Final Report

AMPC
AUSTRALIAN MEAT PROCESSOR CORPORATION

Feasibility Study

Feasibility Study for a Refuse Derived Fuel (RDF) created from Paunch, Biosolids and C&D Waste

Project Code
2023-1003

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1.0 Project Description

Stara Real Estate Capital & Advisory Pty Ltd (“Stara”) was retained by Australian Meat Processor Corporation (“AMPC”) to undertake a Stage 1 desk-top feasibility analysis for co-combusting a range of biomass fuels generated within the red meat supply chain, specifically paunch and collateral waste from the red meat processing (RMP) industry, in combination with C&D waste, for adoption into "business as usual" operations at three Queensland processors to be nominated by AMPC as a base line for the analysis i.e. combustion in existing boilers.

For paunch waste, there is currently an end of waste (EOW) code developed that outlines the quality criteria and approved use. A resource producer can treat and process the waste under an EA to meet the appropriate quality criteria but the only approved uses for paunch are currently:

- as a feedstock in an anaerobic biogas plant;
- as a feedstock in the manufacturing of compost; and/or
- as a feedstock in the manufacturing of soil conditioner.

The use of paunch in a refuse derived fuel (RDF) will require its inclusion as an additional use to the paunch EOW code.

Stara was retained to provide advice on the preparation of an application for or attendance at a pre-lodgment meeting and advice on the preparation of an application for a variation of the paunch EOW code if a commercial business model (cost of supply & energy generated in specific boilers) could be developed (on paper) to enable the use of paunch, and other on-site wastes, to be combined with off-site C&D wastes to derive a commercially viable RDF fit for use in existing boilers (with or without modifications to infeed fuel trains) and specific built boilers.

2.0 Project Objectives

The project will consider output streams from RMPs (i.e. with a view that the proposed RDF should have no worse environmental affect than participants existing fuels), and with a particular emphasis on materials that are landfilled.

2.1 Desktop Study

The participating RMPs should have alignment on objectives around a desktop study to establish:

1. Principles to assess the economic viability of a RDF comprising the most suitable waste combination (e.g. processor wastes and C&D wood waste)

2. Key parameters impacting the economic and technical viability of waste to energy (W2E) facilities for processors e.g. types of waste, volume, scale, etc.
3. Feasibility studies for [three] specific case studies considering how waste type, tonnages, transport, composition and technology selection impacts CAPEX, OPEX, and economic viability of a W2E project using a RDF. Feasibility should be supported by a LCOE illustrative comparison of the before and after estimates for adoption
4. Whether remote W2E generation, using a suitable RDF, can deliver electricity to RMPs cheaper and at lower risk than purchasing from the grid over the life of plant, reducing operating costs (if applicable)
5. Whether combusting a suitable RDF will result in reduced thermal energy costs based on current pricing for existing fuel sources
6. Whether combusting a suitable RDF will result in reduced waste disposal costs
7. Whether combusting a suitable RDF will result in improved environmental outcomes and social license to operate and in particular reduction in Scope 1 & 2 emissions
8. Whether participants will be likely to accept onsite processing or C&D waste to a RDF
9. Whether onsite or remote W2E RDF supply provides energy security and a reduced reliance on fuels from third parties and / or energy utilities

Stage 1 Objectives might consider alignment with potential future Stage 2 Objectives (i.e. not part of this project), and whether suitable participant RDF's align with Qld Energy from Waste (i.e. EfW) policy.

If this stage 1 desktop study results in a positive outcome against any or all of the objectives: AMPC and AKM Earth will endeavour to work with those RMP supply chains having a desktop commercial applicability to undertake a Stage 2 (and beyond) process, taking into account the requirements of Qld EfW Policy.

3.0 Methodology

3.1 Stage 1 Analysis

The analysis for stage 1 required the following information from at least 3 and up to 6 QLD processing sites and where information is not able to be obtained from each processing location, a best estimate will be used for each data point.

Determination of the following in business-as-usual operations in each RMP (to be provided as part of a RFI process):

- Annual thermal spend $
- Boiler fuel

- $/G LHV cost of current fuel purchase
- Steam usage (tpa) and pressure/ temperature
- Thermal load in MWt
- $/t steam cost
- Waste streams generated
    - Paunch
    - DAF Sludge
    - Waste activated sludge from aerobic ponds
    - Red stream screenings
    - Green stream screenings
    - Manure
    - Kitchen/cafeteria waste
    - Contaminated plastics e.g. vacuum packaging, single use plastics, PPE
    - Contaminated cardboard
    - Ad hoc wood from construction/ demolition waste; packaging; damaged crates
- Waste disposal cost
- Where electricity is consumed from the grid:
    - Average power consumption
    - Maximum power consumption
    - Cost of electricity in $/kWh, including the volume and demand charges
- Size, capacity and configuration of boiler and fuel handling systems.
- OEM specifications for boiler fuel and fuel handling system,
- Estimated boiler efficiencies.

3.1.1 Information Provided

Information was provided in a response from the owner of one site (“Site A”) as follows:

Data	Description		Per Annum
Energy	Grid Electricity Consumption	kWh/yr	19,849,557.85
	Grid Gas Consumption	GJ	141,753.023
Waste	Paunch Solids	Tonnes (all to compost)	6445.4516
	Waste Oil	Recycled	5,000l
	General Waste	tonnes to landfill (i.e. mostly contaminated plastic and cardboard)	279.98
Render	Input	Tonnes	49,191.86
	Output	Tonnes	27,868.07
Wastewater	Volume p.a., & COD concentration, % COD removed) Discharged from site Yr 21/22	(P 190mg/L / N 34mg/L)	772,721 m^3
	Irrigation	Yr 21/22	772,721 m^3
Throughput	Cattle slaughtered in year FY 21/22		203,919 head
	Cattle slaughtered in year FY 21/22		136,725.26t LW
	Cattle slaughtered in year FY 21/22		77,958.01t HSCW

AMPC previously retained All Energy Pty Ltd to explore how RMPs can aggregate localised bio-wastes to help make distributed Waste to Energy (W2E) facilities more feasible in regional locations. Information for this report was also drawn from the Public Report prepared by All Energy Pty Ltd for AMPC and submitted on 29 August 2020 under Project Code 2020-1006 ("All Energy Report").

We have also obtained information from AKM Earth Pty Ltd which provided proprietary information on:

- Transportation costs for C&D and other waste streams
- Palletisation process for comingled waste streams
  Processes for manufacture of various RDFs
- Calorific value and moisture content for various waste streams

3.1.2 Qualification

The volumes of waste produced from Site A and their treatment may or may not be typical of comparable RMPs. We also received no information on the cost of composting paunch on Site A. We understand that paunch may have a significant disposal cost for many RMPs resulting from the need to dry and transport paunch to landfills.

We have assumed that the volume of paunch produced per head of cattle slaughtered is relatively consistent across the industry.

4.0 Project Outputs/Deliverables

4.1 Principles to assess economic viability of a RDF comprising the most suitable waste combination (e.g. processor wastes and C&D wood waste).

In general, the economic viability of a RDF will be determined by an assessment of the following factors against the cost (measured as the LCOE i.e. levelised cost of electricity or the average net present cost of electricity generation over the life of a generation plant) and environmental impact of generation plant using current fuels:

- Capital Costs – the cost of acquiring/developing/converting plant to accommodate the use and delivery of the RDF feedstock and to manage emissions within specified target emission limit values
- Operating Costs
- Feedstock Costs (including cost of delivery of feedstock)

- Feedstock composition – the suitability and quality of the fuel
- Cost avoidance (waste disposal and transport costs for processor wastes)
- Energy output
- Energy input – i.e. cost of producing the RDF
- Efficiency
- Environmental impact
- Government incentives and regulations

We have assumed in this report that RMP wastes are suitable for use as a RDF. We have included in Appendix 1 a fee proposal from Assured Environmental to undertake a study of the suitability of material produced at RMP facilities (including paunch, PPE and other materials) and to advise on the environmental considerations for use of a RDF that need to be addressed as part of any approvals process, including any existing environmental approval licences, and the possible reclassification of paunch under the End of Waste code.

It is recommended that the Assured Environmental study be undertaken as a precursor to any pre-lodgment meeting with the Department of Environment and Science or any further action.

4.2 Key parameters impacting economic and technical viability of waste to Principles to assess the economic viability of waste to energy (W2E) facilities for processors e.g. types of waste, volume, scale, etc.

The practical implications of W2E are noted in the All Energy Report as being:

4.2.1 Reduced Power Cost

Expensive grid tariffs and the compounding year on year increases in prices present a significant risk to processors. W2E can deliver power cheaper over the life of plant, reducing operating costs.

4.2.2 Reduced Thermal Energy Costs

For RMPs on the east coast purchasing natural gas or LPG as a thermal fuel, this is a very large operating cost and continuity risk, able to be offset by burning biogas or syngas from gasification.

4.2.3 Reduced waste disposal costs

Anaerobic Digestion and gasification can reduce the waste disposal costs paid by RMPs, particularly

those located in metro areas or Queensland, where landfilling costs have suddenly increased by $75/t as of 1/7/2019, increasing by $5/t every year until 2023.

4.2.4 Improved environmental and social license to operate

There is pressure from within the industry and the community to maintain the clean and green image of Australian red meat; W2E can aid in progressing towards the broad CN30 industry goal, individual business targets, international sustainability accreditation and circular economy solutions.

4.2.5 Decreased Reliance on Fuels

Decreased reliance on fuels hauled / reticulated to site: onsite W2E provides energy security and a reduced reliance on fuels from third parties and / or energy utilities.

4.2.6 Reduction in scope 1 and scope 2 greenhouse gas emissions

Scope 1 emissions may be reduced by offsetting thermal fossil fuels; scope 2 emissions may be reduced by reducing grid electricity consumption.

4.2.7 Additional saleable products

Additional saleable products such as soil conditioner at a retail standard $/t steam cost.

Key parameters impacting the economic and technical viability of W2E facilities for processors include:

- Types of W2E processes – biological, chemical, mechanical, or thermal
- Technology of W2E process
- Types of waste/feedstocks – biosolids, food waste, green waste, agricultural residues, organic waste, waste oils, fats, mixed non-putrescible waste, mixed residual waste, RFDs, sorted homogenous feedstocks
- Does the waste qualify as residual waste i.e.it is not technically, environmentally or economically practicable to reuse of recycle? Is it available for use as a feedstock for the particular type of W2E process? As noted above, Paunch is presently approved for use as a feedstock for thermal W2E processes.
- Composition of feedstock
- Feedstock availability and security of supply
- Location of Feedstock gate and processing plant
- Variability of feedstock
- Transport of feedstock

- Storage/stockpiling of feedstock
- Emission limit values

This project has considered the economic viability of using a RDF comprising a combination of processor wastes and C&D wastes in a thermal W2E process.

4.3 Feasibility Studies for at least three and up to six specific case studies considering how waste type, tonnages, transport, composition and technology selection impacts CAPEX, OPEX, and economic viability of a W2E project using a RDF. Feasibility should be supported by a LCOE illustrative comparison of the before and after estimates for adoption.

Because of the limited response received from participating RMPs, we were unable to undertake detailed feasibility studies for the required three to six case studies, and the information provided for Site A has only enabled us to undertake a limited analysis. Based on the information received, we can make the following observations:

1. Given that the waste streams from Site A are generally diverted to compost (Paunch @6,645t p.a.) or recycled (Oil @5,000/ p.a.) there is a relatively small amount of other general waste generated that has calorific value and is suitable for use as feedstock (280 tonnes per annum). Even allowing for the potential use of paunch as feedstock, it is clear that other suitable wastes would need to be aggregated with the waste streams from Site A to materially contribute to its energy requirements. This is consistent with the comment in the All Energy Report that “due to the small generation of organic wastes and, difficulties is handling dam sludges, it is likely that to reach the minimum scale for viability, third party wastes will need to be aggregated in the first stage” and “the partner site recognized the limitation of W2E using their own meat processing wastes, and hence the value in aggregating suitable wastes”.

2. We have no information on the cost involved in composting paunch, but we have assumed that it is either:
    a. composted on site (which will have a zero or minimal cost of transport) or
    b. transported, in which case the cost of transport for composting would be comparable to the cost of transport to a waste receiving and RDF processing facility (“Processing facility”).

3. A key consideration is the location of the Processing facility and its proximity to Site A. The optimal location of the Processing facility will be determined by:

    - Planning considerations - site must be suitably zoned and have development approvals
    - Licensing consideration – site must hold appropriate waste management and thermal processing licences
    - Amenity – the Processing facility will be receiving large volumes of waste material, which may be incompatible with a nearby food processing plant and other medium industry. It will also require a large number of truck movements which may not be compatible with local traffic planning. There have also been numerous public objections and planning challenges to the location of waste management and thermal processing facilities.
    - Proximity to market for waste materials – in the case of C& D waste, the larger the demand for feedstock for Site A, the more likely that the Processing facility will need to be located near to a major urban centre to ensure security of waste supply.

4. Based on our knowledge and information from AKM Earth Pty Ltd of the licenced waste management facilities in South East Queensland, we have assumed that the Processing Centre will be somewhere between 0km (i.e. on Site A or immediately adjacent to it) and 150km from Site A and that waste materials will need to be transported to the Processing Centre or RDF will need to be transported from the Processing Centre to Site A. In either case a journey of up to 150km will be required at an approximately equivalent cost.

5. We have also assumed that there will also good reasons to assume that the Processing Centre will not be located on or adjacent to Site A for the Planning, Licensing, Amenity and Proximity reasons outlined above. Whilst the All Energy Report indicated that based on a workshop with a RMP “there was no expected opposition to taking third party wastes on site or opposition to a third party operating adjacent (to the RMP site)” we suggest that, for the reasons outlined above that is unlikely.

6. Based on the information in the AKM Proprietary Database, and depending on the type of feedstock and the technology used to generate electricity the thermal efficiency of plant will generally range from 5-42% - i.e. 1MW of electrical energy will require between 20 and 2.5MW of thermal energy. A coal fired power station will generally be around 33% efficient in converting thermal energy into electricity. A gas fired power station will generally be about 42% efficient in converting thermal energy into electricity. A RDF fired power station will generally be 10-20% efficient in converting thermal energy into electricity.

7. Subject to our comments below, it is reasonable to assume that RDF will generally have a calorific value of 13-15Mj/kg. This range is consistent with the biomass assay in the All Energy Report and the AKM Pty Ltd proprietary database.

At the upper end of that range:

- Replacement of gas used to fire the boilers at Site A from RDF will require 9,451 tonnes of RDF per annum. Using B-double configured trucks (loaded to 33 tonnes per truck to allow for a margin of error) that would require 286 loads per annum. If the RDF was delivered to Site A from a RDF processing site approximately 150k from Site A transport costs would be approximately $112 + GST per tonne or $1,058,512 per annum. This compares to estimated gas consumption cost of approximately $1,969,500 for 142,753 GJ (or 39,378,983 kWh) at $13.89/Gj. This assumes that gas is used to generate steam for rendering and other applications and is not used to generate electricity to supplement electricity supply from the grid.

- Replacement of electricity (from the grid) used at Site A [assuming 15% efficiency and an estimate for parasitic load from fuel feeding systems, boiler water pumps, cooling equipment and pollution control devices] from RDF will require 35,000 tonnes of RDF per annum. Using B-double configured trucks (loaded to 33 tonnes per truck to allow for a margin of error) that would require 1,060 loads per annum If the RDF was delivered to Site A from a RDF processing site approximately 100k from Site A transport costs would be approximately $112 + GST per tonne or $3,920,000. This compares to estimated electricity cost from grid supply of $1,786,455 for 19,849,500 kWh at $0.09kW/h.

- Approximately 1-3% of the total tonnage of RDF delivered to Site A could need to be removed from the site in the form of ash and taken to landfill at an approximate cost of $300 + GST per tonne. There are limited disposal options close to Site A. The approximate cost of disposal of 1,300 tonnes of ash would be $400,000 per annum.

8. One of the present benefits of RDF as a feedstock is that it has a negative input cost because the alternative to processing waste to RDF is disposal via landfill, which incurs a gate fee, including a government levy which is increased by circa 5% per annum. The All Energy Report assumed the cost to be -$53.43 per tonne. The future cost will be influenced by landfill disposal costs and future demand for RDF as fuel stock.

9. Based on a cost differential between the transport costs of 44,570 ton of RDF at $112 per tonne ($4,991,840) plus ash disposal costs ($315,000) and the current total cost ($3,755,955) of electricity ($1,786,455), the price of RDF per tonne would need to be in the order of -$91.58 per tonne for the costs of transport and disposal to be equal to the current cost of electricity. That price is not considered to be achievable in the current market, given the current cost of landfill disposal and RDF processing costs.

10. Based on a cost differential between the transport costs of 35,000 tonnes of RDF at $112 per tonne ($3,920,000) plus ash disposal costs ($400,000) and the current total cost ($3,755,955) of gas ($1,969,500) and electricity ($1,786,455), the price of RDF per tonne would need to be in the order of -$80.44 per tonne for the costs of transport and disposal to be equal to the current cost of gas and electricity. That price is not considered to be achievable in the current market, given the current cost of landfill disposal and RDF processing costs.

11. Based on a cost differential between the transport costs of 9,451 tonnes of RDF at $112 per tonne ($1,058,512) plus ash disposal costs ($85,000) and the current cost of gas ($1,969,500) the price of RDF per tonne would need to be in the order of $87.39 per tonne for the costs of transport and disposal to be equal to the current cost of gas. At a price of $0 per tonne, use of imported RDF as a substitute for gas would result in savings of $910,988. At the price of -$53.43 assumed by All Energy, use of imported RDF as a substitute for gas would result in savings of $1,415,955. The projected savings would be supplemented by:

    a. any savings in transport and disposal costs of general waste which could be combined with imported RDF – the limitation being the potential cost of transport of general waste to the Processing facility could negate any additional savings. This could be mitigated by loading general waste on to trucks delivering RDF to site that would otherwise return unladen to the Processing facility.
    b. Any savings in transport and disposal costs of paunch however, as noted, the paunch from Site A is composted and we don't have an indication of the costs associated with composting.

12. These figures do not take into account:

    a. The capital costs required to acquire, develop or convert existing plant. We have not been provided with the specifications of the boiler at Site A, but we have assumed that the boiler capacity would need to be upgraded significantly to process the tonnage of RDF required to replace or supplement supply from the grid. For example, the All Energy Report assumes a $3.5m capital cost for a 2.5MW biomass boiler.

    b. Additional operating costs which would include feedstock stockpiling and maintenance, feedstock handling and ash handling.

13. Based on these figures, and subject to the qualifications above:

    a. Substitution of RDF processing and supplied from a remote site for gas is a feasible option whilst the input price of RDF remains negative.
    b. We consider that further investigation of the capital costs for acquisition of additional boiler capacity and/or conversion of existing boiler capacity at Site A and the additional operating

costs for RDF is warranted to determine the impact on the projected savings from substituting RDF for gas.

c. We consider that further investigation is warranted to determine the cost of managing and composting paunch and whether further savings can be generated from either transporting paunch to the Processing facility for it to be combined with and form part of RDF to be resupplied to Site A.
d. we do not consider that the LCOE from the development and operation of a RDF fuelled W2E plant on Site A to replace or supplement electricity from the grid to be feasible for the foreseeable future because of volume of RDF required to generate electricity and the costs of transport of the RDF to Site A from the Processing facility.

4.4 Whether remote W2E Generation, using a suitable RDF, can deliver electricity to RMPs cheaper and at lower risk than purchasing form the grid over the life of plant, reducing operating costs (if applicable).

1. Efficient generation of electricity from RDF will require:

    a. An appropriately zoned site that holds the requisite licences for waste management and power generation/operate electricity infrastructure.
    b. A site of sufficient size to receive, process and stockpile a volume of waste sufficient to provide the requisite amount of RDF feedstock to ensure continuous operation of the generating plant.
    c. A reliable and predictable supply of feedstock.
    d. Efficient processing, feedstock handling, generation, and ash disposal
    e. Secure grid access
    f. Battery Storage and voltage management capability

2. In order to access electricity from a remote W2E generator a RMP will need to enter into a Power Purchase Agreement (PPA) with the power generator. A PPA can either be a physicall PPA, where the electricity is supplied directly (i.e. the supplier is not connected to the wholesale National Energy Market) or a virtual PPA. A virtual PPA involves two distinct agreements which operate in parallel. Unlike a physical PPA, the energy is not physically supplied and sold directly from the generator to the purchaser. Instead, the generator must connect to the NEM, where the purchaser is supplied energy through a contract with an authorised market retailer. At the same time a separate agreement, often taking the form of a ‘contract-for-differences’ is agreed between the generator and the purchaser to guard against fluctuations in the spot price for electricity which will be reflected in the retail contract. This means that, in effect, the energy and relevant renewable energy certificates are provided to the purchaser at a ‘fixed price’.

3. Given the site requirements for efficient electricity generation from RDF it is unlikely that a RMP could access electricity from a power generator under a physical PPA.

4. CSIRO's 2022 assessment of the cost of various generation technologies **GenCost 2021-2** indicated that LCOE for small scale biomass plants are comparable to other thermal generation plants.

Technology LCOE projections, 2021-22/MWh

Category	Assumption	Technology	2021		2030		2040		2050	
			Low	High	Low	High	Low	High	Low	High
Peaking 20% load		Gas turbine small	178	211	173	248	172	257	170	255
		Gas turbine large	160	195	150	230	149	241	148	239
		Gas reciprocating	184	213	179	245	177	251	174	249
		H_2 reciprocating	277	359	274	357	237	303	219	276
Flexible 60-80% load, high emission		Black coal	81	109	81	116	75	113	73	111
		Brown coal	110	143	108	140	105	136	103	133
		Gas	93	123	90	149	90	156	89	155
	Climate policy risk premium	Black coal	118	159	118	164	110	160	107	156
		Brown coal	189	248	184	242	179	236	174	228
		Gas	105	139	101	165	101	171	100	170
Flexible 60-80% load, low emission		Black coal with CCS	153	204	153	213	138	209	132	198
		Gas with CCS	140	184	134	214	129	222	125	213
		Solar thermal 12hrs	153	190	115	166	95	148	82	129
		Nuclear (SMR)			136	326	135	325	134	325
		Biomass (small scale)	111	162	111	162	108	162	106	162
Variable	Standalone	Solar PV	44	65	27	56	21	43	20	39
		Wind onshore	49	61	40	59	37	59	34	58
		Wind offshore	128	166	90	163	79	162	72	160
Variable with integration costs	Wind & solar PV combined	60% share			53	73				
		70% share			55	76				
		80% share			58	79				
		90% share			61	82				

These figures were updated in CSIRO's **GenCost 2022-3** report.

Based on the CSIRO figures (see Appendix 2), the capital cost for small scale biomass electricity generation plant is higher than comparable generation technologies and is projected to remain higher for the next 30 years. Similarly, the cost of large-scale biomass electricity generation plant with carbon capture and storage is projected to be significantly higher than comparable generation technologies for the foreseeable future.

CSIRO predicts the O&M costs (see Appendix 2) for small scale biomass plants to be as high or higher than comparable generation technologies. This prediction is based on a projected efficiency of 29%, which is considerably better than the assumptions we have used in this report for RDF efficiency, based on the figures in the AKM Earth Pty Ltd Database.

Given the potential future mix of generation technologies which are likely to include a greater

reliance on solar and wind generation we consider it unlikely that the future capital cost of a biomass plant to be less than the future weighted average cost of generation plant used to supply the grid. The current weighted average cost of generation plant used to supply the grid is lower than the replacement value of the generation plant used to supply the grid because of the historical cost of large-scale coal and gas generation plant. Similarly, the O&M costs for operating biomass plant is unlikely to be cheaper than the weighted average cost of generation plant used to supply the grid.

Based on these assumptions we consider it unlikely that the capital cost of a biomass plant and the O&M costs of a biomass plant will result in a cheaper price of electricity than electricity purchased from the grid over the life of the plant in the absence of considerations of the price of the fuel.

The use of RDF with a negative input cost will reduce the LCOE below a standard biomass plant with a neutral (e.g. gin trash) or positive (e.g., wood chip) input cost.

Our conclusion is that remote generation of electricity from RDF can deliver electricity to a RMP more cheaply than the grid only and to the extent to which the cost of RDF (including processing and transport costs to the W2E plant) is negative, Based on the calculations in paragraph 9 of Section 4.3 the cost of RDF would need to be cheaper than -$91.58 per tonne, which is not considered achievable in the current market.

Factors that would impact on that conclusion are:

- A significant reduction in RDF/waste transport costs
- Co-location of the waste collection/RDF processing/generation functions on one site to reduce transport costs. Based on our enquiries with Energex and other industry players the optimal export capacity for a co-located waste collection/RDF processing/generation facility is 5MW given network capacity constraints

Risks and other considerations include:

- Availability of a counterparty willing to enter into a VPP from a W2E plant to the RMP
- Secure electricity supply under the VPP – the counterparty would need to be willing to guarantee electricity supply to meet RMP demand
- Future variations in pricing of C&D waste streams impacting on pricing under the VPP
- Secure supply of C&D waste streams to underpin the supply guarantee under the VPP
- Single supplier risk – presumably the RMP would need to retain the ability to draw electricity from the grid in the event of counterparty breach
- Regulatory risk impacting on the use of RDF as fuel and the supply of RDF sourced electricity.

4.5 Whether combusting a suitable RDF will result in reduced thermal energy costings based on current pricing for existing fuel sources.

As noted in Section 4.3 substitution of gas with RDF supplied from a remote site is feasible while the input price of RDF remains negative.

4.6 Whether combusting a suitable RDF will result in reduced waste disposal costs.

If waste streams from RMP sites are to be transported to a remote site for processing into RDF it is likely that waste disposal costs will be reduced by the cost of disposal in landfill. Subject to the location of the Processing facility costs of transport of waste from RMP sites may be higher or lower than the cost of transport to landfill.

4.7 RDF – Improved environmental outcomes

Whether combusting a suitable RDF will result in improved environmental outcomes and social license to operate and in particular reduction in Scope 1 & 2 emissions.

It is likely that the use of RDF in place of gas will result in improved Scope 1 emissions. The extent to the reduction will require an assessment of the process of collection, processing and transport of the RDF, the use of fossil fuels in those processes and the extent of the savings over the displaced fuel (i.e. gas). Based on our conclusion that remote generation of electricity from RDF is not feasible, we do not consider that there is likely to be any reduction in Scope 2 emissions.

4.8 Onsite Processing

Whether participants will be likely to accept onsite processing or C&D waste to a RDF

Although the feedback to All Energy noted in its Report suggested that "there was no expected opposition to taking third party wastes on site or opposition to a third party operating adjacent (to the RMP site)", we are of the view that the considerations in paragraph 3 of Section 4.3 make it unlikely that the C&D waste can be processed into RDF on RMP sites.

4.9 Onsite W2E RDF Supply

Whether onsite or remote W2E RDF supply provides energy security and a reduced reliance on fuels from third parties and/or energy utilities

For the reasons set out in Sections 4.3 we do not consider the development and operation of a RDF fueled W2E plant on Site A to replace or supplement electricity from the grid to be feasible for the foreseeable future because of volume of RDF required to generate electricity and the costs of transport of the RDF to Site A from the Processing facility.

For the reasons set out in Section 4.4 our conclusion is that remote generation of electricity from RDF can deliver electricity to a RMP more cheaply than the grid only and to the extent to which the cost of RDF (including processing and transport costs to the W2E plant) is negative. Based on the calculations in paragraph 9 of Section 4.3 the cost would need to be cheaper than -$91.58 per tonne, which is not considered achievable in the current market.

We also note the additional considerations and risks outlined in paragraph 5 of Section 4.4 to impact on energy security.

5.0 Conclusions / Recommendations

We conclude:

5.1 Substitution of gas with RDF processed and supplied from a remote site is a feasible option whilst the input price of RDF remains negative.

5.2 Further investigation of the capital costs for acquisition of additional boiler capacity and/or conversion of existing boiler capacity at Site A and the additional operating costs for RDF is warranted to determine the impact on the projected savings from substituting RDF for gas.

5.3 Further investigation is warranted to determine the cost of managing and composting paunch and whether further savings can be generated from either transporting paunch to the Processing facility for it to be combined with and form part of RDF to be resupplied to Site A.

5.4 The LCOE from the development and operation of a RDF fuelled W2E plant on Site A to replace or supplement electricity from the grid is unlikely to be feasible for the foreseeable future because of volume of RDF required to generate electricity and the costs of transport of the RDF to Site A from the Processing facility.

5.5 Remote generation of electricity from RDF can deliver electricity to a RMP more cheaply than the grid only and to the extent to which the cost of RDF (including processing and transport costs to the W2E plant) is negative. Based on the calculations in paragraph 9 of Section 4.3 the cost would need to be cheaper than -$91.58 per tonne, which is not considered achievable in the current market.

We recommended that the Assured Environmental study referred to in Section 4.1 be commissioned as a precursor to any pre-lodgement meeting with the Department of Environment and Science or any further action.

6.0 Bibliography

Barnes and Forde, All Energy Pty Ltd Final Report AMPC Project Code 2020-1006

CSIRO July 2022 GenCost: annual electricity estimates for Australia

CSIRO July 2023 GenCost: annual electricity estimates for Australia
https://www.csiro.au/en/research/technology-space/energy/Energy-data-modelling/GenCost

7.0 Appendices

Appendix 1 Assured Environment Pty Ltd: AMPC Waste Trial Fee Proposal

Appendix 2 CSIRO Current and projected generation technology capital costs under the Current policies scenario (Source: GenCost: annual electricity cost estimates for Australia CSIRO July 2023)

Appendix 3 CSIRO Current and projected generation technology capital costs under the Current policies scenario (Source: GenCost: annual electricity cost estimates for Australia CSIRO July 2023)

Appendix 1

Assured Environment Pty Ltd: AMPC Waste Trial Fee Proposal

ASSURED ENVIRONMENTAL PTY LTD

Your environmental compliance partner

BRISBANE, SYDNEY, HOBART, GLADSTONE & DARWIN

2021

AMPC Waste Trial - Fee Proposal

Client: AKM Earth
Project ID: 13830
Date: 23/07/2021 Release: R0

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DOCUMENT CONTROL PAGE

Project Title: - Fee Proposal

Project Reference ID: 13830

Report Prepared by:

Assured Environmental
Unit 7, 142 Tennyson Memorial Avenue
Tennyson, QLD, 4105

Report Prepared for:

AKM Earth
890 Pumicestone Road
Elibah, QLD

M. Clifton

Author: Michelle Clifton

Reviewer: Craig Beyers

Table 1: History of Revisions

Revision	Date	Issued to	Changes
R0	23/07/2021	J. Meredith	Initial Release

ACCREDITED FOR COMPLIANCE TO ISO/IEC 17025 TESTING

The results of the tests, calibrations and/or measurements included in this document is traceable to Australian/national standards.

Accreditation number: 19703

NATA
WORLD RECOGNISED ACCREDITATION
NATA ID: 19703

EXECUTIVE SUMMARY

AKM Earth are seeking to understand the viability of a waste management concept being canvassed with the APMC. Specifically, the opportunity would involve waste material produced at APMC facilities (including paunch, PPE, and other materials) being collected, processed, and pelletised into a fuel for boilers operating at these facilities.

AKM Earth are seeking to understand the viability of this through consideration of:

- The suitability of the material for pelletising into a fuel source;
- The quality of the fuel and its suitability for use at the facilities;
- Specific requirements for environmental approval of both the pelletising process and use of the material as a fuel source; and
- Any specific environmental issues associated with its use as a fuel source.

This fee proposal sets out an anticipated scope of work to undertake the tasks outlined above. In preparing the proposal, it has been assumed that all tasks would be undertaken in consultation with AKM Earth personnel and, in particular, would draw on specific industry skills present within the AKM Earth team to ensure an appropriate understanding of the opportunities and risks is developed.

TABLE OF CONTENTS

LIST OF TABLES

1 INTRODUCTION

Assured Environmental (AE) values the opportunity to partner with AKM Earth to investigate this innovative approach to the management of waste materials at APMC facilities. This proposal describes how our experience and practical results driven approach can assist AKM Earth to understand both the environmental opportunities and risks associated with the application.

Figure 1 outlines the stages to be undertaken for this fee proposal.

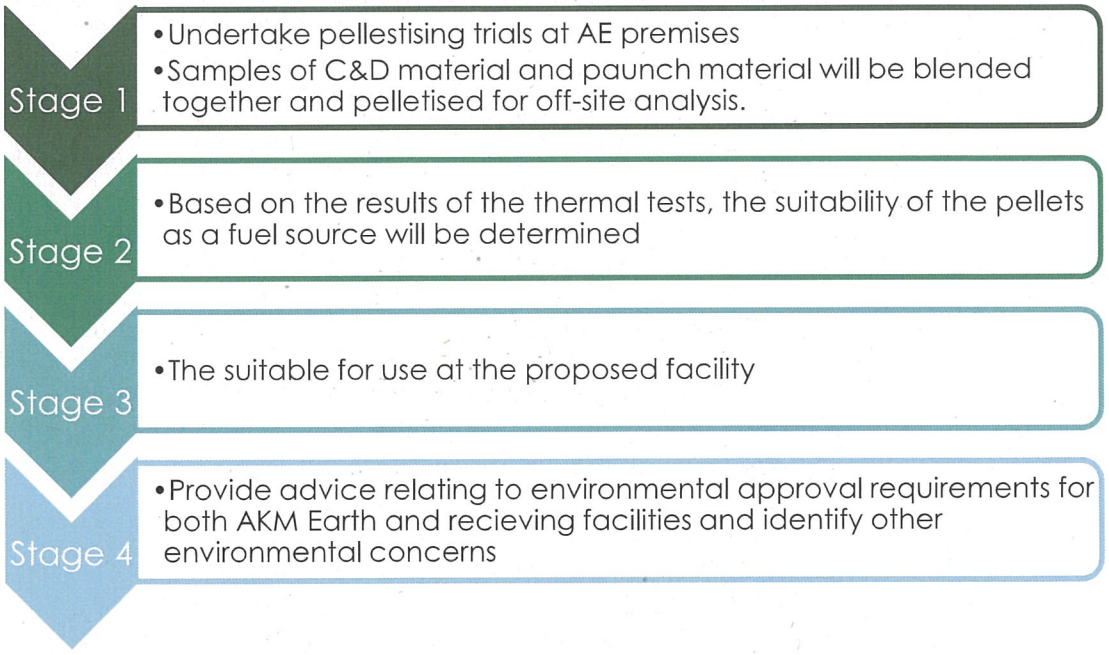


Figure 1: Proposal Stages

2 METHODOLOGY

2.1 Pelletising Trial

A mobile pelletiser will be installed temporarily at AE's premises to allow the pelletising of C&D material and paunch to be blended and pelletised. For the purposes of this proposal, four biofuel mixes will be pelletised as listed in Table 2.

Table 2: Paunch to C&D Ratios for Pelletising

Paunch Type	Pelletised : C&D Mix
Paunch – grain fed 70% moisture content	Paunch 50:50 PEF mix
	Paunch 25:75 PEF mix
Paunch – grain fed 50% moisture content	Paunch 50:50 PEF mix
	Paunch 25:75 PEF mix

a) It should be noted that the End of Waste Code for Paunch has a maximum moisture content of 70%.

2.1.1 Thermal Analysis

The eight types of pelletised samples will be sent to a laboratory (HRL) for analysis on the pellets. These samples include the four-types listed in Table 2 for both pelletised and loose material. The analysis will include:

- Carbon, hydrogen, and nitrogen;
- Calorific Value (gross dry, gross wet, net wet);
- Halides (S, Cl, Br, F, I);
- Moisture Content (Free & Inherent);
- Ash Yield;
- Trace Elements;
- AFT (Oxidising);
- Volatile Matter (& Fixed Carbon).

2.1.2 Emissions Test

The emissions from the pellets are assumed to be the same for both moisture content grades of paunch. In addition, the difference in emissions between any loose material and pelletised material is expected to be negligible and a function of boiler efficiency. As such, emissions testing will only be undertaken on 2 samples as follows:

- Pelletised paunch 50:50 PEF mix; and
- Pelletised paunch 25:75 PEF mix.

The pollutants required to be tested have been defined by DES. The emissions tests will be undertaken at Newcastle Institute for Energy and Resources and the analysis will include the following information:

- emission analysis for the following:
  - TSP;
  - PM_{10};
  - $PM_{2.5}$;
  - Carbon monoxide (CO);

- Volatile organic compounds (VOCs) measured as n-propane;
- Oxides of nitrogen (NO_X);
- Sulphur dioxide (SO_2);
- Polycyclic Aromatic Hydrocarbons (PAHs) as benzo-a-pyrene;
- Dioxins/furans;
- Total Heavy metals including
- Cadmium (Cd) and mercury (Hg);
- Hydrogen Fluorine (HF);
- Acid gases (as HCl); and

The emissions testing results will be utilised as inputs into any emissions modelling for the facility if the pellet is considered a suitable fuel.

2.2 Suitability of Material as a Pellet and Quality of Fuel

A review of the thermal test results will be undertaken to determine the suitability of the pelletised material as a fuel. As part of the review, the following will be undertaken:

- Determine the energy efficiency of the pellets to be determined;
- Compare the energy efficiency to the current coal fired boilers;
- Determine whether the pellets could displace coal as a fuel; and
- Identify the embodied energy of the pellets to determine whether there are energy savings from using the paunch as an end product compared to coal. This would form any environmental case for submission to DES to update the End of Waste Code for paunch.

2.3 Suitability for Use at Facilities

The emissions testing results will be reviewed and compared to best practice stack concentrations limits in Australia and overseas. This will include the Protection of the Environment Operations (POEO) Regulations and European Industrial Emissions Directive (2010/75/EU).

2.4 Environmental Approval Considerations

There are environmental considerations for the pelletising of material and its use as a fuel for both AKM Earth and the end user facilities.

Communications with Department of Environment (DES) in relation to pelletising paunch waste into a refuse derived fuel (RDF) identified a number of concerns including the energy recovery vs the energy required to produce this fuel and the impact to the end user if the RDF is to be sold as a fuel.

AE will identify the following:

- environmental considerations (i.e. odour, stack emissions etc) that need to be addressed as part of any approvals process including any existing environmental approval licences.

This may include advice on how to seek pre-lodgement advice from DES in order to amend a facility's EA conditions to allow the receival, storage and combustion of the RDF. At present, the End of Waste Code for Paunch (dated February 2020) lists three approved uses of paunch; these are as follows:

- as a feedstock in an anaerobic biogas plant;
- as a feedstock in the manufacturing of compost; and/or
- as a feedstock in the manufacturing of soil conditioner.

If the analysis identifies the paunch mixes are suitable for burning, there may be considerable effort in trying to get DES to change the end of waste code for paunch to allow its use a RDF fuel.

- how these considerations can be addressed, mitigated, or eliminated.
- potential cost considerations in relation to potential changes in technology, transportation, and storage.

2.5 Specific Environmental Issues

AE are able to provide both general and specific environmental advice in relation to the proposed fuel. Specific advice relating to air and odour emissions, emissions technologies, noise impacts and storage considerations.

Whilst not included in this scope, AE are able to complete dispersion modelling of the emissions results to identify site specific risks and compliance with air quality limits.

2.6 Reporting

The overall results of the burns tests and environmental considerations would be provided in a report (pdf) within four weeks after receiving the analysis results from the laboratory. In preparing the report, the following would be considered:

- the methodology adopted for the tests;
- the results of the analysis;
- review of the data and whether the material is suitable for use as fuel (loose or pelletised);
- a review of environmental considerations; and
- identification of specific environmental issues.

All reports would be prepared in plain English with a focus on explanation of the data to a non-scientific community. Through this focus on reporting, AE seek to improve the understanding of monitoring data to the client and other interested stakeholders and, in doing so, increase the engagement with environmental monitoring as an important tool in the management of the works.

3 PROJECT COSTING

The estimated project fees for the scope is listed in Table 3.

Table 3: Project Fees

Stage	Activity	Price (ex GST)
Stage 1 (pelletising trial)	Pelletising of materials Thermal analysis x 8 Emissions tests x 2	$5,000 $2,500 per sample $69,375 for the first sample; $45,094 for second sample (includes a 35% reduction for additional samples).
Stage 2 (suitability of pellets as fuel)	Review of data for use as pellets	$10,000
Stage 3 (suitability for facilities)	Review of data for use as fuel	$10,000
Stage 4 (advice)	Environmental Approval consideration	$8,000

4 ASSURED ENVIRONMENTAL

Assured Environmental (AE) is an independently owned environmental consultancy business providing industry with expert service in air quality, noise, vibration, meteorology, water, and groundwater. Our services and technologies help our clients maintain regulatory compliance, manage health and amenity issues, and maximise operational efficiencies. Over our years of experience, we have developed a reputation of reliability and quality service.

Through the specialist knowledge and experience of our consultants, we seek to provide clients with accurate, timely information that assists them to understand their impact on the environment and, make changes to continually improve the sustainability of their businesses. Our ability to monitor, interpret and convey the results of monitoring programs represents a core focus of our systems, with many of our clients specifically identifying this as a determining factor in using our services.

We continue to invest significantly in training to ensure technical excellence with all staff actively participating in relevant professional development programs both in Australia and Internationally.

To achieve the quality objectives of the firm, we operate an in-house quality assurance system compliant with the requirements of ISO 9001 and ISO 17025. The company also holds internationally recognised accreditation for a range of monitoring and analysis methods by NATA.

5 QUALIFICATIONS

5.1 Timing

Project scheduling is completed upon contract award. Should there be specific timing constraints we will always endeavour to meet them. Please advise any specific requirements at or prior to commissioning us to complete this project.

5.2 Workplace Health and Safety

5.2.1 Overview

Safety is always the first consideration when planning and conducting a monitoring program. There are several inherent hazards associated with environmental monitoring, however, appropriate, and effective controls can easily be implemented to control these hazards such as engineering, administrative and PPE controls.

It is worth noting that when monitoring programs are performed at a high level of safety and comfort, the quality of work and on-site throughput generally increases.

Before commencing the on-site work, the AE Project Manager would discuss specific safety concerns for the project. This involves submitting a JSEA/SWMS to the client for approval as part of the pre-mobilisation procedure. Additional risks may be present at the various times the project takes place and would be assessed each day prior to commencing field work (e.g., exceptionally hot day/heavy rain forecast, other work crews in the area).

AE has developed a comprehensive safety manual relating to the many specific risks associated with environmental monitoring that AE staff must be intimately familiar with prior to managing projects independently.

This document is available upon request.

5.3 Insurances

We maintain the following insurances:

- Workers Compensation;
- Public Liability Insurance ($ 20,000,000);
- Professional Indemnity ($ 10,000,000);
- Vehicle and equipment insurance cover.

5.4 Invoicing

All invoices would be raised monthly in arrears for work undertaken during the month. Invoices would be issued to Council for payment in accordance with the terms and conditions of engagement.

PROJECT ACCEPTANCE FORM

This form is to be signed by the Client accepting this proposal and the responsibility for payment of all associated invoices.

Project Number:	13830 - R0
Date of Proposal:	23/07/2021
Description:	AKM Earth
Project Fees:	See Table 3
Basis for Additional Tasks:	Hourly rates plus expenses
Company Accepting Proposal:	
Client ABN:	
Client Representative:	
Client Representative Position:	
Billing Address:	
Email Address for Invoice:	
Authorised by:	
Signature & Date:	

By signing this acceptance form, you confirm that:

- *the Assured Environmental proposal detailed above and the Assured Environmental Pty Ltd Terms and Conditions that accompany the proposal are accepted in full;*
- *you are legally authorised to accept this fee proposal on behalf of the Client.*

ASSURED ENVIRONMENTAL

INDUSTRY LEADERS AND EXPERTS IN AIR QUALITY, ACOUSTICS AND VIBRATION

ABOUT US

Assured Environmental (AE) is an independently owned environmental consultancy business providing industry with expert service in monitoring and consulting. Our services relate to air quality, noise, vibration, stack emissions testing, meteorology, ambient monitoring, and occupational exposure monitoring.

Our services and technologies help our clients maintain regulatory compliance, manage health and amenity issues, and maximise operational efficiencies. Over our years of experience, we have developed a reputation of reliability and quality service.

AE is NATA accredited for a range of ambient, stack emission and occupational air monitoring.

MONITORING SERVICES

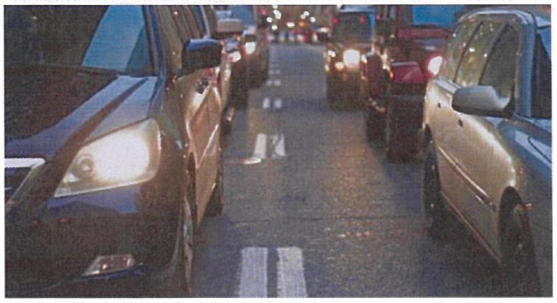
We deliver quality monitoring services including:

- Emissions monitoring
- Odour sampling & analysis
- Ambient air monitoring
- Indoor air quality (IAQ)
- Workplace monitoring
- Employee and client training
- Process and environment monitoring
- CEMS consulting service
- CEMS calibration
- Skilled staff hire

CONSULTING SERVICES

We deliver expertise consulting services including:

- Air dispersion modelling & impact assessments
- Noise prediction modelling & impact assessments
- Vibration monitoring and impact assessments
- Odour impact assessments
- Environmental Impact Statements (EIS)
- Expert witness
- Construction & operational management plans
- NPI reporting
- Acoustic & air emissions engineering solutions



Unit 7, 142 Tennyson Memorial Avenue – Tennyson – Queensland

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07 3333 1960 or
Toll free 1300 662 495

All Energy Pty Ltd
www.allenergypl.com.au

ACN: 16 9802 555
ABN: 95 169 802 555

Appendix 1: ALL ENERGY PTY LTD TERMS AND CONDITIONS OF BUSINESS

APPENDIX 1 - TERMS AND CONDITIONS OF BUSINESS

Introduction
All Energy Pty Ltd ("All Energy") have set out in this document our basic terms and conditions of business (the "Terms"), which together with our Proposal for Professional Services (the "Proposal"), which together are call the "Agreement" will apply for all work All Energy undertakes for you outlined within our Proposal.

Conflict
Where any conflict exists between these Terms and other documents outside the Agreement, the Agreement will take precedence. Where conflict exists between our Terms and our Proposal, the Proposal takes precedence.

Terms of Payment
All Energy's terms of payment are 15 days from the date of invoice. Please note that any monies due on outstanding amounts in excess of 30 days will attract;

- a late penalty fee, and;
- interest on the outstanding amount calculated at 15% per annum, compounding monthly.

Proposal Validity
All Energy's Proposal is valid for a period of 30 days from the date the Proposal, after which the Proposal expires.

Provision of Electronic Source Documents
Documentation (drawings, specifications, reports and the like) issued from All Energy can only be taken as true and correct from the printed version. All Energy does not guarantee that the electronic versions of our document are 100% accurate to the intent of the document. In using electronic source documents, it is the user's responsibility to check the accuracy of the electronic information. All electronic source documentation should not be copied wholly or in part other than for the intended use without the written permission of All Energy. All Energy still reserves all rights associated with the electronic source documentation unless otherwise stated.

Goods and Services Tax
The fees payable for any supply made or to be made under this Agreement have been calculated initially without regard to, and exclusive of any Goods and Services Tax (GST). If GST is payable on any supply made or to be made under this Agreement, the parties agree that the fees payable for any such supply shall be increased by an amount equal to the amount of GST payable by All Energy in respect of that supply.

Variation
No variation of this Agreement will be valid unless confirmed in writing by authorized signatories of both parties on or after the date of signature on the Proposal.

Engagement of Sub-Consultants, Sub-contractors, and/or Suppliers
Engagement and payment of Sub-consultants, Sub-contractors and/or Suppliers unless otherwise explicitly stated within our Proposal is not included. It is expected that the client will directly engage and make all required payments to Sub-consultants, Sub-Contractors and/or Suppliers unless confirmed in writing by authorized signatories of both parties.

Disbursements
All disbursements such as photocopying, car rental, travel, accommodation and the like unless otherwise explicitly stated within our Proposal will be charged additional to our Proposal at the cost of the disbursement + a 15% handling fee.

Research and Development (R&D) Concession Application
Unless otherwise stated, please be aware that All Energy reserves the right that all projects undertaken by All Energy shall form part of All Energy's R&D Tax Concession Application.

Conditions of Engagement
Our terms of engagement are AS4122-2010 General Conditions of Engagement of Consultants, together with Parts A & B to the General Conditions of Contract contained within these Terms.

Secondment of Staff
Upon agreeing to engage All Energy or one of our employees on secondment assignment you agree to pay the agreed fee within 14 days of the commencement of the engagement.

Contract Annexure Part A to AS4122

Clause Reference	All Energy Standard Condition
The Law applicable: (Clause 1)	The Law in the State of Queensland.
The Contract Documents: (Clause 2)	The above General Conditions of Contract as amended here; - All Energy's Proposal
The Program & Final Completion Date: (Clause 3a,b)	As stated in the Proposal
Intellectual Property Rights - Alternative applying: (Clause 8.1)	Alternative 1
Additional Purposes for which Contract Material may be used: (Clause 8.2)	Nil
The Consultant's liability is limited as follows: (Clause 9.1)	The sum of monies owed to the Consultant under the agreement or the cost of re-design whichever is the lesser to apply.
Amount of Professional Indemnity Insurance shall not be less than: (Clause 10.1)	$5 million any one claim and $10 million in the aggregate.
The Period for which professional indemnity insurance shall be maintained is: (Clause 10.1)	Completion of the Services
The amount of Public Liability Insurance shall be not less than: (Clause 10.2)	$20 million dollars per claim and in the aggregate.
Claims for payment shall be made: (Clause 13.1)	By the end of 1st week in each month.
The Consultant's Fee shall be determined as follows: (Clause 13.2)	As stated in the Consultant's Proposal.
The Times for payment shall be: (Clause 13.3)	15 days from the date of submission of Claim/invoice
Interest on overdue payments: (Clause 13.4)	15% per annum
The deemed frustration date if Services are not complete: (Clause 14.1)	6 months after the Date for Completion of the Services
The completion date(s) for the components of the Service/the Services: (Clause 15.1)	As stated in the Consultant's Proposal
An arbitrator shall be nominated by (Clause 15.3):	The Chairperson for the time being of the Chapter of the Institute of Arbitrators and Mediators Australia, in the State of Queensland.

Contract Annexure Part B to AS4122-2000

Clause Reference	All Energy Standard Condition
Item 1 Clauses Deleted	Clause 15.4 - Expert Determination
Item 2 Clauses Amended	Nil
Item 3 Clauses Added	17 - DURATION OF LIABILITY The Consultants liability to the Client arising out of the performance or non-performance of the services shall end three months from the handover of the final completed deliverable described in the Consultants Proposal.

Appendix 2

CSIRO Current and projected generation technology capital costs under the Current policies scenario (Source: GenCost: annual electricity cost estimates for Australia CSIRO July 2023)

	Constant						Low assumption			High assumption		
	Economic life	Construction time	Efficiency	O&M fixed	O&M variable	CO_2 storage	Capital	Fuel	Capacity factor	Capital	Fuel	Capacity factor
	Years	Years		$/kW	$/MWh	$/MWh	$/kW	$/GJ		$/kW	$/GJ	
2022												
Gas with CCS	25	1.5	44%	16.4	7.2	1.9	4354	14.0	89%	4354	20.0	53%
Gas combined cycle	25	1.5	51%	10.9	3.7	0.0	1766	14.0	89%	1766	20.0	53%
Gas open cycle (small)	25	1.5	36%	12.6	12.0	0.0	1499	14.0	20%	1499	20.0	20%
Gas open cycle (large)	25	1.3	33%	10.2	7.3	0.0	943	14.0	20%	943	20.0	20%
Gas reciprocating	25	1.1	41%	24.1	7.6	0.0	2004	14.0	20%	2004	20.0	20%
Hydrogen reciprocating	25	1.0	32%	33.0	0.0	0.0	2438	14.6	20%	2438	21.9	20%
Black coal with CCS	30	2.0	30%	77.8	8.0	4.1	11040	6.9	89%	11040	10.5	53%
Black coal	30	2.0	40%	53.2	4.2	0.0	5398	6.9	89%	5398	10.5	53%
Brown coal	30	4.0	32%	69.0	5.3	0.0	8180	0.6	89%	8180	0.7	53%
Biomass (small scale)	30	1.3	29%	131.6	8.4	0.0	7825	0.5	89%	7825	2.0	53%
Large scale solar PV	30	0.5	100%	17.0	0.0	0.0	1572	0.0	32%	1572	0.0	19%
Wind onshore	25	1.0	100%	25.0	0.0	0.0	2642	0.0	48%	2642	0.0	29%
Wind offshore (fixed)	25	3.0	100%	149.9	0.0	0.0	5682	0.0	52%	5682	0.0	40%
2030												
Gas with CCS	25	1.5	44%	16.4	7.2	1.9	4283	8.0	89%	4279	16.8	53%
Gas combined cycle	25	1.5	51%	10.9	3.7	0.0	1672	8.0	89%	1636	16.8	53%
Gas open cycle (small)	25	1.5	36%	12.6	12.0	0.0	1392	8.0	20%	1354	16.8	20%
Gas open cycle (large)	25	1.3	33%	10.2	7.3	0.0	803	8.0	20%	803	16.8	20%
Gas reciprocating	25	1.1	41%	24.1	7.6	0.0	1752	8.0	20%	1716	16.8	20%
Hydrogen reciprocating	25	1.0	32%	33.0	0.0	0.0	2089	14.6	20%	2087	21.9	20%
Black coal with CCS	30	2.0	30%	77.8	8.0	4.1	9639	2.3	89%	9597	4.0	53%
Black coal	30	2.0	40%	53.2	4.2	0.0	4668	2.3	89%	4558	4.0	53%
Brown coal	30	4.0	32%	69.0	5.3	0.0	7208	0.7	89%	7035	0.7	53%
Biomass (small scale)	30	1.3	29%	131.6	8.4	0.0	7571	0.5	89%	7519	2.0	53%
Nuclear (SMR)	30	3.0	35%	200.0	5.3	0.0	14586	0.5	89%	18167	0.7	60%
Large scale solar PV	30	0.5	100%	17.0	0.0	0.0	1071	0.0	32%	1058	0.0	19%
Wind onshore	25	1.0	100%	25.0	0.0	0.0	1913	0.0	48%	1989	0.0	29%
Wind offshore (fixed)	25	3.0	100%	149.9	0.0	0.0	2755	0.0	54%	4803	0.0	40%

Appendix 3

CSIRO Data assumption for LCOE calculations (Souce: GenCost: annual electricity cost estimates for Australia CSIRO July 2023)

	Black coal	Black coal with CCS	Brown coal	Gas combined cycle	Gas open cycle (small)	Gas open cycle (large)	Gas with CCS	Gas reciprocating	Hydrogen reciprocating	Biomass (small scale)	Biomass with CCS (large scale)	Large scale solar PV	Rooftop solar panels	Solar thermal (15hrs)	Wind	Offshore wind fixed	Offshore wind floating	Wave	Nuclear (SMR)	Tidal /ocean current	Fuel cell
	$/kW	$/kW	$/kW	$/kW	$/kW	$/kW	$/kW	$/kW	$/kW	$/kW	$/kW	$/kW	$/kW	$/kW	$/kW	$/kW	$/kW	$/kW	$/kW	$/kW	$/kW
2022	5398	11040	8180	1766	1499	943	4354	2004	2438	7825	21935	1572	1454	6525	2642	5682	7872	11662	-	8663	9787
2023	4964	10513	7745	1706	1593	1002	4340	1759	2140	8666	21121	1516	1400	6478	2644	5480	7591	10987	-	8158	8612
2024	4890	10380	7609	1699	1540	963	4331	1759	2133	8496	20802	1407	1307	6339	2519	5288	7154	10869	-	8058	7979
2025	4825	10265	7487	1694	1490	926	4329	1762	2129	8340	20517	1301	1223	6202	2398	5103	6737	10756	-	7959	7389
2026	4761	10153	7368	1690	1442	888	4328	1765	2126	8189	20241	1197	1150	6050	2284	4924	6344	10645	-	7862	6844
2027	4673	9926	7219	1671	1397	847	4307	1750	2112	7898	19710	1141	1092	5911	2152	4834	6008	10447	-	7717	6404
2028	4608	9744	7112	1654	1369	806	4290	1735	2101	7671	19284	1103	1042	5789	2056	4799	5790	10291	-	7605	6117
2029	4566	9606	7048	1639	1356	805	4279	1719	2091	7506	18960	1091	1009	5669	1996	4818	5685	10176	-	7524	5672
2030	4558	9597	7035	1636	1354	803	4279	1716	2087	7519	18934	1058	977	5562	1989	4803	5657	10180	18167	7524	5271
2031	4550	9588	7023	1633	1351	802	4279	1713	2084	7532	18909	1038	956	5465	1983	4789	5643	10184	18199	7524	4864
2032	4542	9579	7011	1630	1349	800	4280	1710	2080	7545	18884	1022	939	5376	1978	4774	5641	10189	18231	7524	4721
2033	4535	9571	6999	1628	1347	799	4280	1707	2077	7558	18860	1010	926	5294	1974	4759	5631	10193	18264	7524	4565
2034	4527	9563	6987	1625	1345	798	4281	1704	2073	7572	18836	999	913	5218	1972	4745	5600	10198	18297	7514	4386
2035	4520	9428	6976	1622	1342	796	4156	1701	2070	7586	18685	984	897	5147	1969	4730	5567	10202	18331	7503	4242
2036	4512	9274	6964	1620	1340	795	4014	1699	2066	7601	18516	971	884	5080	1967	4716	5544	10207	18365	7492	4065
2037	4505	9101	6953	1617	1338	794	3851	1696	2063	7615	18327	947	861	5016	1964	4702	5543	10212	18401	7492	3894
2038	4498	9035	6942	1614	1336	793	3794	1693	2060	7630	18246	922	837	4956	1962	4688	5546	10217	18436	7492	3711
2039	4491	8963	6932	1612	1334	791	3731	1691	2057	7645	18160	876	797	4898	1960	4673	5548	10222	18473	7487	3576
2040	4484	8896	6921	1610	1332	790	3673	1688	2054	7660	18079	839	764	4826	1959	4659	5550	10227	18510	7482	3491
2041	4471	8827	6901	1605	1328	788	3620	1683	2048	7665	17983	791	723	4740	1956	4644	5549	10228	18520	7477	3437
2042	4458	8781	6881	1600	1324	786	3589	1678	2042	7669	17910	759	695	4642	1953	4628	5548	10230	18531	7477	3414
2043	4445	8744	6861	1596	1320	783	3567	1673	2036	7674	17846	724	665	4550	1949	4613	5547	10232	18543	7473	3405
2044	4432	8713	6841	1591	1316	781	3551	1669	2030	7679	17789	706	649	4464	1945	4597	5545	10233	18554	7469	3407
2045	4419	8682	6821	1586	1313	779	3535	1664	2024	7683	17731	695	639	4383	1940	4582	5543	10235	18565	7464	3409
2046	4407	8657	6801	1582	1309	776	3525	1659	2018	7688	17680	691	634	4306	1937	4566	5541	10236	18576	7464	3409
2047	4394	8633	6782	1577	1305	774	3516	1654	2012	7692	17630	687	630	4233	1933	4551	5540	10238	18587	7463	3405
2048	4381	8609	6762	1573	1301	772	3507	1649	2006	7697	17580	683	626	4164	1931	4536	5541	10239	18599	7463	3399
2049	4369	8582	6743	1568	1297	770	3495	1645	2001	7702	17527	679	622	4099	1928	4521	5541	10241	18610	7457	3394
2050	4361	8566	6731	1565	1295	768	3488	1642	1997	7707	17496	676	619	4051	1927	4511	5541	10242	18622	7451	3391
2051	4346	8534	6707	1560	1291	768	3473	1636	1990	7707	17432	674	616	4002	1925	4495	5540	10242	18622	7445	3383
2052	4336	8513	6692	1556	1288	762	3464	1632	1985	7707	17391	672	615	3955	1924	4485	5540	10242	18622	7444	3379
2053	4315	8474	6661	1549	1282	762	3448	1624	1976	7707	17310	669	612	3908	1922	4464	5538	10242	18622	7443	3369
2054	4305	8455	6645	1545	1279	757	3441	1621	1972	7707	17271	667	610	3862	1921	4453	5538	10242	18622	7443	3364
2055	4295	8436	6629	1542	1276	757	3434	1617	1967	7707	17231	666	609	3816	1920	4443	5537	10242	18622	7443	3359