final report

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Feasibility of an Integrated and Automated Bio-energy and Waste Water Treatment Plant (WWTP)

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Executive Summary

Red meat processors are experiencing rising organic waste disposal and energy (power and thermal energy) costs. Both are contributing to rising operating costs for facilities and contribute to the environmental footprint of processors, including the creation of landfill and greenhouse gas emissions. Additionally, there is a vision to minimize potential visual amenity and odour associated with waste water treatment. Hence, concept level design and cost-benefit analyses were completed for innovative solutions to organic and solid wastes generated at a typical Australian processing plant.

This report summarizes the project objectives that were achieved:

- Findings of a cost-benefit analysis (CBA) for an Integrated and Automated Bio-energy and Waste Water Treatment Plant (WWTP). Including:
    - anaerobic digester feasibility study
    - decanter feasibility study
    - WWTP monitoring and control considerations
- Strategy for management of non-organic waste streams including non-recyclable waste plastics and boiler ash.

It is estimated that for a facility currently sending solid wastes to landfill at market rates, the use of anaerobic digestion to reduce landfilled amounts, can off-set power by towards 41% and thermal heating towards 20%.

The facility outlined below was designed to treat an inlet of 43,000 tonnes per annum of organic wastes at a solids content of 17%, with 82% of the solids being volatile (dry weight basis). The volatile solids is sourced from paunch (43%), red stream decanted solids (28%), green stream screenings (19%), DAF float with fat removed (5%), and dewatered aerated tank sludge (5%).

The Capital Cost estimate presented in the table below was completed to a Class 5 to 4 level (approximately +/- 50 to 30%). The cost-benefit analysis found that an anaerobic digester operating at its design capacity could provide a simple payback of around 4 to 5 years. The economics are eroded where large changes to materials handling / dewatering equipment are required or cost effective/low cost organics disposal options exist.

Table 1: Waste Water Treatment Plant Capital Cost estimate.

WWTP Capital Cost Estimate	Cap Ex Estimate
Anaerobic Digester	
Digester #1, control room, flare, materials handling	
Power cabling	
Cogen #1	
Digester #2	
Cogen #2	
Sludge / liquids Decanter (WAS decanter)	
WWTP DCS Automation	
DAF Decanter	
Decanter civil/structurals and cake handling	
Aerated tanks	
Green stream rotating screen upgrade to maximise solids removal (i.e. finer mesh)	
TOTAL – INDICATIVE	~$12mil

The findings of the waste management review are summarized in the following table. The key opportunities uncovered are:

- Fat removal from dissolved air floatation (DAF) float.
- Reuse of contaminated plastics (extrusion).
- Chipping and co-firing of contaminated combustibles that cannot be recycled.

Table 2: Waste Strategy – Summary of Options.

	Billing / density	Key opportunity	Limitations
General Waste - Tonnes	Billing based on assumed 80 kg/m^3.	Waste to energy: Payback: 1 month to 1 year+ depending upon environmental approval and reporting complexity.	Environmental approval. Materials handling.
General Bulk Compactor - Tonnes	Evidence that tonnage is weighted	Recycling of paper, cardboard, metal, plastic, glass: immediate payback.	Contamination and segregation
Paunch - Cubic Metres General Waste – assumed density for tonnes Sludge - Cubic Metres	Billing based on volume.	Compaction: $50k for roller. Payback: 3 months at 25% compaction 6 months at 15% compaction This option becomes obsolete after anaerobic digester is available.	Bins currently close to weight limit (would require smaller bins). Compaction ratio that could be achieved.
Ash - Cubic Metres	Billing based on volume.	Reuse. Under consideration by Cleanaway.	
Liquid - Tonnes	Billing based on volume.	Further on-site processing: decant fat; Tricanter: 8 month payback Separator and pump: 5 month payback Liquid/solids report to anaerobic digester.	Tricanter: high cap ex and op ex. Separator and pump: requires trial to determine ability to achieve acceptable split.

Recommendations for future actions:

- Anaerobic digester general and detailed design with associated capital cost estimation to a higher level of accuracy,
- Pilot scale anaerobic digester,
- State and council level approvals,
- Trial of a three phase separator for the DAF float,
- Trial of multi-layer plastic recycling.

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Glossary of Terms

AD Anaerobic digestion

BOD Biological Oxygen Demand

CO_2 Carbon dioxide

COD Chemical Oxygen Demand

Cogen Cogeneration engine (for making power and heat)

DAF Dissolved air flotation

dw Dry weight (i.e. 0% moisture)

H_2O Water

hr hour

kg kilogram

kW Kilowatts

kWe Kilowatts of electrical load

kWh Kilowatt hour

kWt Kilowatts of thermal load (e.g. heating requirement for sheds)

LHV Lower Heating Value (net heat value that includes the latent heat of water)

m^3 or m^3 Cubic metres

MJ Megajoule

ML Megalitre

MW Megawatt

MWh Megawatt hour

NH_3 Ammonia

NH_4+ Ammonium

NO Nitrogen monoxide

ppm Parts per million

P Phosphorus

PE Poly ethylene (type of plastic)

PET Polyethylene terephthalate (type of plastic)

pH An indication of a solutions acidity (or alkalinity)

PP Polypropylene (type of plastic)

PV Solar photo-voltaic (power generation)

PVC Poly vinyl chloride (type of plastic)

PVdC Polyvinylidene chloride (type of plastic)

REC Renewable energy certificate

RET Renewable Energy Target

RMP Red meat processor

s seconds (time)

TS Total solids

t Metric tonne (1,000 kg)

tpa Metric tonnes per annum

tpd Metric tonnes per day

tph Metric tonnes per day

tpw Metric tonne per week

VS Volatile solids

W Watts

WTE Waste to Energy

WWTP Waste water treatment plant

yr year

1 Background

The red meat industry is experiencing rising organic waste disposal and energy (power and thermal energy) costs. Both are contributing to rising operating costs for facilities and contribute to the environmental footprint of the red meat industry, including the creation of landfill and greenhouse gas emissions. Additionally, there is a vision to minimize potential visual amenity and odour associated with waste water treatment.

The overall objective of this project is to complete a feasibility study of an integrated waste water treatment plant (WWTP) and organic waste processing plant capable of processing paunch, sludge, red solids, green solids and any other site generated organics.

Red meat processors (RMPs) are experiencing pressure to change traditional practices due to increasing waste stewardship / limited waste disposal options and rising costs associated with waste management. Pressure for the industry to change is coming from a range of stakeholders: clients, competitors (with a lower cost of business and /or reduced waste and energy cost risks), product end users / consumers, state level environmental permitting authorities, councils, and internal staff.

RMPs in urban areas have the additional pressure of being surround by densely populated areas and other commercial / industrial businesses. Further, there exists no State Govt based levy in Queensland for landfill. Such a levy could see landfilling costs increase dramatically. Most sites have a goal of minimizing odour and visual impact, hence may be looking to phase out open ponds and any open processing systems.

Improved and automated WWTP systems provide RMPs an opportunity to deal with these multiple pressures via a single, integrated program of works whilst also being able to reduce costs (power, heating, landfilling) and generate revenues (renewable energy credits, Emissions Reduction Fund). Hence, the aim is for the project to deliver an acceptable financial return whilst improving waste stewardship practices.

1.1 Background Information – Anaerobic Digestion

Anaerobic digestion is the processes in which microorganisms break down the biodegradable material in the absence of oxygen. Commonly used in industrial application to treat waste and/or produce fuels and energy.

A brief explanation of the processes involved in the digestion are included below:

1. Bacterial hydrolysis insoluble organic polymers (i.e. carbohydrates) are broken down to soluble derivatives opening availability to other bacteria.
2. Acidogenic bacteria convert sugars and amino acids into carbon dioxide, hydrogen, ammonia, and organic acids. The organic acids are broken down to acetic acid, ammonia, hydrogen and carbon dioxide[6]
3. Methanogens convert these compounds to methane and carbon dioxide[7]

Anaerobic digestion acts to reduce the emission of landfill gas and is widely used as a source of renewable energy. This process can be used to generate capturable biogas which consists of the methane and carbon dioxide as well as other trace gases.[1] This gas can then be fed through a generator in combined heat and power engines to offset emissions and reduce energy costs or alternatively be upgraded to biomethane. The digestate remaining can be utilized as a fertilizer. Improved technology has allowed for the reduction of capital costs and Germany, UK and Denmark especially has seen an influx of installation of these facilities and manufactures.

The key components of an anaerobic digester plant are outlined in the following figure, provided by Biogass Renewables Pty Ltd:

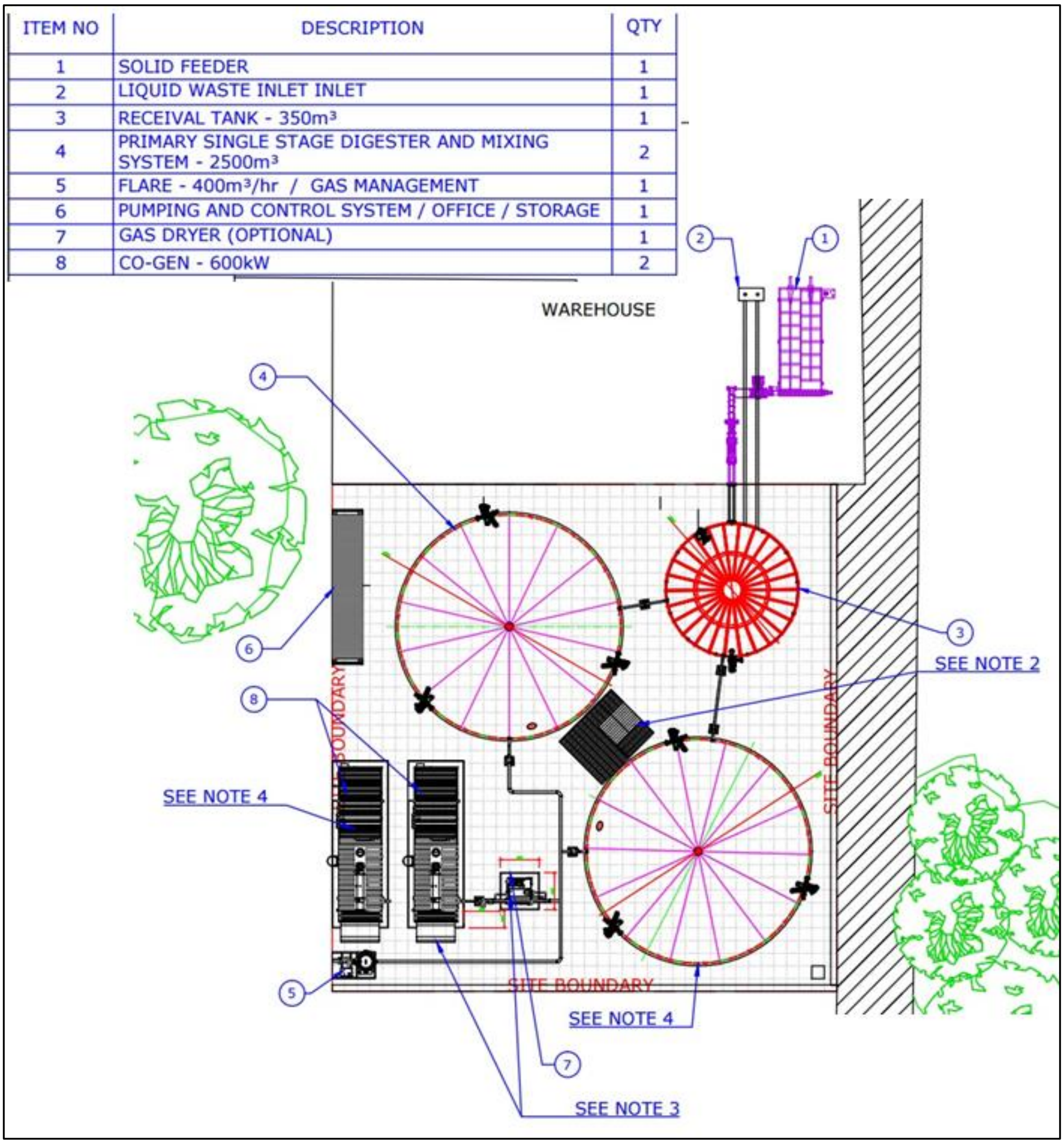

Figure 1: Sample layout of an anaerobic digester facility.

1.2 Background Information - Sludge Decanting

Efficient separation of solids and liquids in industrial applications is more important than ever to meet regulatory, efficiency, cost reduction, disposal cost reduction, and sustainability objectives. The separation of mixtures into their respective phases is important, not only from a cost saving on water treatment but through potential new revenue generations. Within industrial processing, solid material is inevitably mixed with various liquid phase streams. This renders it unsuitable for reintroduction into water supplies and can create a sludge not suitable for disposal. A decanter is a common feature in waste water facilities and the chemical, and food processing industries that assists with these kind of applications to separate the liquid from solid phase with high efficiency. Centrifuges utilize high rotational speeds to separate the different components based on their densities. It is appropriate to consider the specific application of the technology and what the processing characteristics will be as multiple factors can affect the performance and design heuristics will need to be followed.

Operating Principal

Decanter centrifuges operate using gravitational separation as the main separation mechanism. Small suspended particles can settle in seconds compared to hours or days. Not only is this process faster, but also greater control over operational parameters with a variable feed. Through the continuous rotational operation the system can generate gravitational forces equivalent to 1000-4000 times greater than naturally occurring gravitational force, driving higher density components to fall to the bottom of a particular mixture, with the less dense component suspended at the top.

Operating Process

The feed slurry is introduced into the feed chamber assembly by a stationary feed tube. It is accelerated up to speed in the feed chamber and discharged into the pond of the bowl through the feed ports.

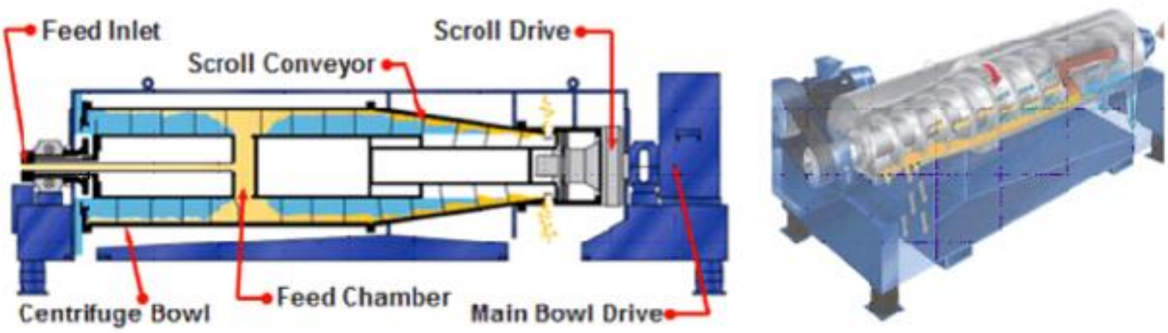

Figure 2: Decanter details for sludge dewatering and red stream solids recovery systems.

The liquid flows from the point where it is introduced to the pond to the liquid weirs at the large end of the rotating assembly. As the liquid flows through the pond, the g-force causes the solids to settle out of the liquid and to sediment against the bowl wall. This causes a blanket of solids to build up against the bowl wall.

The solids that build up against the bowl wall are pushed to the opposite end of the liquid discharge by the screw conveyor, which turns at a slightly different speed than the bowl. The solids are pushed in the horizontal direction, up an incline and ultimately out of the liquid prior to being discharged from the bowl. Centrifugal force is constantly exerted on the solids in order to produce the desired solids in the discharged product.

Optimization of the decanter performance can be achieved by varying the following:

- Bowl speed, optimised separation through g-force to suit processing stream,
- Conveying speed, for optimized balance between liquid clarity and solids dryness, and inter-phase settings between the heavy and light liquid phases,
- Feed flow [9] .

Polymers

For a large proportion of operations decanter centrifuges require polyelectrolytes. When examining the life cycle costs of a centrifuge installation, the polymer cost is larger than the maintenance, power, and labour costs put together. The success of the centrifuge is dependent upon the reaction between the sludge and the polymer. The polymer cost is one of the largest in the plant. To minimize this cost, it is important to have a polymer system that can handle more than one form of polymer. Polyelectrolytes are water-soluble molecules with active sites, which react with sludge particles. Dry, emulsion and liquid solution polymers exist with key differences being the handling and dosing requirements.

Economics

Based on total operating costs, the decanter centrifuge has significant advantages over the belt filter press. These are summarized as follows:

- Electrical costs – the belt filter press has an advantage in electrical consumption, However, this difference is between 2 – 5 % of the total operating cost of the system,
- Conditioning costs – a centrifuge can be operated at slightly higher polymer dosage for much dryer cake solids or at lower dosage levels for the same cake solids level versus a belt filter press depending on whether cartage or conditioning costs are controlling,
- Operator attention – current estimates are that centrifuges require one quarter of the labour of belt filter presses,
- Major servicing for centrifuges:
    a. STC spray on conveyer tips with a useful life between 2,000 –8,000 hours depending on the application,
    b. STC tiles would have a useful life between 15,000 – 40,000 hours depending on the application.
- Major servicing of belt filter presses: 2,000 – 3,000 per belt depending on the application.

Benefits and Limitations

Benefits:

- Clean appearance and have little to no odour problems.
- Easy to install and fast at starting up and shutting down.
- Small area for operation compared to other competitive processes.

- Versatile design with application specific selection of cylindrical bowl section length and the cone angle. Design curves to predict the sludge type can be pre-programmed providing advantages over the belt filter press where belt cannot be altered[1]
- The versatility allows various functions such as operating for thickening or dewatering.
- The machine can operate with a higher throughput capacity than smaller machines.[2]
- Simple to optimise and operate with few major variables and reliable feedback info[1]
- Reduced labour costs compared to other processes with low continuous maintenance and operator attention.
- Greater process flexibility and higher levels of performance compared to belt filter.
- Low maintenance with common twenty-four hours a day, seven days a week operation.
- If a short-term run is required the feed pump may be switched off and the machine left running.
- Belt presses designs have a limitation as to how much dewatering can occur within a certain floor space is determined by the belt width. The same is not true with centrifuges. The capacity/floor space footprint increases geometrically with the diameter of the bowl.
- In addition, centrifuges can be operated at higher flow rates, if necessary, by sacrificing cake dryness or by increasing the polymer dosage.
- Finally, a centrifuge can be installed outside in warm climates. This is not practical for belt filter presses which must be covered.

Limitations:

- The machine can be very noisy and can cause vibration.
- The device has a high-energy consumption due to high g-forces.
- Hard surfacing and abrasion protection materials are required for the scroll to reduce wear and therefore reduce the maintenance of the scroll wear driving up initial capital costs.

1.3 Background Information – Waste Management

The table below summarizes the waste management best practices a range of waste streams generated at Australian red meat processing facilities (Source: AMPC Waste solids Environmental Best Practice Manual 2003).

Table 3: Waste options for typical red meat industry wastes.

	Strategies		
Solid Waste Management Practice	**Avoid/Reduce**	**Reus/Recycle**	**Treat/Dispose**
Cardboard	• Automated carton assembly to achieve up to 50% reduction n waste than manual assembly	• Utilise reusable packaging systems, such as Pallecons, for transport of meat.	• Avoid disposal in general Rubbish bins
Plastic	• Reduce vacuum packaging through correct bag sizing and automation	• Maximize the recycling of polyethylene and avoid contamination	• Avoid mixture with other wastes and dispose of contaminated waste to landfill
Drums	• Purchase largest containers to reduce waste after use	• Look for drums with recyclable logos	• Avoid plastic and metal container disposal
Boiler	• Eliminate coal fired boilers in favor of gas fuels to prevent production of any ash		
Redundant Plant and Equipment	• Sell scrap metal as soon as possible to avoid stockpiling and wasted area on site		
Paper Towels/ Office Paper	• Provide Recycling bins to separate waste • On site shredding and composting should be carried out in absence of recycling facilities		
Canteen Waste	• Recycling of food scraps through compost • Recycling and separation of aluminium cans and plastic bottles instead of general bins		
Monitoring & Reporting	• Amount of solid waste to landfill and specifically packaging landfill should be measured and recorded in order to gauge environmental sustainability programs effectiveness		

Shown in the table below are packaging waste stream estimates for the Australian red meat industry.

Table 4: Packaging waste stream estimates for the Australian red meat industry in tonnes per annum[1].

Packaging	Domestic (tonnes)	Export (tonnes)	On-plant waste (tonnes)	Total (tonnes)
Cardboard	14,191	28,568	985	43,745
Plastic	232	2,471	141	2,735
Vacuum bags	1,607	1,681	320	3,608
Strapping	375	781	23	1,179

The figure below shows a break down the waste streams into their constituent elements with associated percentages to provide a visual of approximation of wastes generated by the industry. The contamination of plastic is a key limitation to reducing landfilling amounts.

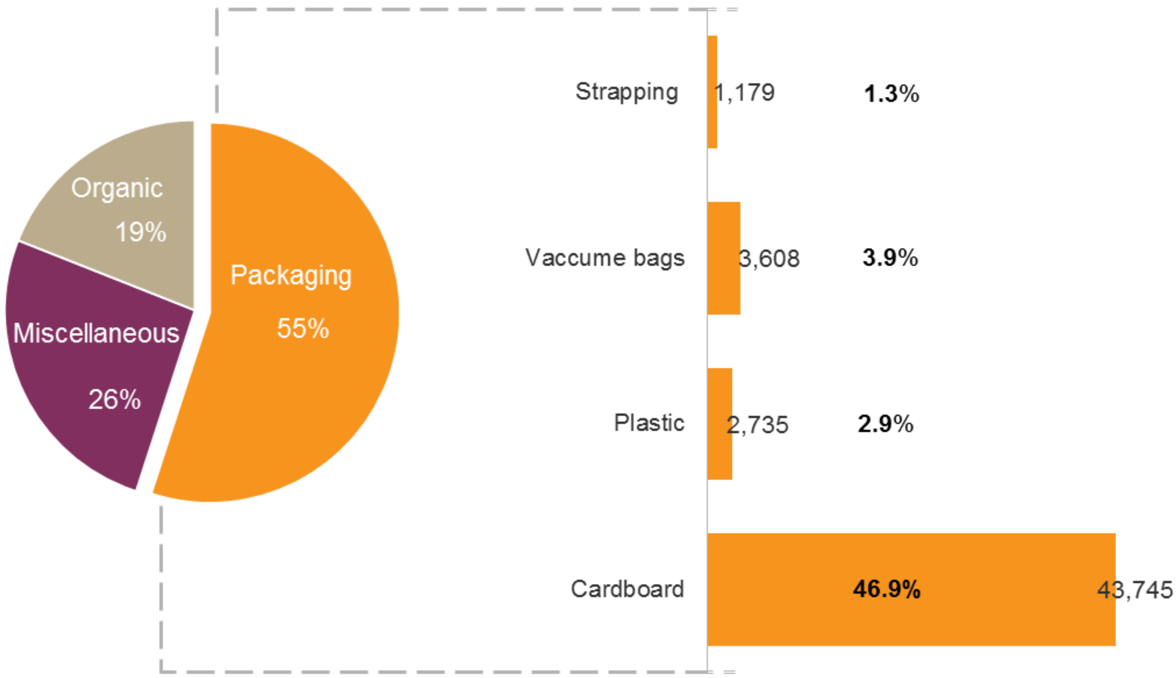

Figure 3: Breakdown of wastes types and annual tonnages from the Australian red meat industry[2].

Using industry heuristics, it would be expected that the break down of plastic waste is assumed to be 48% vacuum bags / Cryovac, 36% other plastics (trays, pipes, etc.) and the balance (16%) as strapping.

[1] AMPC waste solids Environmental Best Practice Manual 2003.

[2] AMPC waste solids Environmental Best Practice Manual, 2003.

2 Project Objectives

2.1 Milestones

Milestone 1: Contract execution

Milestone 2: Preliminary report on detailed feasibility study on anaerobic digester presented and approved by project group. Anaerobic digester feasibility study including analysis of a waste to energy plant to process all organic wastes.

Milestone 3: Decanter feasibility study for sludge generated by a meat processing plant. Preliminary report on detailed feasibility study on Decanter.

Milestone 4: WWTP DCS preliminary design and costing for complete monitoring and control of the proposed integrated facility. Preliminary report on detailed feasibility study on WWTP DCS.

Milestone 5: Inorganic waste management strategy for management of non-organic waste streams including non-recyclable waste plastics and boiler ash. Solutions will be defined for utilisation of these streams including plastic incineration, and boiler ash for use as a feedstock in the cement industry / building industry.

Final report on works completed including the cost benefit analysis with plant operating costs and deferred costs / revenue outcomes for the project.

3 Methodology

3.1 Basis of design and Assumptions

The key CBA assumptions that were made are as follows:

- Scenarios are for Earnings Before Income Tax, Depreciation and Amortization (EBITDA).
- 7% discount rate.
- Internal rate of return for 25 year plant life.
- "Overnight capital" (All start-up costs are expended at the start of the first year of full scale operation).

The basis for these assumptions and details of additional assumptions are outlined throughout the report.

Table 5: Summary of main assumptions for cost-benefit analysis.

Item	Notes
CPI Multiplier	1.8 multiplier for CPI Dec14 to Dec15 & Dec13 and Dec14.
Sludge: waste management cost per 15 m^3 bin	Increase according to CPI average
Paunch: waste management cost per 25 m^3 bin	Increase according to CPI average
Decanted DAF float (FOGS removed) @ 22% solids - assume the same as sludge	Increase according to CPI average
Power	Increase according to CPI average
Heating – estimated for coal fired boiler with associated running costs	Increase according to CPI average
Large-scale Generation Certificates (LGCs) - Renewable Energy Credits.	Tax-effective level of the shortfall penalty: $92.86. Reference: http://greenmarkets.com.au/ resources/lgc-market-prices
Labour costs (semi-skilled plant operator)	Increase according to CPI average
Potable water	Increase according to CPI average

4 Results - Waste Management

4.1 Solid waste co-firing

There are both technical and environmental permitting challenges to consider for the co-firing of waste with coal. The technical requirements for solid waste co-firing include reducing the size of the fuel so that it does not block the fuel feeding mechanism and for the particle density to be suitable for a fluidized bed boiler (e.g. plastic films may have a very low residence time). The fuel can either be added / mixed with existing fuel (low cost option) or be fed into the boiler using a designated hopper (high cost option). Boiler monitoring and fine tuning for utilizing a new co-fuel is estimated at $15,000. This study would include aspects of: ash handling, materials handling (e.g. impact of film on clogging of fuel feeding system), materials handling requirements.

The environmental permitting will be more complex. Certain wastes that generate potentially hazardous emissions such as PVC or flammable materials would need to be segregated from the waste.

It is anticipated that council and state based approvals may be required for the co-firing of solid wastes. For example, the Queensland Government Dept. Environment and Heritage Protection Environmentally relevant activities lists “2(a) Incinerating or thermally treating general waste: <5,000t/yr” with an aggregate environmental score (AES) of 18 and an annual fee of $4,404.60. More than one ERA can be operated under the one environmental authority as part of a single integrated operation, with the annual fee being the highest annual fee for any ERA conducted under the environmental authority. A red meat processing (RMP) plant is likely to trigger:

- Meat processing (including rendering): >50,000t/yr, AES of 66, Annual fee of $16,150.20,
- Fuel burning operation using equipment capable of burning at least 500kg/hr of fuel (AES of 35),
- Edible oil manufacturing or processing: 1,000t/yr or more (AES of 38).

It can be seen most RMPs will currently be undertaking several ERAs above that expected for thermally treating general waste, hence it is anticipated that there will be no major hindrance at the state level for co-firing of general waste. However, there may be restrictions on the emissions to air and the need for continuous emissions monitoring (CEM) which are estimated to be in the order of $300,000 capital outlay and $200,000 per annum ongoing maintenance and calibration.

At the council level, waste incineration and rendering are classed as “Special industry” (e.g. potential for extreme impacts) as opposed to an abattoir without rendering (e.g. potential for significant impacts) which is a “High Impact Industry”. Hence, where rendering is already in place the level of industry is already in the highest bracket. The industry code calls upon items including air quality assessment, hazard and risk reporting, noise impact assessment, refuse and recycling, and storm water contamination. Council approval requirements vary throughout Australia.

The environmental permitting process is estimated at negligible if no additional modelling or material change of use submissions are required. Where AusPlume/TAPM modelling is required (emissions to air and odour) and a material change of use submission is required, costs are estimated at up to $90,000 or more.

Additional approval / operating costs for a mixed fuel will need to be considered. The main feedstock challenge is if it is wet, resulting in bridging / blocking of the fuel feeding mechanism.

Hence, some grinding of plastics and wood will be required with a 25 mm screen/recycle. Where small particle are found to bridge the fuel feeding mechanism, a screen to remove sub-6 mm could be employed.

Table 6: Solid waste co-firing project cost estimate.

Cost Item	
Boiler monitoring and fine tuning	$15,000
Environmental permitting	$90,000 +
Shredder / Grinder	$2000 to $20,000 equipment only. Cost will depending upon materials to be processed; automation; materials handling requirements.
Screen	$32,000 equipment only.
Sub-total costs	$17,000 to $157,000 +
Revenue / cost avoidance	
Avoided waste management costs	$164,000 p.a.
Energy in waste off-setting coal energy at $5 / GJ.	$100,400 p.a.
Sub-total Revenue / cost avoidance	$264,400 p.a.
Simple payback	1 month to +1 year (depending upon material handling requirements and complexity for environmental approval)

Figure 4: Example of a shredder for creating 20 mm particles from solid waste.

Where the fuel is relatively high in density (e.g. > 500 kg/m3 bulk density), hydrophobic, low in fines / dust, moisture ~10% and a 25 mm top size, then minimal works are expected to be required. Wastes such as chipped wood and shredded hard plastics are examples of waste that would meet this requirement. The total general waste tonnage, is assumed to be combustible materials (plastic, wood, paper cardboard) could represent towards 19% of a site's fuel requirements.

The main feedstock challenge is if it is wet, resulting in bridging / blocking of the fuel feeding mechanism.

4.2 Packaged Plant Solid Fuel Boiler

Where a facility does not currently operate a solid fuel boiler, a small-scale packaged plant could be procured to generate steam and/or hot water to off-set existing site loads. The boiler presented in Figure 8 below was specifically designed for biomass pellets, hence would require revision in terms of the feeding screw mechanism, particle sizing requirements, combustion chamber residence time, fuel hopper, ash removal, boiler residence time and flue gas cyclone. The budget price fully installed is estimated at $630,000. Such a plant is rated to combust approximately 1000 tonnes per annum of fuel, hence for the mixed waste feed would generate around 753 kW of thermal energy (kWt) if running at 80% efficiency. Assuming that the system costs $1/GJ to run in terms of staff and maintenance, generates heat valued at $5 / GJ, and has similar environmental permitting costs to 5.1.1 above, the simple payback period is estimated at 3.4 years.

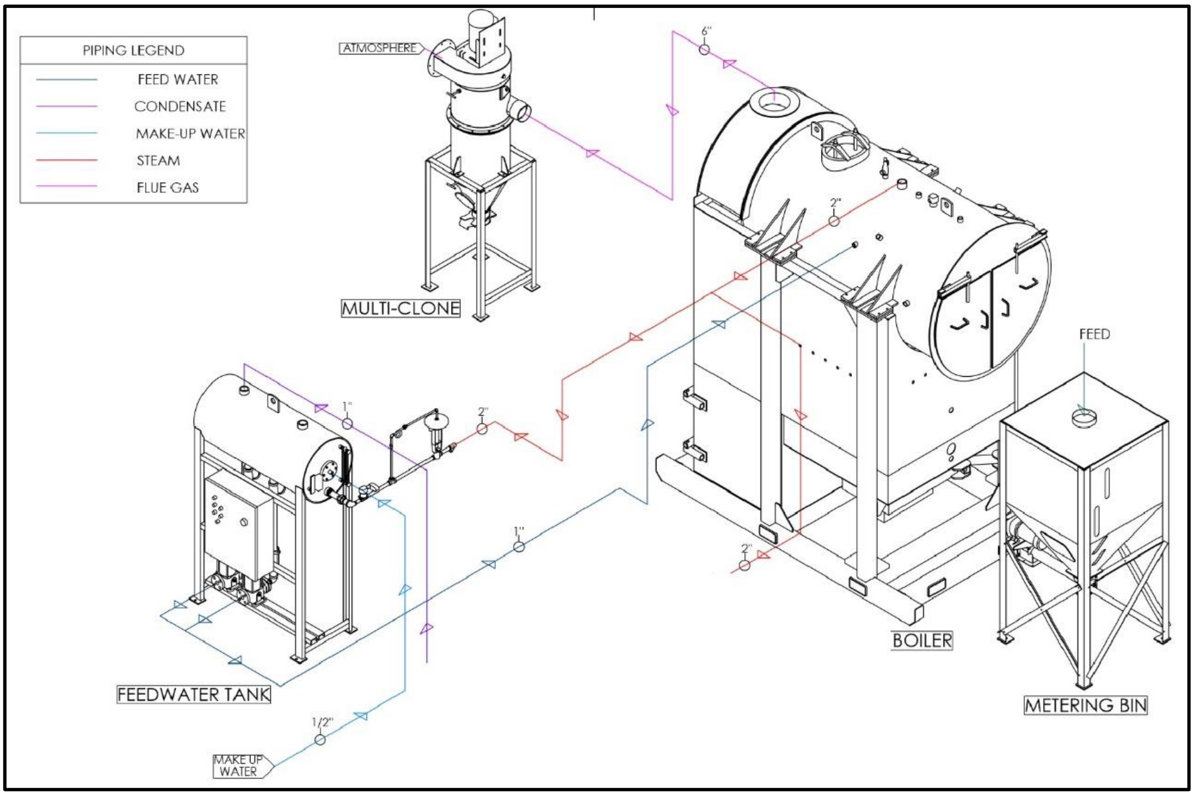

Figure 5: Small scale packaged plant solid fuel boiler.

4.3 Multi-layer Film Recycling

The specific polymer material created by red meat processors that is most difficult to recycle is the multi-layered Cryovac, Modified Atmosphere Packaging (MAP), or vacuum packaging. Multi-layers are used to provide the multiple advantages of the different types of polymers used: barriers (e.g. nylon, PET, EVOH) such as for water and oxygen transmission reduction, structural integrity / puncture resistance, shrinkage reduction, printing, direct oven cooking and other advantages. Up to five layers or more can be common place. The exact composition of the material is closely guarded by companies, however examples can include:

- Layers of PE and EVOH
- PVdC coated films of other polymers (e.g. PA, PET)
- PVC film with PE sealants
- Easy to open packages composed of thermoplastic film including a sealing layer and a layer directly adhered comprised of ethylene, acrylic acid and/or methacrylic acid monomers, a modified EVA copolymer, and a polybutylene[3].
- Trays can also be multi-layered such as PP and EVOH.

A successful process has been developed to recycle multi-layered polymers as follows[4]:

- Trammel / ballistic separation of contaminants
- Shredding to 200 mm
- Near infrared (NIR) into fractions (e.g. PE from other mixes, etc.)
- Dry grinding to 30 mm with dry cleaning or wet grinding, washing, sink/float and low temperature drying,
- Melting and dispersion of barrier films (nylon, PET, EVOH) via the use of compatibilisers[5]
- Blending (up to 30%) with miscible materials (e.g. LLDPE)
- Use of coated fillers to aid dispersion and act as volatile adsorbers.
- Vacuum devolatilization
- Extrusion into flake, agglomerate and/or pellet.
- Reforming into garbage bags, sheeting, fencing and hoardings, stock partitions, plastic lumber.

Limitations include:

- Yields can be low (50%) hence lots of waste can be generated.
- Throughput rates are low due to low bulk density.
- Multilayer and PP content needs to be minimised.
- Contaminants are stuck to film (paper, organics).
- Strong odour to recovered films and pellets.
- Moisture and volatiles need to be removed – energy cost, waste water processing costs.

[3] http://ipaustralia.com.au/applicant/cryovac-inc/patents/AU1999037071/, accessed 28 June 2016.
[4] Kosier, E. “Recycling of mixed post consumer films”, Nextek Limited, 2012.
[5] http://plasticsnews.com/article/20160617/NEWS/160619830/dow-hits-holy-grail-with-pouch-recycling-breakthrough, accessed 28 June 2016.

Discussions have commenced with third parties with expertise in the area of multi-layer recycling. Due to the high BOD of wash water, it could be that the shredding and cleaning occurs on-site and the separation, melting and extrusion occurs under a tolling arrangement with a suitable company.

4.4 Other Waste Recycling

Some councils provide commercial businesses with recycling services and may not charge a gate fee for dedicated loads of sorted recyclable materials. Councils can provides commercial companies with 4.5 cubic metre bins for recycling at an indicative cost of $17.80 per cubic metre. Hence, there exists an economic and environmental incentive to segregate recyclable products and to compact the waste. Minimum BCC service is for 12 months and these bins can accept paper, cardboard, glass, metal and plastic (but not plastic bags). Depending upon materials handling requirements, if any council recycling acceptable materials can be easily segregated, it is estimated that such an activity would reduce waste management costs immediately.

4.5 Waste Compaction

Waste management companies generate a great deal of revenue by collecting air or “void space”. Streams which may be charged per bin movement (i.e. volume) are:

1. General waste that is not compacted,
2. Paunch,
3. Sludge.

Hence there exists an opportunity to reduce waste management costs via waste compaction. A suitably sized compactor is around $50,000 for supply and delivery of a mobile rotary compactor[6]. Simple payback is estimated at around 6 months for 15% compaction (not including labour / operating costs). A key limitation is that the bins are at maximum weights, and moving to smaller bins would not improve the economics as collection is based on truck movements. There could exists the opportunity for a truck to collect 2 smaller bins, hence if compaction is considered viable a round table should be held with waste removal companies to determine the optimal bin arrangement followed by a trial to determine compactability.

Figure 6: Stationary rotary compactor

[6] http://www.wasteinitiatives.com.au

Figure 7: Mobile rotary compactor

4.6 Off-site Waste to Energy

Costs are estimated at up to $100 / tonne with up to a further $50 / tonne transport costs to Gladstone for disposal via co-firing in the Cement Australia kiln. Strong collaboration / negotiation could bring this cost lower. Hence, this option is competitive with the current general waste disposal option and will certainly improve in economic viability were a state based landfill to be introduced. Blocks of approximately 600 mm x 600 mm x 600 mm can be accepted, hence a compaction and bailing system could be trialled to determine technical viability of bailing waste and associated transport costs.

Further, the materials handling costs and any associated capital modification need to be reviewed.

4.7 Small scale plastic pyrolysis for liquid fuel

A packaged pyrolysis system is estimated to be in the order of $2 million and capable of processing around 3500 tonnes per annum. Due to the low tonnages of available waste and the lack of a suitable combustion system for burning the liquid pyrolysis oil, the paybacks for this technology would be 10 years plus.

5 Results – WWTP

5.1 WWTP Capital Cost

This report summarizes the findings of a cost-benefit analysis (CBA) for an Integrated and Automated Bio-energy and Waste Water Treatment Plant. The basis of design is to segregate / concentrate available organic wastes to first send to an anaerobic digester to generate renewable energy before then sending to an aerated treatment system. The solids (paunch, screenings, and dewatered aerobic sludge) are mixed with the liquid streams (DAF float with fat removed, decanted red stream) in order to create a slurry that is approximately 15 to 20% solids. Close attention must be paid to ammonia levels to ensure that the systems is not limited by ammonia levels. It is anticipated that the system will not be limited by ammonia however would need to be confirmed during a proposed pilot scale trial.

The facility outlined below was designed to treat an inlet of 43,000 tonnes per annum of organic wastes at a solids content of 17%, with 82% of the solids being volatile (dry weight basis). The volatile solids is sourced from paunch (43%), red stream decanted solids (28%), green stream screenings (19%), DAF float with fat removed (5%), and dewatered aerated tank sludge (5%).

When all wastes from a beef processing facility including rendering are processed through an anaerobic digester facility using closed tanks (red, green, paunch, and DAF sludge with fats removed), it is estimated that approximately 41% of the power load and 20% of the thermal load can be provided if the biogas is utilized in a cogeneration engine. When the biogas is combusted directly in a boiler, around 42% of the thermal load can be provided. The components of the capital cost estimate, to an accuracy of approximately +/- 50% to 30%, are summarized in Table 7 below.

Table 7: Waste Strategy – Summary of Options.

WWTP Cap Ex Estimation	Cap Ex Estimate
Anaerobic Digester (Phase 1 and 2 digester; cogen 1 and 2)	
Digester #1, control room, flare, materials handling	
Power cabling	
Cogen #1	
Digester #2	
Cogen #2	
Sludge / liquids Decanter (WAS decanter)	
WWTP DCS Automation	
DAF Decanter – INDICATIVE	
Decanter civil/structurals and cake handling	
Aerated tanks (for 10khpw)	
Green stream rotating screen upgrade to maximise solids removal (i.e. finer mesh) –	
TOTAL FOR ARENA SUBMISSION – INDICATIVE	~$ 12 mil

The revenue / cost reduction were estimated at 58% landfill cost avoidance, 15% power, 21% Renewable Energy Target (RET) credits and 6% low grade heating (i.e. generation of hot water to reduce the use of steam for creating hot water). The internal rate of return (IRR) was calculated at approximately 40% over 25 years for an anaerobic digester section only operating at capacity and approximately 14% for a WWTP operating at capacity.

Key sources of error / project risks:

[1] Capital equipment with > +/- 10% accuracy are: closed vessel aerated tank system, DAF decanter, decanter civil / structurals and cake handling.

[2] Balance of capital equipment estimated to accuracy of approximately +/- 10% or higher. No equipment yet estimated to "fixed and firm, lump sum" and no contingency has yet been allowed for.

[3] Digestate cake handling costs of $0 / tonne. Market still to be tested in terms of value of cake as soil conditioner.

[4] Detailed dewatering strategy. Anticipated that in future red stream could be dewatered in WAS decanter during operational hours with AD digestate decanted at other times. Green stream dewatered via rotating screen.

[5] Closure of ARENA fund or failure to attract ARENA funding.

With reference to the Australian Tax Office (ATO) document "Taxation Ruling TR 2014/4", the WWTP does not fit into a specific category hence listed below are the life in years of the main equipment of an AD plant:

Waste remediation and materials recovery services (29220); Chippers and shredders: 7 years.

Waste remediation and materials recovery services (29220); Control systems: 10 years.

Waste remediation and materials recovery services (29220); Vibrating screen separators: 10 years.

Gas supply; Control systems (excluding computers): 10 years

Gas supply; Gas meter: 15 years

Basic chemical and chemical product manufacturing (18120, 18130 and 18310); Biogas system assets (excluding effluent pond covers): 25 years

Hence, the life of the entire plant is conservatively estimated to be 25 years.

5.2 Project Phasing - WWTP

To prevent a single large capital outlay and to minimize project risks, the project could be delivered in phases, with a possible suggested staging approach outlined below.

Such phasing allows the capital outlay to occur over 2 or more financial years and also sets up milestone payments under potential funding from the Australian Renewable Energy Agency (ARENA).

All items in Phase 1 are to be delivered to have a functioning anaerobic digester. The items in Phases 2 and 3 can be delivered in any combination of one or more items.

Table 8: Project delivery phases for an integrated WWTP.

Phase 1:		
	Digester #1, control room, flare, materials handling	
	Power cabling	
	Cogen #1	
Phase 2:		
	Decanter civil/structurals and cake handling	
	DAF Decanter	
	Sludge / liquids Decanter (WAS decanter)	
	WWTP DCS Automation	
	Green stream rotating screen upgrade	
Phase 3:		
	Digester #2	
	Cogen #2	
	Aerated tanks (for 10khpw)	
	TOTAL	**~$12 mil**

Indicative Payment Terms:

- 40% of Contract Value upon placement of order [~$1.62 mil excluding contingency].
- 40% of Contract Value at dispatch of main equipment (6.5 months).
- 15% of the Contract Value upon completion of construction (10.5 months).
- 5% of the Contract Value on completion of commissioning (12 months).

5.3 Results – PV Solar

An analysis for PV Solar was also completed for installation on a single storey administration building, with the results for an IRR over 30 years summarized in the table below:

Table 9: Summary of cost-benefit analysis findings for PV solar.

	100kW PV Solar + 4 kWh Batteries. Vendor 1 IRR 30yrs	**100kW Vendor 2 IRR 30yrs**	**99.68kW Vendor 3 IRR 30yrs**	**30kW Vendor 1 IRR 30 yrs**
Cap ex (assumed constant)	$164,985	$134,503	$111,339	$36,265
1st yr of operation - 2016	0.72%	3.75	5.72%	2.05%
2017	0.87%	3.93	5.93%	2.26%
2018	1.05%	4.17	6.20%	2.54%
2021	1.60%	4.87	6.45%	3.36%

Due to the upfront small scale Renewable Energy Target credits for systems <100 kW as opposed to the need to create credits for a large scale system in addition to the limited single storey (i.e. low install cost) roof space available, it was decided to concentrate on a system of <100 kW. Whilst the economics of a larger system may appear reasonable, the few percentage points of additional return is not a sufficient incentive to take.

6 Conclusions/Recommendations

6.1 Recommendations for further work

The recommendations for further work are:

- Anaerobic digester general and detailed design with associated capital cost estimation to a higher level of accuracy, including:
  - Defined and peer reviewed Process Flow diagram.
  - Site geotech information.
  - Creation of production hours, non-production hours and excursion event mass balances for the WWTP.
  - Due diligence.
  - Submissions for funding.1000
- Pilot scale anaerobic digestion of actual organic wastes,
- State and council level approvals,
- Trial of a three phase separator for the DAF float (Fat pump),
- Trial of multi-layer plastic recycling and options to improve waste segregation for recycling
- Waste co-firing assessment, in particular approvals process.

6.2 Waste co-firing

Review of opportunity to chip and co-fire combustible materials, in particular pallets and crates. The estimated costs are:

Item	Cost
Boiler monitoring and fine tuning	$15,000
Environmental permitting	$90,000 +
Shredder / Grinder	$2000 to $20,000 equipment only. Cost will depending upon materials to be processed; automation; materials handling requirements.
Screen / metals recovery	$32,000 equipment only.
Sub-total costs	$17,000 to $157,000 +

6.3 Three Phase separator (Fat pump)

A submission has been received by Raw Power Systems (www.rawpowersystems.net) for a trial of a system to remove the fat from the DAF float.

Step 1: The water has passed through a series of screens to remove the floating solids and enters the RPS Columnar Liquid Separation (CLS) plant. The CPS is specifically designed for each application in order to optimise the performance with respect to the actual flow rate, supply pressure and characteristics of the lower density phase to be separated. This system exploits the density difference between the two liquids and removes the lighter component in a continuous process. The system is static, relying on the flow of the liquids to be separated, however a small pump will remove the lighter liquid from its collection reservoir. It is anticipated that this oily matter can be burned in a boiler and contribute some energy value

Step 2: Whilst the majority of the solid particles will have been removed in the existing screen filtration, there will be particles of a size small enough to pass the filter mesh, but large enough to pose an issue in the analysis of the treated water after the process. A specifically designed hydro-cyclone will be constructed to centrifuge the solids from the flow. This may require an additional pump to supply an adequate continuous stream of fluid, with a second pump collecting the post hydro-cyclone waste water. The solids thus collected will have a fat content that may permit the material to be burned or your client may have some other use to which the solids may be applied.

Step 3: The final step is a polishing stage intended to remove colloids without the expense of costly membranes. The water will be pumped through a proprietary mix of resins or minerals to ensure that the water that is treated is capable of being discharged or recycled. The polishing system filtration medium is a consumable item, however, its life will depend entirely upon the degree of colloidal contamination in the water. The medium is inexpensive, non-toxic and has no constraints on its manner of disposal. The key to establishing a reliable system lies in the separation of the oily matter and the dirty water. It is suggested therefore that prior to incurring major capital expenditure that we provide a customised CLS on site for a period of one week pilot program so that the separation of the oily matter can be achieved. Once that matter has been determined, then a bespoke system can be designed that will optimise the water condition on discharge whilst permitting the contaminants to be retrieved as far as is possible.

An estimated cost for the pilot program would be $25,000, which would be credited to the final cost should a full system be ordered from RPS.