final report

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Abottoir Waste to Revenue

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Executive summary

This project involved an evaluation of various options to convert waste from a large beef processing facility into higher value products. The benefits to industry of this project are greatly improved waste and wastewater management practices, thereby reducing or off-setting handling and/or disposal costs. The table below summarizes a range of options considered for the creation of profit from wastes generated at red meat processing plants (RMPs).

Scenario	Cap ex $AUS	Op Ex $ pa	Revenue $ pa	IRR	Pay-back	Lag to revenue	Production tpa	Profit pa
1) Aquaculture - Recirculating aquaculture system (RAS)	5.5 mil	3.53 mil	5.325 mil	17.7%	7 yrs	2 yrs	300 live fish	1.798 mil
2) Mushrooms	12.8 mil	9.29 mil	12.350 mil	33.7%	5 yrs	3 months	1,333	3.192 mil
3) Black Soldier Fly Larvae (BSFL) whole live – Manual @ 104 tpa substrate	0.48 mil	0.33 mil	0.989 mil (Assumes 50% of $4.99 / 25 g)	123% @ 10 yrs	1.8 yrs	12 months	9880 kg pa live larvae	0.584 mil
5) BSFL rendered – Mechanised @ 20 ktpa RMP substrate	3.4 mil	1.30 mil	1.617 mil	11.3% @ 25 years	11 yrs	2 months	433 meal 538 oil	0.318 mil
5) BSFL rendered – Mechanised @ 160 ktpa feedlot + RMP substrate	12.3 mil	5.78 mil	11.6 mil	47% @ 25 years	3 yrs	2 months	3,497 meal 5016 oil	5.79 mil
6) Water recycling	0.43	0.08 mil	0.604 mil	122%	0.8 yrs	0 months	140,888 Class A+ water	0.524

Due to the high levels of contaminants in RMP waste water and pellet feeding costs, aquaculture was found to not provide an internal rate of return (IRR) as high as other options available. Whilst waste water available at RMPs show nutrient levels considered "good" and "permissible" that could be suited to horticultural operations, the high microbial levels in the water as well as the high capital and high labour costs means that the technical and financial viability of mushrooms could be lower than systems less susceptible to microbials levels and more automated / low labour horticultural operations.

Black soldier fly larvae (BSFL) operations show the strongest viability for small "niche" operations generating larvae and also at a large scale (160 ktpa or more of solid wastes) that warrants an automated / mechanised plant with rendering to create a meal (fish meal replacement) and oil. It was found that an automated / mechanised plant (i.e. 20 ktpa of wastes) showed lower economic viability compared to the niche and large scale operations. Hence, there is numerical data to support the operation of a small whole larvae facility that could provide brood stock / strain optimization for a much larger BSFL facility producing meal and oil. A critical element that is not understood is how the commercial production of whole live BSFL would saturate the market.

Water recycling of selected "cleaner" waste water streams (i.e. sterilization and vicera table water) for use in utilities (biofilter, wash downs, cooling towers, boiler make-up) exhibits an excellent economic proposition. Further refinement of the mass balance is required to understand the exact current potable water uses that can be switched to Class A+ water.

Table of contents

1 Background

The Meat Industry Strategic Plan (MISP 2020) shows a very flat predicted net industry income through to 2030, whilst industry wide data cannot be directly applied to individual plants, it shows a general trend as to a comparatively minimal change in the margins for business in the RMI. A key opportunity to improve margins is to look to where cost reductions and innovation can drive down the cost of business throughout the supply chain. Productivity and profitability improvements pose no negligible downside risk but could add over $2.1 bil to the value of the RMI to 2030. Supply chain efficiency and integrity has opportunities of $1.4 bil and a downside risk of $2.1 bil.

The use of hypothetical cost-benefit analyses (CBAs) provides an opportunity to rapidly assess a range of technologies at comparatively low costs before commencing trial or pilot works. CBAs can hence be performed to determine the added value of the proposed opportunity, taking into consideration potential reduction in waste management costs and conversion of solids into higher value materials. The total capital outlay, operating costs, cost savings / revenue can be calculated in order to determine the internal rate of return (IRR) and simple payback period.

2 Project objectives

The overall project objectives were to:

- Prepare the basis of design, technical specification, vendor pricing, and CBA for utilising existing red meat processing waste streams to create aquaculture feed. Target products include aquaculture (e.g. fish).
- Prepare the basis of design and CBA for utilising existing red meat processing waste streams to create water suitable for aquaculture and/or aquaculture feed creation.
- Prepare the basis of design and CBA for a fish processing facility.

3 Methodology and Results

3.1 Black Soldier Fly Larvae

3.1.1 Assumptions

- Waste activity sludge (WAS) specific yield at 9.5% in 12 days. Source: large lab scale Research Organisation A results. (Note: 9.06% live larvae specific yield (tonnes larvae per tonne substrate) in 15 days for small lab WAS. 9.05% live larvae specific yield (tonnes larvae per tonne substrate) in 13 days for WAS+DAF+Paunch.
- All numbers presented in $AUS assuming exchange rate of $AUS 0.782 / $US as of 23 Oct 2017[1].
- Market value for BSFL protein meal assumed at $1,446 / tonne[2] which is lower than the current Agriprotein "Magmeal" value of $1758 / t.
- Market value for BSFL tallow assumed at $1,298 / tonne[3] which is the current Agriprotein "Magoil" value.
- Whole live larvae, at small amounts, retails for $4.99 / 0.025 kg ($199,600 / tonne)[4]. Dropping to $140,000[5] to $160,000[4] / tonne for 50g, then to $100,000 / tonne for 1.0 kg or more[5]. Dried whole larvae are sold at $120,000 / tonne for 50g and $80,000 / tonne for 1.0 kg [5], which provides a long term storage option during periods of over-supply of live larvae.
- Commercial scale facility based on Buhler data using a foactorial interpolation at 0.6 for a plant to generate 1.90 tph of larvae as opposed to 4 tph plant costing $US 15mil.
- The 4 tph larvae facility requires 16 FTE staff, hence the FTE number was maintained.
- All other assumptions are detailed within individual CBAs, and in the following sections.

[1] http://www.xe.com/currencyconverter, accessed 23 Oct 2017.
[2] http://www.indexmundi.com/commodities/; June 2017, accessed 23 Oct 2017.
[3](http://www.indexmundi.com/commodities/; June 2017, accessed 23 Oct 2017.
[4] https://www.mypetwarehouse.com.au/pisces-fly-pupae-live-25gm-p-17141, accessed 23 Oct 2017.
[5] https://www.futuregreensolutions.com.au/, accessed 23 Oct 2017.

3.1.2 Process and Equipment Description

The information in this section is to provide the reader with some visual indication of a commercial BSFL operation.

Table 3.1: Summary of equipment requirements for a Black Soldier Fly Larvae (BSFL) operation.

No.	Description	Image
1	Light cages  Source: http://www.freshroomslifesciences.com/	 Figure 12: A love cage is being filled with freshly emerged adults Source: Sandec: Department of Sanitation, Water and Solid Waste for Development, 2017.
2	Hatchery / Nursery	
3	Dark cages: Nursery and pupation for breeding	 Figure 11: Dark cage with pupation containers stacked within

No.	Description	Image
4.	Grow out trays ("laverros") For commercial pilot: 1m^3 pod containing 3 trays, 300mm high with 200mm substrate. Approx. 12 day cycle. Proposed manual handling for pilot using a 1 tonne electronic lifter.	  Source: Agriprotein.  Figure 16: Stack of larveros with ventilation frames in-between levels
5.	Harvesting: Rotating vibrating screen	

3.1.3 Process Flow Diagram (PFD)

Presented below is a preliminary PFD for a RMP. The attached was used in order to prepare op ex / cap ex estimation and to present the flow of materials.

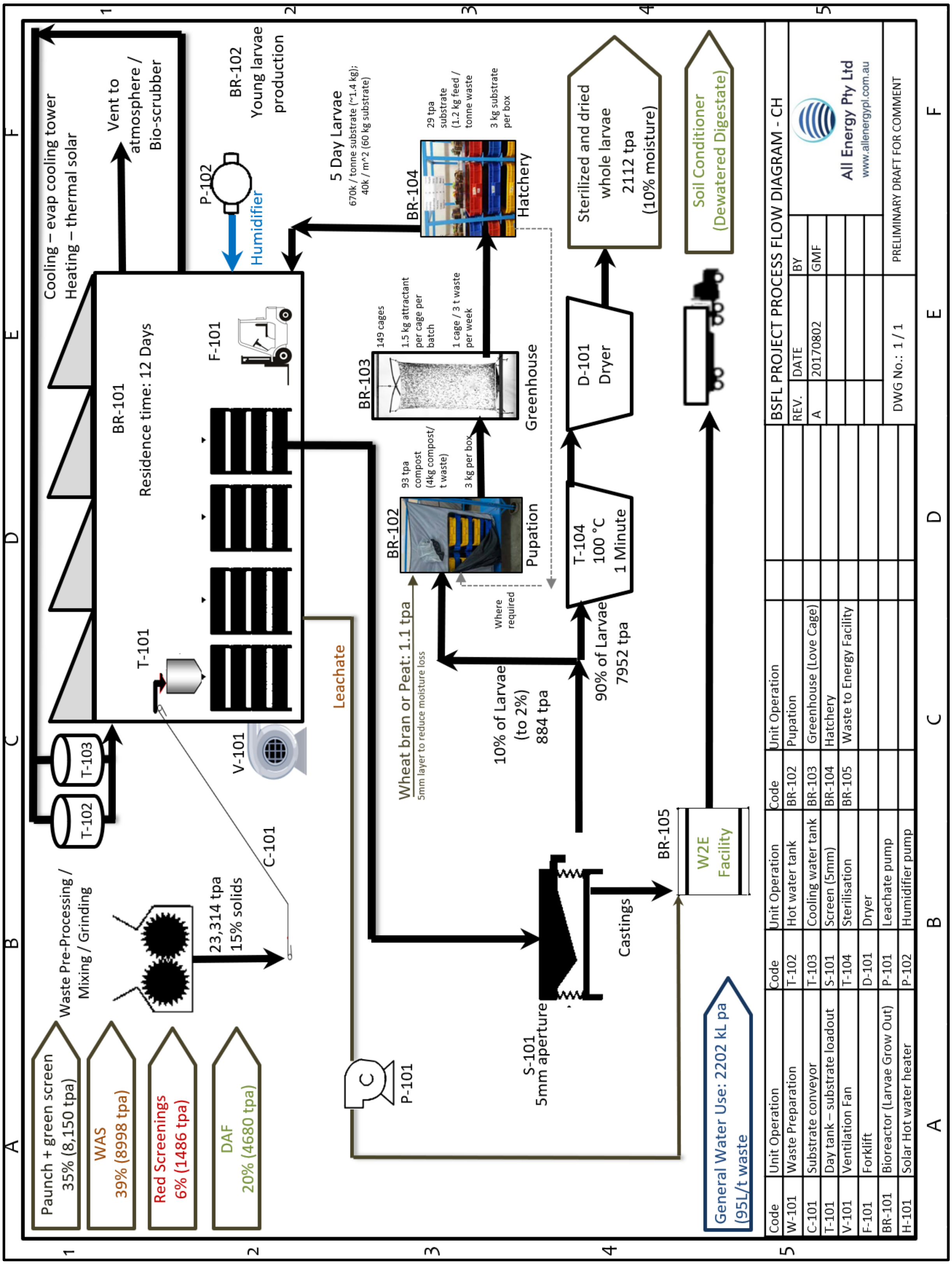


Figure 3.1: Process flow diagram for a BSFL facility utilizing red meat processing wastes.

3.1.4 Small scale Lab scale results – Research Organisation A

The following table summarizes results from bench top testing for larvae growth on a range of Processor A substrates. The line highlighted in yellow showed the highest specific-time yield (weight larvae per weight substrate per day) also happens to be the approximate mix of available Processor A CH wastes. Whilst this stream did not exhibit the highest specific weight, however this could be optimized via further works. Highlighted in yellow is the substrate, which showed the highest specific/time yield results: Waste Activated Sludge (WAS). The specific yield is difficult to compare as different time periods were analysed, however for the CBA a yield of 9.5% was used for WAS. The smaller particle size of the WAS improves uptake by the BSFL as well as improving the post-grow out sieving operations, as confirmed by Research Organisation A during the large lab testing.

Table 3.3: Research Organisation A results for small (in black text; starting substrate approx. 20 g dry weight with additional substrate added as required) and large-scale (in grey italics; approx. 9 kg substrate) lab results for BSFL results.

	Residue weight reduction %	g larvae / kg substrate / day	Specific yield (kg live weight / substrate wet weight)
Pellets	58.3%	13.45	15.00%
WAS	43.4%	6.07	9.063% (15 days) *9.5% (12 days)*
DAF	64.2%	0.39	1.56%
WAS+DAF	46.2%	4.68	8.82%
DAF+P	39.1%	6.50	7.81%
WAS+DAF+P	45.3%	6.92	9.055% (13 days) *8.4% (12 days)*
WAS+DAF+Red	50.3%	5.16	9.93%

3.1.5 Pilot Scale: 104 tonnes per annum substrate

The key assumptions and findings for a BSFL facility processing 104 tonnes per annum (2 tonnes per week) of substrate into 9,880 kg per annum of whole, live larvae. The total capital investment was estimated at $474,578.

3.1.6 RMP Organics – 20,000 tonnes per annum substrate

Presented below are the key assumptions and findings for a BSFL facility processing 20 ktpa of RMP solid wastes (paunch, waste activated sludge (WAS), DAF float, green screenings and red screenings). The total capital investment was estimated at $3.445 million based on a factorial interpolation of a Buhler facility based on tonnes larvae per hour.

Table 3.5: Assumptions and key results for BSFL facility processing 20 ktpa of substrate from RMP solid wastes.

Basis of Design:					
	20000	tpa substrate for BSFL growout. Suitable for processing ACC's organic waste.			
	1900	tpa whole live larvae	0.2375	tph larvae	
Total Capital Investment (TCI)	$ 3,444,796	Factorial estimate based on Buhler data			
OP EX	Units	# Units	$ / Unit	Value $ pa	% Op ex
FIXED COSTS					
Personnel	Staffing number	4.6	78,000	358,394	27.6%
Plant Maintenance and repair @ 5% cap ex	Maint cost pa		5%	172,240	13.3%
Environmental Fees - DERM ERA Environmental Fee	Annual fee			5,000.00	0.4%
Laboratory costs	TBA%			31,200	2.4%
Management / Supervision	20%	of "Personnel"		71,679	5.5%
Royalties	TBA%	of fixed capital			0.0%
Overheads	@1%			6,385	0.5%
Capital charges	5%	of fixed capital		172,240	13.3%
Insurance	1%	of fixed capital		34,448	2.7%
Egg production op ex				178,125	13.7%
Sales; Processing; Shipping and packing	TBA%			190,000	14.6%
VARIABLE COSTS					
Electrical load (kW)	kWh pa	$ 0.14	482,130	67,498	5.2%
Rendering costs	$/GJ	$ 5.90	2,050	12,093	0.9%
TOTAL ESTIMATED ANNUAL OPERATING EXPENSES Per Annum	$ pa			1,299,301	
Revenue / Cost avoidance			tpa		
Revenue from larvae meal	$/t	$1,446	433.07	626,216	39%
Revenue from oil	$/t	$1,298	538.16	698,537	43%
Waste management savings	$/t	$ 32.28	9060	292,412	18%
TOTAL ESTIMATED REVENUE / COST SAVING Per Annum	$ pa			1,617,165	
EBITDA (with capital charges)	$ pa			317,864	

3.1.7 Feedlot + RMP Organics – 160,000 tonnes per annum substrate

Presented below are the key assumptions and findings for a BSFL facility processing 160 ktpa of substrate made up of approximately 75 to 80% of cattle manure from a steak flaked grain feedlot with the balance being RMP solid wastes (paunch, waste activated sludge (WAS), DAF float, green screenings and red screenings). The total capital investment was estimated at $12.272 million based on a factorial interpolation of a Buhler facility based on tonnes larvae per hour.

Table 3.6: Assumptions and key results for BSFL facility processing 160 ktpa of substrate from a steam flaked grain feedlot and RMP solid wastes.

Basis of Design:					
	160000 tpa substrate for BSFL growout. Suitable for processing ACC's organic waste.				
	9.50% specific yield				
	15200 tpa whole live larvae			1.90 tph larvae	
Total Capital Investment (TCI)	$ 12,271,585	Factorial estimate based on Buhler data			
OP EX	Units	# Units	$ / Unit	Value $ pa	% Op ex
FIXED COSTS					
Personnel	Staffing number	16.0	78,000	1,248,000	21.6%
Plant Maintenance and repair @ 5% cap ex	Maint cost pa		5%	613,579	10.6%
Environmental Fees - DERM ERA Environmental Fee	Annual fee			5,000.00	0.1%
Laboratory costs	TBA%			31,200	0.5%
Management / Supervision	20%	of "Personnel"		249,600	4.3%
Royalties	TBA%	of fixed capital			0.0%
Overheads	@1%			21,474	0.4%
Capital charges	5%	of fixed capital		613,579	10.6%
Insurance	1%	of fixed capital		122,716	2.1%
Egg production op ex				1,425,000	24.7%
Sales; Processing; Shipping and packing	TBA%			380,000	6.6%
VARIABLE COSTS					
Electrical load (kW)	kWh pa	$ 0.14	4,821,300	674,982	11.7%
Rendering costs	$/GJ	$ 5.90	16,397	96,741	1.7%
Waste management ($30.44/tonne cost CY17 Jan-Jun data + $39.61/t haulage)	$/t	$ 9.17	32,499	298,016	
TOTAL ESTIMATED ANNUAL OPERATING EXPENSES Per Annum	$ pa			5,779,887	
Revenue / Cost avoidance			tpa		
Revenue from larvae meal (http://www.indexmundi.com/commodities/; June 2017)	$/t	$1,446	3496.00	5,055,705	44%
Revenue from oil	$/t	$1,298	5016.00	6,510,537	56%
Frass (Composting minus sale price)	$/t	$ -	72480	-	0%
TOTAL ESTIMATED REVENUE / COST SAVING Per Annum	$ pa			11,566,243	
EBITDA (with capital charges)	$ pa			5,786,355	

The following image (Figure 3.2) provides a sense of scale for of a facility to generate 4 t/h of larvae. A 160,000 tpa of substrate facility would generate around 1.9 tph of larvae.

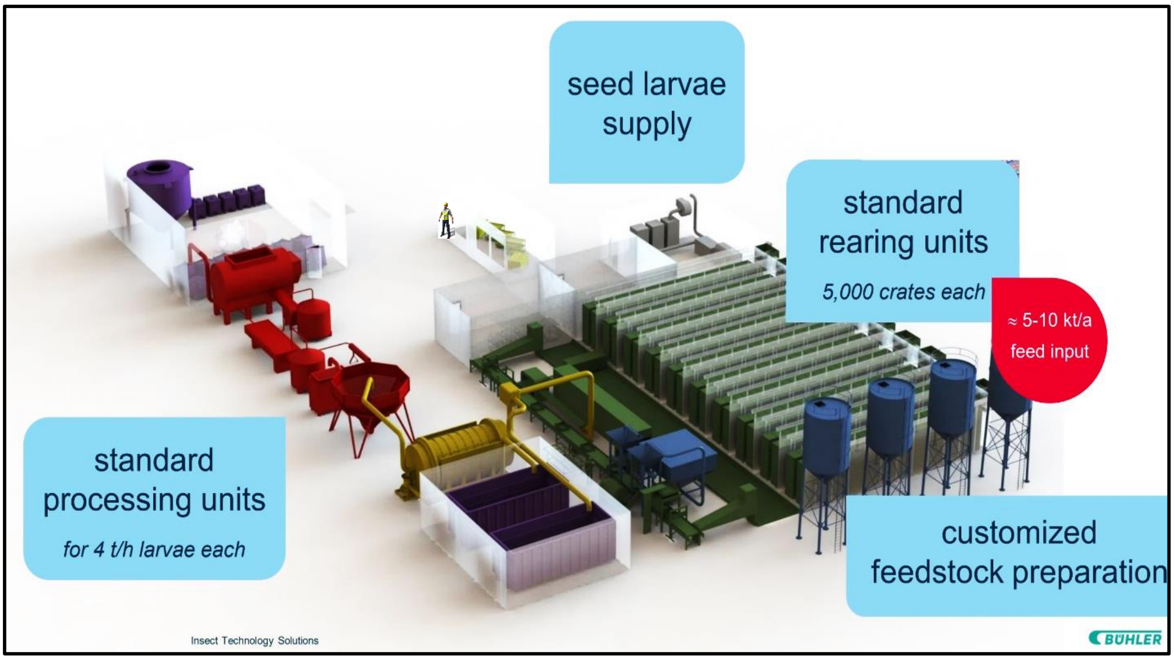


Figure 3.2: Commercial scale automated / mechanised BSFL facility producing 4 tonnes per hour of larvae.

3.2 Value adding – Small Scale Rendering

Value adding for small scale operations of fish heads, offals and associated processing by-products as well as small scale BSFL rendering were considered. Presented below are the results of a skid-mounted, modular rendering option utilizing a KY1 supplied by AKT (https://www.akt-kix.com) to understand the capital and operating costs associated with a small scale, packaged rendering operation. For fish wastes, small-scale rendering would have a negative net present value (NPV) against sale of the wet weight wastes at $800 / tonne directly to pet food manufacturers. Likewise, for larvae, the sale of rendered BSFL product (larvae meal at $1,446/t and larvae oil at $1,298/t) is dramatically lower than current markets rates as high as $199,600 / tonne for whole and $120,000 / tonne for whole dried larvae.

The rendering plant specifications considered were:

· Evaporation Rate: 180 – 220 L/hr
· Air Flow: 100 m3/min
· Burner Size: 254 kW (for ACC, heat supplied via existing boiler)

Table 3.7: Packaged Rendering Plant Information.

	Tpa – All CH waste	**Tpa – Phase 1.6 (1082 tpa substrate)**	**Tpa – Phase 1.1 (23 tpa substrate)**
Processing (live weight) tpa	1812 to 1899	89	1.9
Oil tpa	538 to 627	29.4	0.63
Meal tpa	433 to 504	21.3	23.6
Evap L/hr	206 (@7000 hpa operation)	180 (@ 200 hpa)	39 (@ 40 hpa)

Equipment	**Description**
S-101	Sizer, cutter or macerator located in the WRF to particularize gut material to less than 15 mm. The gut material can be delivered from the base of the cyclones directly to sizer S-101 if the cyclones can be positioned on suitable plinths.
HX-102	Pre-heater. This heat exchanger will increase the temperature of the stream to 80 °C. It is expected that the recycled heat from the AD will provide this heat.
P-103	Gear Pump to feed material to the decanter (50 L/min).
C-104	Centrifuge / decanter or press to separate oil from the water and solids.
D-105	Dehydrator and Infeed Buffer Bin – screw conveyor and 0.3 m^3 bin. Product: 70 oC. Air: 320 oC.
HX-106	Burner and Combustion Chamber
P-107	Anti-Oxidant Dosing Pump
S-108	Meal Screen
S-109	Sizer #2 in processing section

P-110	Gear Pump to transport material from processing section to WRF (50 L/min).
	Engineering and installation of 80 mm piping for material transport from processing section to WRF
	Commissioning and training
P-111	Gear Pump for oil dispatch
	Oil Rendering and Fish Meal Plant Electrical and automation at 10%
Total Capital OR and FM Plant	$AUS 489,000[6]

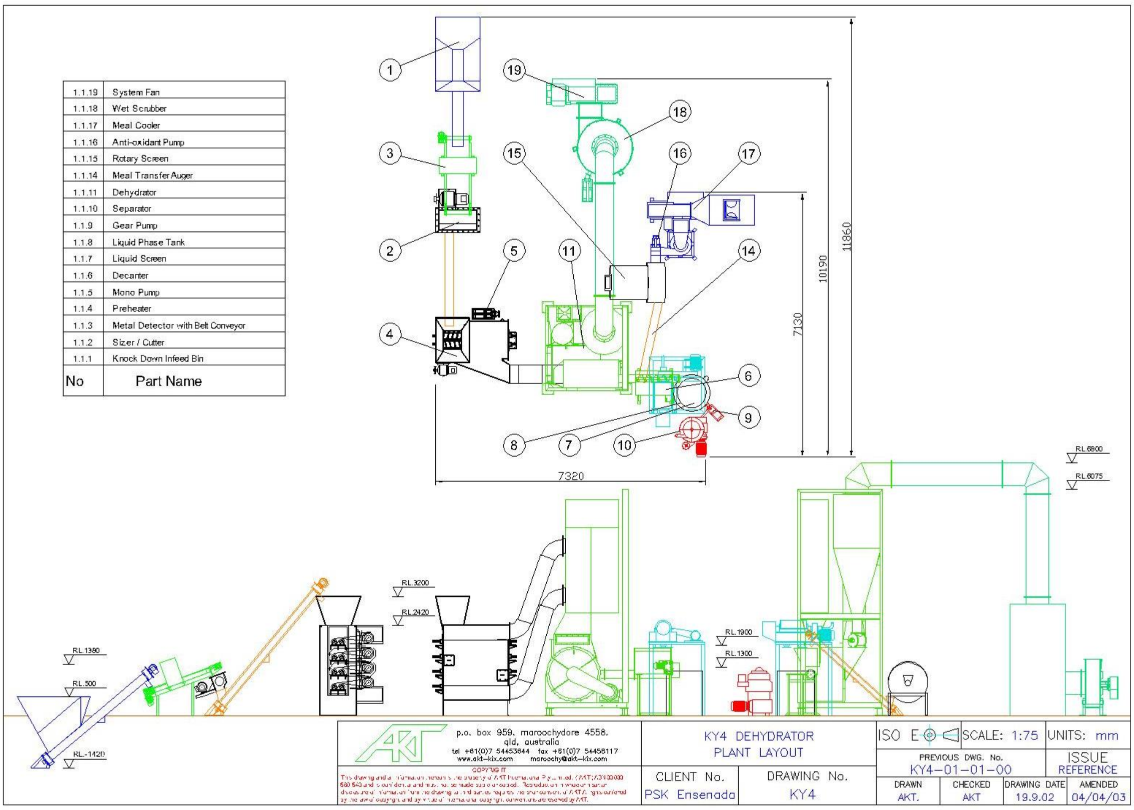


Figure 3.3: Plan and elevation of a packed small scale rendering plant.

[6] CPI All Groups Australia, http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/6401.0Jun%202017?OpenDocument#Time, accessed 11 Sept 2017.

Figure 3.4: Images of an AKT packaged rendering system (KY1). Source: https://www.akt-kix.com

3.3 Recirculating aquaculture systems (RAS)

Species options are most effective when matched to available feed and water. The advice from industry experts is to consider a “unique” Australian species that is not at the mercy of low cost imports so as to maximise revenue. Whilst research has shown that the consumer prefers a marine/salt water barramundi to all other species and in preference to fresh water barramundi, selecting an endangered species offer advantages of supporting expansion of wild populations and create a new, innovative aquaculture product.

Growth in demand for farmed Barramundi is outweighing growth in supply, resulting in the majority of Australia’s consumption being imported from SE Asia. The following attributes[7] make Barramundi highly suitable for aquaculture:

- High stocking density tolerance
- Tolerance for handling and grading
- Medium-fast growth rate
- Easy to wean to artificial diets
- Relatively broad water quality requirements
- Good food conversion ratio
- Similar species to those with good demand in Asian markets
- Existing R&D and extension networks and infrastructure in commercialisation of Barramundi

Murray cod was also considered due to the uniqueness of the species. Other species considered included groper (more suited to salt water), eel (unable to obtain fingerlings), sturgeon (no brood

[7] Murray Cod Australia Limited (MCA), Australia’s Premium Native Fish (Presentation)

stock in Australia; up to 10-year lag in revenue), perch/carp/goldfish (low market value; completes with low cost imports), and sleep cod / Mary River cod (less knowledge, brood stock, fingerling availability; smaller existing / proven market).

Due to the urban location of Processor A ’s facility, a Recirculating Aquaculture System (RAS) was considered in detail with the results of the cost-benefit analysis (CBA) presented.

RAS CBA Assumptions:

Basis of Design: 300 tpa live weight 3.0 kg average Barramundi (2.8 - 3.2 kg range)

Lag time until revenue: Initial grow out period for plate sized fish (avg 300 g; range 2.8 – 3.2 grams) at 2 years.

Total Capital Investment (TCI): $5,547,976

Table 3.8: Assumptions and findings for a recirculating aquaculture systems producing 300 tpa live weight fish.

Parameter	Assumption
Feed type	Assume Ridley listing price for "Marine Float C"
Feed cost $/t	2,088.91
Feed to biomass ratio	1.50%
Biomass tonnes in stock per tonne live weight produced	400
Feed efficiency: tonnes feed per annum per tonnes live weight per	2.1915
Barramundi Feed Cost $/tonne	2088.91
Cap ex $ / tonne live weight per annum	$18,493.25
Staffing numbers per tonne live weight	0.010
Fingerlings $ / tonne live weight production	$200.00
Fingerlings $ / tonne delivered	$20,000.00

OP EX	Units	# Units	$ / Unit	Value $ pa	Processor A $/kg
FIXED COSTS					
Management Services (Radaqua) - First 2 years only	Included Below	1	500,000	500,000	14.2%
Personnel - 1 day shift of 2 people, 7 days per week	Staffing number	3.08	98,000	301,840	8.6%
Plant Maintenance and repair @ 5% cap ex	Maint. cost pa		5%	277,399	7.9%
Environmental Fees - DERM ERA Environmental Fee - "2(a) Aquaculture (land based): other than crustaceans 100m2 -10ha"	Annual fee			2,403.50	0.1%
Laboratory costs	TBA%	Assume incl. in Radaqua fees			0.0%
Management / Supervision	20%	of "Personnel "		60,368	1.7%
Sales expenses	TBA%				0.0%
Overheads	TBA%				0.0%

Capital charges	5%	of fixed capital		277,399	7.9%
Insurance	1%	of fixed capital		55,480	1.6%
Royalties	TBA%	of fixed capital			0.0%
VARIABLE COSTS					0.0%
Fingerlings - including delivery to site	tpa	3	20,000	60,000	1.7%
Feed (assume Ridley listing price for "Marine Float C")	tpa	657	2,089	1,373,354	38.9%
Electrical load (kW)	kWh pa	0.14	2,629,800	368,172	10.4%
Bulk liquid O2 supply, vet services, chemicals, delivery fees, consumables.				198,474	5.6%
Reclaimed water - incoming (after start-up)	kL pa	43,800	1.00	43,800	1.2%
Waste - exiting	kL pa	42,465	0.2	8,493	0.2%
Processing; Shipping and packing	TBA%				0.0%
TOTAL ESTIMATED ANNUAL OPERATING EXPENSES Per Annum First 2 years	$ pa			3,527,182	$11.76/kg farmgate
TOTAL ESTIMATED ANNUAL OPERATING EXPENSES Per Annum After 2 years	$ pa			3,027,182	$10.09/kg farmgate
Revenue / Cost avoidance					
Revenue from wholefish	$/kg	300000	17.75	5325000	
Pet food	$/kg	37500.00	0	-	
GGS (gilled and gutted; head and skin on)	**$/kg**	262500.00	0.00	-	
TOTAL ESTIMATED REVENUE / COST SAVING Per Annum	$ pa			5,325,000	
EBITDA - First 2 years	$ pa			1,797,818	
EBITDA - After 2 years	$ pa			2,297,818	

Aquaculture: Time series Revenue - Non-discounted; 2.50% CPI

FY starting	2018	2019	2020	2021	2022	2023	…	2043
Total Capital Investment								
EBITDA	-9,075,158	-3,527,182	2,414,145	2,474,499	2,536,361	2,599,770	…	4,260,027
Cumulative NCF	-9,075,158	-	-	-	-	-2,577,563	…	65,492,938

3.4 Horticulture

Whilst it was found that the levels of ammonia and microbes are a limitor for use of RMP waters in RAS systems, the use of water containing nutrients could be a huge advantage for horticultural operations. That is, rather than complete removal of ammonia there is an opportunity to biologically convert it into nitrate (refer N-cycle diagram below). Further, some waste water streams from RMPs could be suitable for use in horticultural operations with cattle wash and vicera table wash showing nutrient levels in the “good” region and the WWTP outfall in the “permissible” region. Information on some typical RMP waste water streams is also provided.

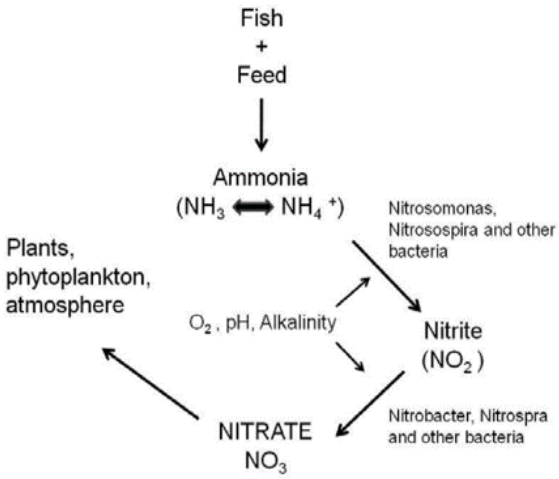
Water Classification	*Electric Conductance (mmho/cm)*	*Total Dissolved Solids (Salts), mg/L, ppm*	*Sodium (% of Total Solids)*	*Boron (mg/L, ppm)*
Excellent	<0.25	<175	<20	<0.33
Good	0.25 to 0.75	175 to 525	20 to 40	0.33 to 0.67
Permissible	0.75 to 2.0	525 to 1400	40 to 60	0.67 to 1.00
Doubtful	2.0 to 3.0	1400 to 2100	60 to 80	1.00 to 1.25
Unsuitable	>3.0	>210	>80	>1.25

Source: Waters, W.E., Geraldson, C.M., and Woltz, S.S., 1972, The Interpretation of Soluble Salt Tests and Soil Analysis by Different Procedures, AREC Mimeo Report GC-1972,

Element	*Concentration, mg/L (ppm)*
Boron (B)	<1
Calcium (Ca)	<200
Carbonates (CO_3)	<60
Chloride (Cl)	<70
Magnesium (Mg)	<60
Sodium (Na)	<180
Zinc (Zn)	<1

Source: Smith, R., 1999, *The Growing Edge* 11(1):14–16.

Figure 3.5: Water classification from “Excellent” to “Unsuitable” for horticultural / hydroponic operations.



Ideal parameters for aquaponics as a compromise between all three organisms (fish, plants and bacteria)

	Temperature	pH	Ammonia	Nitrite	Nitrate	DO
Aquaponics	18 – 29 °C	6-7	< 1 ppm	< 1 ppm	5-150 ppm	> 5 ppm

Figure 3.6: The nitrogen cycle (conversion of ammonia and nitrite into the biologically available nitrate) and recommended nutrient levels.

3.4.1 Mushrooms

A particularly innovative aspect of the project that contributes greatly to overall project and plant sustainability is the integration of high value agriculture with the aquaculture and red meat processing plant. National demand for fresh mushrooms has seen good periods of growth, causing established players to increase production capacities in an attempt to meet demand[8,9].

It is envisioned that digestate solids from a proposed waste to energy (anaerobic digestion) plant will be sterilised and used as the substrate for growing mushrooms. After mushroom products are harvested as an output, by-products will be used for growing BSFL into an animal feed (eventually for the aquaculture facility), creating a highly innovative and sustainable semi-circular production economy within Processor A. The ability to use digestate solids within a mushroom production facility is a large assumption that will need to be interrogated.

[8] Parwan Valley Mushrooms Pty Ltd, 2012. Facts sheet: Parwan Valley Mushrooms Pty Ltd. Available http://www.aquapr.com.au/03_enews/newsletter.asp?ID=224
[9] Australian Manufacturing, 2017. $60m Monarto mushroom expansion to generate 200 new jobs in SA. Available http://www.australianmanufacturing.com.au/45088/60m-monarto-mushroom-expansion-to-generate-200-new-jobs-in-sa

The pasteurised nature of digestate means that it could be well suited to mushroom growing, however further nutritional analysis is required to determine this. The BSFL compost is considered less suited to mushroom growing, as it is a potential source of contamination, hence digestate is to be used for a horticultural purpose first before being used as BSFL substrate.

Mushrooms Cost-Benefit Analysis:

Basis of Design: Utilization of 3500 m^2 of available building envelope, 6 m roof height.

Table 3.10: Assumptions and key findings for a mushroom production facility.

Parameter	**Assumption**
tpa mushrooms	1,333
tpa compost	8,665
FTE / tonne	0.0321
peat/mushroom casing requirement as % of compost	33%
Lag to revenue	3 months

OP EX	Units	# Units	$ / Unit	Value $ pa	Processor A $/kg
FIXED COSTS					
Management Services Initial Grow Out Period	Mmt cost pa	-	-	-	0.0%
Personnel - 1 day shift of 2 people, 7 days per week	Staffing number	43	98,000	4,187,273	45.7%
Plant Maintenance and repair @ 5% cap ex	Maint cost pa		5%	640,909	7.0%
Environmental Fees - DERM ERA Environmental Fee - "2(a) Aquaculture (land based): other than crustaceans 100m2-10ha"	Annual fee			2,403.50	0.0%
Laboratory costs	TBA%				0.0%
Management / Supervision	20%	of "Personnel"		837,455	9.1%
Sales expenses	TBA%				0.0%
Overheads	TBA%				0.0%
Capital charges	5%	of fixed capital		640,909	7.0%
Insurance	1%	of fixed capital		128,182	1.4%
Royalties	TBA%	of fixed capital			0.0%
VARIABLE COSTS					0.0%
Spores and compost - including delivery to site	kg pa	88,873	14	1,284,211	14.0%
Compost	tpa	8,887	80	710,982	7.8%
Peat	tpa	2,932.80	120	351,936	3.8%
Electrical load (kW)	kWh pa	0.14	2,629,800	368,172	4.0%
					0.0%
Reclaimed water - incoming (after start-up)	kL pa	3,178	2.00	6,356	0.1%
Waste - exiting	kL pa	-	-		
Processing; Shipping and packing	TBA%				
TOTAL ESTIMATED ANNUAL OPERATING EXPENSES Per Annum	$ pa			9,158,787	$6.87 / kg
Revenue / Cost avoidance					
Revenue from whole mushrooms - Prepacked @ 70% of retail	$/kg	666,545	8.26	5,505,665	
Revenue from sliced mushrooms - Prepacked @ 70% of retail	$/kg	666,545	10.269	6,844,755	
Revenue from "mushroom compost" - assume sent to BSFL facility	**$/t**	8,887	0.00	-	
TOTAL ESTIMATED REVENUE / COST SAVING Per Annum	$ pa			12,350,421	
EBITDA	$ pa			3,191,634	

Mushrooms: Time series Revenue - Non-discounted; 2.50% CPI

FY starting	2018	2019	2020	2021	2022	2023	2024	...	2043
Total Capital Investment	(12,818,182)								
EBITDA	-10,424,457	3,271,424	3,353,210	3,437,040	3,522,966	3,611,040	3,701,316	...	5,917,110
Cumulative NCF	-10,424,457	-7,153,032	-3,799,822	-362,782	3,160,184	6,771,225	10,472,541	...	101,320,086

3.5 Water Recycling

There exists the opportunity to reduce potable water costs at RMPs via judicious selection of sources of and uses for recycled water. The following sections considered the “cleanest” source of waste water and matched it with non-production uses. The following provides a list of the different qualities of water in existence at a typical RMP, in approximate order from highest to lowest quality.

RO make up water for Boiler

Potable + RO for cooling tower make up

Sterilizer water

Warm water

Potable water / cold wash water

Biofilter water

→ Used within plant and utility processes

Re-use water (e.g. belt press wash)

Cattle wash water

→ Currently sourced from used water. Could be sent through new recycling plant.

Used sterilizer water

Vicera table wash

→ Water with minimal contamination currently sent to WWTP that could be sent through recycling plant.

RO reject and blow down water

Treated waste water

Rendering plant liquid wastes / stick water

Paunch press water

→ Water with higher level of contaminants with potential for other purposes (BSFL; Horticulture; W2E).

3.5.1 Technical Specification

Basis of Design:

		kL pa	Notes
Available for recycle	Slaughter Hot	145,350	Potable with minor contaminants at 70 oC
	Visera table (estimated)	20,400	As per analysis at ambient
	TOTAL AVAILABLE FOR RECYCLE	165,750	
Demand	Cattle wash + biofilter	134,105	1st target for recycled water
	Cold reuse	8,007	2nd target for recycled water
	Cooling towers	36,910	3rd target for recycled water
	Potable for boiler plant (to RO plant, etc)	24,605	4th target for recycled water
	TOTAL DEMAND FOR RECYCLED WATER	203,627	

Received Date Aug 09, 2017

Client Sample ID			**VICERA TABLE EURO PUMP**
Sample Matrix			**Water**
Eurofins | mgt Sample No.			**M17-Au12978**
Date Sampled			**Aug 09, 2017**
Test/Reference	LOR	Unit	
Chemical Oxygen Demand (COD)	25	mg/L	170
Chloride	1	mg/L	97
Ferric Iron - Fe3+	0.05	mg/L	0.27
Ferrous Iron - Fe2+	0.05	mg/L	< 0.05
Fluoride	0.5	mg/L	0.6
Nitrate (as N)	0.02	mg/L	< 0.02
Phosphate total (as P)	0.05	mg/L	0.22
Reactive Silica (as SiO2)	2	mg/L	3.5
Sulphate (as S)	5	mg/L	8.5
Sulphate (as SO4)	5	mg/L	26
Sulphide (as S)	0.05	mg/L	< 0.05
Sulphite (as S)	0.5	mg/L	< 2.5
Suspended Solids	1	mg/L	54
Thiosulphate (as S)	1	mg/L	< 5
Total Sulphur (as S)	5	mg/L	26
Volatile Solids	10	mg/L	150
Heavy Metals			
Barium	0.02	mg/L	0.03
Boron	0.05	mg/L	0.06
Iron	0.05	mg/L	0.27
Manganese	0.005	mg/L	0.006
Manganese (filtered)	0.005	mg/L	< 0.005
Strontium	0.005	mg/L	0.19
Alkali Metals			
Calcium	0.5	mg/L	22
Magnesium	0.5	mg/L	14
Potassium	0.5	mg/L	3.2
Sodium	0.5	mg/L	45

3.5.2 Submission received

Feed Water Quality	Source	Process Water
	TSS	<51 mg/L
	pH	TBA
	Free chlorine	<0.1 mg/L
	Iron	<0.3 mg/L
	Manganese	<0.006 mg/L
	Aluminium	<0.05 mg/L
	BOD (as O_2)	<5 mg/L
	COD (as O_2)	<170 mg/L
	TOC (as C)	<2 mg/L
Product Quality	End Use	Process Water
	TSS	<1 mg/L
	pH	TBA (same as feed)
	Free chlorine	0.2~2
Production Volume	1,200 m^3 per day	
Assembly	Skid mounted	
Model No. Offered	UF-1500-XX-X-C-X-X	

Item	Summary of work	MAK Water	Client
1	Design, manufacture and supply a suitable pre-tested plant, including drawings and documentation, as described above	✓	
2	Preserve UF membranes for storage after completion of factory acceptance test (FAT) NOTE: Membranes require re-preservation should plant commissioning be delayed for more than 1 month after FAT	✓	
3	Onsite plant commissioning and basic operator training/plant familiarisation	✓	

Estimated at $379,180 (ex GST). Additional allowances were made for transport and insurance ($15k), feed storage and filtrate tank (22.7 kL; 2 x $2950 incl delivery, power, travel costs during commissioning, connection of lines (Processor A). It was assumed that wastewater would report to an existing drain to the onsite WWTP.

3.5.3 Water Recycling CBA

Table 3.10: Assumptions and key findings for a water recycling facility at an RMP.

			At Current Rates		
			5823 hpw	At UF System Capacity	At 6400 hpw
CAP EX	Containerized Equipment (MAK)	$	379,180		
	Transport and Insurance	$	15,000		
	Feed and filtrate tank	$	12,000		
	Install materials and labour excl. by MAK	$	18,959		
	Flights	$	2,000		
	Comm. Consumables	$	1,000		
	TOTAL CAPITAL INVESTMENT	$	428,139	428,139	428,139
	Recycled water @ 15% wastage	**kL pa**	**140,888**	438,000	154,848
	Filter replacement (assume @ 5 years)	after 5 - 7 years	15,000	15,000	15,000
OP EX	Motor load energy costs (@ 12kW)	$ pa	8,568	8,568	8,568
	Labour and Maint. @ 8%	$ pa	34,251	34,251	34,251
	Cleaning Chemicals	$ pa	30,000	65,158	32,973
	Testing	$ pa	4,900		4,900
	Op ex p.a.	**$ pa**	**80,719**	102,409	**83,692**
	Water value @ potable offset of $4.29/kL	$ pa	604,407	1,826,460	645,716
	Net Profit	**$ pa**	**523,688**		
	Payback	**yrs**	**0.82**	0.2	0.76
	IRR	%	122%		
	Life of plant:	~15 years			

4 Conclusions / recommendations

The opportunities that are of highest financial viability are water recycling and BSFL. Water recycling utilizes “off the shelf equipment” hence whilst it may require some further testing and design works, it does not require extensive piloting and research works. Hence, this section will expand upon the commercial development of a BSFL facility.

4.1 Commercialization of BSFL

4.1.1 Scale Up

Detailed consideration has been given to scale up, as outlined in the staged expansion below. An 18 month program of works is expected to enable scale up from Phase 1.1 to Phase 1.3 only.

PHASE	1m^2 trays	Start (month)	End (month)	Substrate tonnes/ week	Substrate per annum	Larvae tonnes per week	Larvae tonnes pa	Eggs kg/ week	FTE Staff	Operating Mode	Meal tpa	Oil tpa
1.1	3	0	2	0.45	23.4	0.04	2.12	0.675	2	M-W-F	0.51	0.63
1.2	6	2	4	0.9	46.8	0.08	4.24	1.35	2	M-W-F	1.01	1.26
1.3	12	4	6	1.8	93.6	0.16	8.48	2.7	2	M-W-F	2.03	2.52
1.4	30	6	12	4.5	234	0.41	21.20	6.75	2	M-W-F	5.07	6.30
1.5	60	12	18	9	468	0.82	42.40	13.5	3	M-W-F	10.13	12.59
1.6	140	18	36	21	1092	1.90	98.94	31.5	3	Every day	23.65	29.38
…												
CH (6400 hpw)	4,461	TBA	TBA	669	34,792	61	3,152	1,004	8	Every day	753	936
OCFL (25,000 SCUs)	16,667	TBA	TBA	2,500	130,000	227	11,778	3,750	16	Every day	2,815	3,498
CH + OCFL	20,513	TBA	TBA	3,077	160,000	279	14,496	4,615	16	Every day	3,465	4,305-4784

4.1.2 Next Phase Scope of works

Outlined below are potential critical stages for an R&D project. Milestones are presented to provide "Go / No-go" points, where M1 and M4 are started immediately with the other milestone commenced when agreed.

M1: Breeding and laboratory. Approximately 0.45 tonnes substrate per week.
M2: Substrate handling. Approximately 1 tonne substrate per week.
M3: Grow out and harvesting. Approximately 2 tonnes substrate per week.
M4: Digital ledger / supply chain management tool
M5: Plant data and automation
M6: Final report.

4.1.3 Market Assessment and Due Diligence

Extensive market assessment and due diligence has been completed on national and international companies with headline data on key operational numbers. The table below summarizes the due diligence on BSFL technology; in particular a market, assessment and due diligence on the headline data on key operational numbers and review of how other groups scaled up to commercial scale.

	Large Scale Commercial		
1	Protix Biosystems	Netherlands	June 13: $65.53mil AUS in funding. Currently sold into 12 countries. 1600 tpa larvae in pilot
2	Enterra Feed	Canada	VLeung@enterrafeed.com. Approval for use in poultry broilers **36,500 tpa waste** 20000 tpa larvae meal
3	Enviroflight	US	Just taken on 2 large partners. 272 tonnes larvae pa. 1858 m^2 facility. 0.81 t meal /m^2 p 18.2 kg larvae per bin per day cheryl@enviro Black Soldie
4	Agriprotein Technologies	South Africa	Capacity to roll out 25 x 91ktpa factories per year. Building up our licen ex Cape **91,250 tpa waste** 5000 tpa larvae meal
5	Ynsect (meal worms)	France	Évry, Île-de-France, Ynsect currently employs 35 engineers, farmers, scientists and business developers. 10000 tpa larvae meal
6	Entologics	Brazil	Pan-Europe / Brasil, hence difficult to follow business model. Uses crowd funding
7	Hangzhou Tianyuan Agriculture Company	China	Pig manure. Low tech, high manual labour operations.
	Small Scale Commercial		
	Future Green Solutions (Partnered with Ridley a	Australia	https://www.futuregreensolutions.com.au Target: **73,000 tpa waste $ 100,000** /tonne live $ 80,000 /tonne dried
	Grubbly Farms	US	Domestic chicken market. Dried pupae / BSFL. 35% protein, 25% fat, 3.5% Ca, 1.6% lysine **$ 37,400** /tonne dried
	Millibeter	Belgium	http://www.millibeter.be/wat-doet-millibeter/ At 15 Ja **36.5** tpa waste 10.95 tpa larvae
	Commercial Development Phase		
	goterra	Australia	Canberra; with 2 commercisal roll outs, one in Qld. Goterra is currently advancing through Research and Development phases and we anticip
	Karma3	Australia	Moving to Geelong. The company hopes to recycle about 500,000 tonnes of waste per month. Focused on commercial negotiations with animal feed producers.

There are a number of Australian based businesses pursuing BSFL commercial operations, including:

- Future Green Solutions
- Goterra
- Karma3
- Twynam Group / Agriprotein.

BSF are a domestically present Australian species hence procuring third party brood stock and genetics is not required to start a commercial operation. It is suggested that BSF arrived in Australia as recently as 1940's on US army consignments. Regardless, BSF are entrenched through Australia with entomologist having noted distinct variations between southern and northern BSF (i.e. temperature sensitivities and optimal growth temperatures). Hence, there is a suggestion that a SE Qld based BSFL operation should look for a local BSFL species.

How other groups have scaled up has been discussed and documented. Sensitivity analysis (based on actual lab data from Research Organisation A, research articles, published reports, site visits) has been undertaken to determine costs, benefits, and commercial viability across a range of project sizes.