale Meats
	P.PIP.0398	Nippon bio-gas recovery & feasibility study for co-generation or tri-generation (this one is still being finalised and is not yet a project)