Bindaree Beef

Report on Use of Post-digestion Wastewater Outputs

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EXECUTIVE SUMMARY

Bindaree Beef abattoir is located 4km west of Inverell, NSW, and operates a plant processing 1,000 head of cattle per day. The company also operates existing irrigation areas to the south of the abattoir on the neighbouring "Alsace" farm, which is a 479ha property owned by Bindaree Beef.

Utilitas have been contracted to design, procure, and manage the construction of a biogas plant in order to process the existing wastewater streams produced by the abattoir into a viable waste stream producing biogas, which is to be used to replace the existing coal supply (for boiler firing), as well as produce electricity and heat.

This report details the proposed use of digested waste streams once they have left the biogas plant.

The resulting digestate (or biofertiliser) is a nutrient-rich material produced as a result of the Anaerobic Digestion that is ideally suited for use as an organic fertiliser. All the nitrogen, phosphorous and potassium present in the feedstock (abattoir waste streams) remains in the digestate, however, the nutrients are passed through the process of digestion, and are made considerably more bioavailable, making it easier for plants to make use of them. Digestate can be used as fertiliser without any further treatment after its removal from the digester, or alternatively can be further treated to enhance its quality and marketability and to produce standardised biofertilisers (solid or liquid) that are commonly sold in hardware stores and nurseries.

With limited biogas plants operating in Australia, examples of the use of digestate as a fertiliser as standard practice are given throughout the world, including, but no limited to Austria, Canada, Denmark, Germany, Netherlands, Sweden, Switzerland and the United Kingdom. While climatic and soil conditions in the above examples may vary somewhat from those at Inverell comparison data, including data from the Bindaree Beef pilot plant, and local examples such as the Berrybank Biodigester case example show that similar results would be achieved.

The design proposed for Bindaree Beef will have a digestate output of 955m^3/day over seven days (equivalent to approx. 1.3Ml of influent per day over the five plant operating days), some or all of which will potentially be used as fertilizer for the Alsace farm. Water and nutrient balance calculations, yet to be finalised, will be used to determine the maximum volume of digestate that can be sustainably used on average each year and to ensure the requisite amount is applied at the right times to meet the crop requirements while ensuring increases in runoff and percolation are minimised.

Further analysis is required to determine an accurate picture of the digestate coming from the ne biodigester plant. The *NSW Environmental Guidelines* – 'Use of Effluent by Irrigation' should be used as a starting point to classify the digestate streams and as a basis for assessing and managing their use. These Guidelines however acknowledge that they may not provide guidance in all circumstances and that the onus is on the producer to discuss likely impacts with DEC or the local council so that appropriate 'strength' classification. Bindaree should enter into enter into discussions with DEC and/or the local council to determine an appropriate strength classification.

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1. INTRODUCTION

Abattoirs are a large user of water for washdown of livestock, cleaning and sanitizing of plant and equipment in order to maintain strict hygienic standards for meat processing. The resulting wastewater contains contaminants such as blood, fat, manure, paunch contents, brines, detergents, disinfectants and bacteria.

Wastewater from the abattoir is discharged into an effluent stream and undergoes primary and secondary effluent treatment before final discharge back into the environment. Rural abattoirs such as Bindaree Beef will typically discharge the treated effluent via irrigation onto land for crop production.[1]

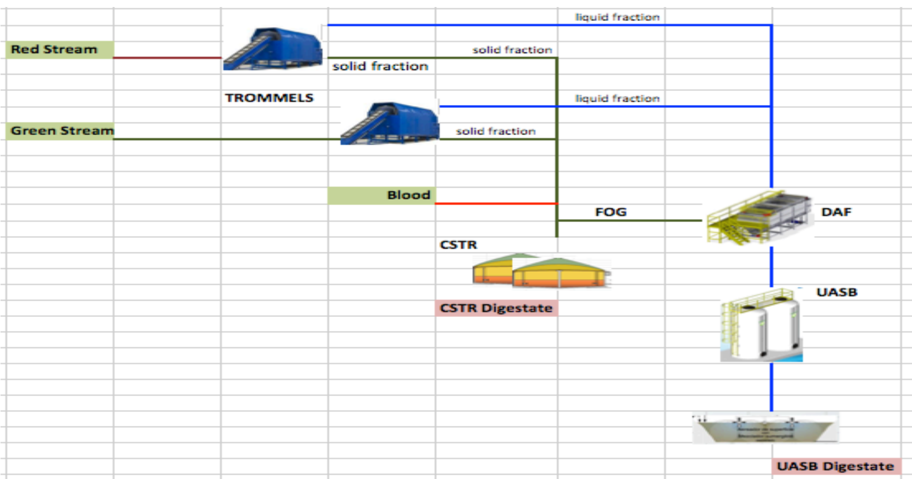
Traditional wastewater from abattoirs contains approximately 45% soluble and 55% coarse suspended organics with most of the organics coming from the blood and paunch.

The effluent is largely biological and contains very little material that is not fully degradable by biological means. The primary treatment of effluent involves the screening of solids and removal of fats from the effluent stream. The secondary treatment of effluent commonly used by abattoirs involves large open anaerobic and aerobic ponds, similar to the current practice at Bindaree Beef.

It is proposed that the existing effluent treatment system and large ponds at Bindaree Beef be replaced with a high tech bio-digester plant. The new plant will incorporating a system of enclosed tanks that provide a stable and controlled environment for microorganisms to efficiently break down biodegradable material in the absence of oxygen. The bio-digester process functions primarily as a waste reduction system, recovering energy from organic waste streams and in the process converting it into biogas for use in burners, generators or similar gas-fired applications.

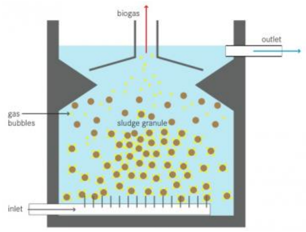
2. BIO-DIGESTER

The Bindaree Beef bio-digester plant design comprises of two synergistic processes: one based on Upflow Anaerobic Sludge Blanket (UASB) technology and the other on Continuously Stirred Tank Reactor (CSTR) technology. The waste stream from the abattoir will be separated into a solid and liquid fraction.

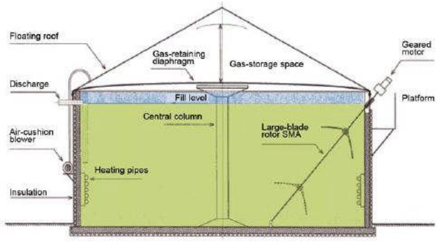


1 Wastewater – MLA Environmental Best Practice Guidelines

The high volume liquid fraction will be treated in the UASB and a dissolved air flotation (DAF) process will be installed prior to the UASB to remove fats oils and grease (FOG) and reduce waste strength. The UASB technology uses an anaerobic process whereby a suspended sludge blanket of granular sludge filters and treats the wastewater



The CSTR process will treat the lower volume, but higher nutrient solids, component of the waste stream including the FOG from the DAF as well as the separated render solids, paunch and blood. The digestate is separated with the liquid fraction from this separation system being fed into the UASB effluent storage tank, and to the effluent holding ponds for irrigation onto land. The solid component will be sold offsite or used on land as an organic fertiliser



Based on its current capacity of 1000 head per day of cattle slaughtered our design model predict the following liquid outputs from the digesters:

Process	Volume
	m^3/d
UASB	700
CSTR	255
Combined	955

Table 1: Bindaree Processes and Volumes

3. DISCHARGE FROM THE BIODIGESTER

The combined discharge from the bio-digesters, digestate, is a nutrient-rich material produced as a result of the Anaerobic Digestion (AD) that is ideally suited for use as an organic fertiliser. All the nitrogen, phosphorous and potassium (N:P:K) present in the wastewater (feedstock) remains in the digestate, however, the nutrients are passed through the process of digestion, and are made considerably more bioavailable, making it is easier for plants to make use of them.

Digestate can be used as fertiliser without any further treatment after its removal from the digester, or alternatively can be further separated and treated to enhance its quality and marketability and to produce standardised biofertilisers (solid or liquid). If required further processing to remove some of the nutrients and organic matter from the digestate, such as separation or drying, can be employed.

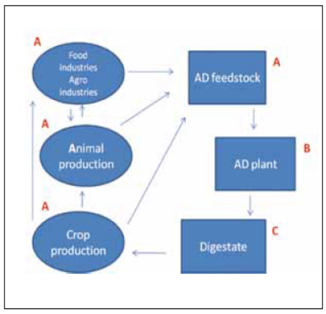


Figure 1: Nutrient Cycle in Anaerobic Digestion

Figure 1 shows the typical nutrient cycle from feedstock to digestion, crop/animal production and agronomic industries. Digestate is used successfully as a regulatory approved fertiliser in many countries around the world, such as Austria, Canada, Denmark, Germany, Netherlands, Sweden, Switzerland and the United Kingdom. Whilst climatic and soil conditions are somewhat different to the examples above they will not significantly affect the efficacy of the digestate as a nutrient source to promote plant growth.

4. NUTRIENTS

During anaerobic digestion, whilst the total content of most nutrients is preserved, the form and availability of some of these is significantly changed. As noted earlier while the use of digestate as an alternative fertilizer is not widely practiced in Australia, the practice is well established, and highly valued in many overseas countries. In Australia, Berrybank Piggery in Victoria produces approximately seven tonnes a day of biofertiliser from its digesters that is used to fertilise crops on their farm. The nutrients in the separated liquid stream replace chemical fertiliser that would otherwise be applied to their cropping land. Composted humus also provides a valuable fertiliser for the farm, as well as the local potting-mix market.

The quantity and crop-availability of the nutrients in digestate will depend on the process input materials, the process itself and any post-treatment manipulation of the digestate such as de-watering. While the total quantity of nutrients will be the same in the whole digestate as in the original input materials, the digestion process changes their crop availability – in particular, the majority of organic (slow release) nitrogen is transformed into (crop-available) ammonium nitrogen during digestion. The enhanced value of nutrients contained in plant available forms in digestate is well recognised and makes it a sought-after biofertiliser. As the organic structure of the feedstock is broken down, nutrients are released in simple, plant available forms such as ammonium (NH_4), phosphate (P_2O_5) and potassium oxide (K_2O), in the case of N:P:K respectively.

Nitrogen

Only a small portion (2%) of soil organic nitrogen will be plant available in any one year and the timing of this conversion to mineral nitrogen may not be coincidental with crop need. Nitrogen in particular is a limiting factor in plant growth and there is mounting evidence across the country of depleting amounts of native organic nitrogen available to mineralise and maintain the soils nitrogen pool. Denitrification has also been a problem in many places in recent years with yields, or in the case of hay low protein levels, being seriously affected by a lack of nitrogen.

By supplementing the farm with the nitrogen from the digestate, which is more readily plant available, the additional nitrogen will be taken up by the plants leading to increased yields until the crop's natural removal rate is reached. Corresponding nitrogen losses will result from removal by crops and harvest plants and the volatilisation of ammonia and nitrite. The natural removal rate is dependent on plants differing capacities for removing nitrogen, and other factors such as whether a crop is removed or not. Any nitrogen that is not removed may be immobilised which can prevent translocation.

The effectiveness, or fertiliser replacement value, of the nitrogen in biofertilisers will initially depend on the proportion of the crop-available nitrogen they contain. However application methods also create nutrient losses. In Danish trials for example up to 80% of N was utilised by crops when applied by either trailing hoses or injection into soil, however the Alsace property is irrigated via a system of travelling sprinklers, which is likely to lead to higher levels of volatilisation and lower crop nitrogen availability. Losses are also higher when slurries are applied to dry soils under warm weather conditions, and in excess of 25% of applied nitrogen in the form of ammonia can be lost to the atmosphere.

Conversely it has also been observed that Ammonia losses are generally smaller from low dry matter slurries because they more rapidly infiltrate into the soil, while higher dry matter slurries remain on the soil/crop surface for longer leading to greater losses.

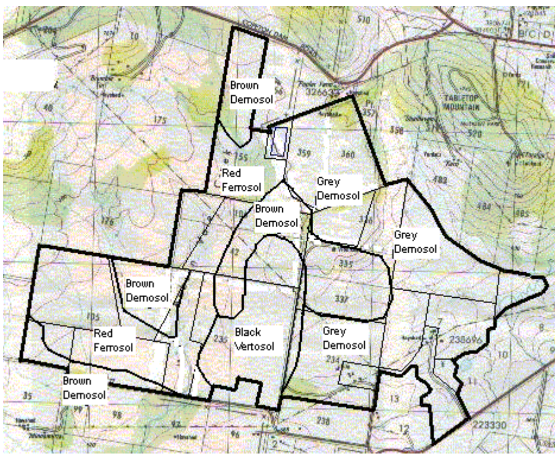
Phosphorus

Soil can act as a sink for phosphorus and some soils can fix phosphorus making it unavailable for plant use. The current Colwell P levels are within the ranges that will maximise crop production and what would be considered within a normal range of natural soil levels. Digestate applications will be geared to maintain sustainable phosphorus levels taking into account removal via crop and a grazing animal production. Consideration will be given to each paddocks P sorption capacity, which is expected to be in excess of 1200kg/ha.

5. THE FARM

The "Alsace" farm, which is owned by Bindaree Beef, is a 479ha property adjacent to the abattoir of which approximately 185ha is currently used for irrigation with abattoir wastewater. There is significant soil variation across the farm. The current Environmental Management Plan is included for reference in appendix 1, and shows the extent of the farm and cropping land.

Much of the property consists of mostly black vertosol and red ferrosol both of which vary in depth from 40cm to >1.2m. Soil pits and testing have recently been completed to assess soil type, depth and fertility and show good soil depth and composition. Soils have good water and nutrient holding capacity suitable for any irrigated or dryland cropping systems with Cation Exchange Capacities (CEC) ranging from moderately acidic to moderately alkaline. Soil phosphorus sorption (PBI) is moderate to high giving the soil capacity to immobilise applied phosphorus (P) that may not be used during the season due to variations in production. Salinity (EC) and sodicity (ESP) are all within acceptable ranges for crop production. None exceed 0.272 dS/m and range from 0.09 – 0.25 1 dS/m.[2]



Of the 185ha currently under irrigation some areas show increased nitrogen and phosphorus levels as a result of irrigation with abattoir wastewater. As identified trough current testing and subsequent sign-off by the ELPA the table below shows the quality of the wastewater presently being irrigated on the property[3]:

[2] Results of testing carried out by Adrian Nelson, Agronomist – March 2014

[3] Bindaree Beef – Annual Environmental Monitoring Report, Jan 2014

Parameter	Current Results
pH	7.99
Conductivity (EC) (uS/cm)	3689
Total Dissolved Salts (mg/L)	2509
Total Suspended Solids (mg/L)	98.83
Biochemical Oxygen Demand (mg/L O²)	96.05
Total Oils and Grease (mg/L)	8.54
Total Phosphorus (mg/L P)	54.55
Total Nitrogen (mg/L N)	371.83
Ammonia (mg/L N)	303.50
Sodium (mg/L)	194.92
Potassium (mg/L)	86.33
Calcium (mg/L)	22.50
Magnesium (mg/L)	11.83
Sodium Absorption Ratio	8.30
Chloride (mg/L)	156.44

Table 2: Current wastewater quality

6. DIGESTATE APPLICATION

The Biodigester system designed for Bindaree Beef will treat all existing wastewater streams and hence the overall nutrient balance will remain the same. However for this bio-digester plant design the two digestate streams from both the UASB and CSTR will be kept separate for different methods of fertiliser application. What this means is the existing nutrient loading will be split between the high volume (700m^3/day) UASB stream and the lower volume (255m^3/day) CSTR stream.

The NSW Environmental Guidelines –'Use of Effluent by Irrigation' stress that effluent irrigation systems should use best management practices to optimize the use of the water, nutrients and organic matter, and to ensure that irrigated areas do not become stressed by the effluent or by the organic, nutrient or chemical loadings applied.[4] The Guidelines[5] also set out parameters for organic, solids and nutrient content, pH, chemical contaminants and other matters to be considered when designing and effluent irrigation system to optimize the use of the water, nutrients and organic matter. For an effluent irrigation system to be ecologically sustainable, the irrigated plants and environment must not become stressed by the effluent or by the organic, nutrient or chemical loadings applied.

While the guidelines recommend classifying effluent for irrigation into one of three categories (low, medium or high) they make it clear that the purpose of classification is simply to provide a risk profile to guide the design of a suitable effluent irrigation system. For an effluent irrigation system to be ecologically sustainable, the irrigated plants and environment must not become stressed by the effluent or by the organic, nutrient or chemical loadings applied. The amount of

[4] Environmental Guidelines – Use of Effluent by Irrigation, Dept. of Environment and Conservation (NSW), p34

[5] ibid

water nutrients and organic matter for optimum sustainable production of any given cropping system will be a function of the crop or cultivar, the agronomic system employed, and site-specific factors such as climate, topography and soil.

The proposed design takes a best practice approach to management of the abattoir's waste stream. Separating the effluent into two distinct streams, one with lower and one higher nutrient concentration, provides Bindaree Beef with greater management control over the dispersal of the nutrient load. Using the UASB stream with its lower nutrient levels as a base to be applied to the existing irrigation area and having greater options with regard to management of the higher nutrient load CSTR stream, coupled with the proposed storage capacity will provide for optimal control of the impacts of effluent disposal.

Utilitas therefore recommends that Bindaree Beef prepare an effluent or ***Digestate Management Plan*** based generally around on the EPA Effluent Guidelines showing how the digestate output will be managed to achieve optimal control over its dispersal and use.

UASB digestate

The UASB will produce approximately 700m^3/day of effluent that contains valuable organic matter and nutrients. The DAF pretreatment process will reduce waste strength by approximately 50% and the UASB can achieve removal of approx. 80% COD, 95% BOD and 80% TSS (Caixeta et al., 2002).

In the proposed biodigester design the waste stream is being separated such that only a portion of the nutrients will be present in the UASB stream. It is proposed that the digestate from the UASB, which is in a liquid form, will be used for irrigation onto the existing farm as per the current practice but with a lower nutrient concentration.

In addition a number of irrigated paddocks are currently growing Lucerne, which is a nitrogen fixer. Growing of more demanding crops to extract nutrients from the soil such as sorghum, triticale, corn, sudan grass or cutting for hay will, in conjunction with the reduction in the nutrient levels, lead to further improvement in soil conditions.

The Minimum Land Area (as per *NSW EPA Environmental guidelines: 'Use of effluent by irrigation'*) is the area required for nutrient application to be in balance with nutrient taken up by land use. The table below shows typical uptake rates of N & P for some alternative crops:

Crop	Yield DM m^3/ha	N kg/ha	P kg/ha
Hybrid Sudan grass or Sudan grass crosses	15	270	45
Forage Sorghum	15	270	45
Oats, Triticale or wheat	9	135	27

Table 4: Nutrient Yield and Uptake Rates

Typical concentration of nutrients in abattoir effluent established by Meat Research Corporation (1995) can be used as a benchmark for UASB digestate irrigation:[6]

6 Nutrient removal from abattoir wastewater, Johns

- Nitrogen 100 – 250 mg/L
- Phosphorus 20 – 50 mg/L

Given these target values will most likely be achievable based on previous research and results from the pilot plant the UASB output could therefore be irrigated in a similar manner to the existing abattoir effluent. Irrigating the UASB output over the existing 185ha irrigation area should be an improvement on existing practice and should ensure that irrigated areas do not become stressed by the organic, nutrient or chemical loadings applied. Over time this may also lead to an overall improvement in soil nutrient balance.

Utilitas recommends that Bindaree Beef incorporate procedures and practices for the use of the UASB digestate, in conjunction with optimal crop selection for maximum nutrient uptake on a paddock-by-paddock basis, into the existing Farm Management Plan.

CSTR digestate

The CSTR process will produce approximately 255m^3/day of digestate. A CSTR biogas plant operating under mesophilic conditions will produce effluent with minimal organic matter, which is suitable for use as low-odour organic fertiliser. During anaerobic digestion, while total content of most nutrients is preserved, the form and availability of some of these is significantly changed.

All the nitrogen, phosphorous and potassium (N:P:K) present in the separated fraction feeding the CSTR will remain in the digestate, however, the nutrients are passed through the process of digestion, and are made considerably more bioavailable, making it is easier for plants to make use of them. As the organic structure of the feedstock is broken down, nutrients are released in simple, plant available forms such as ammonium (NH_4), phosphate (P_2O_5) and potassium oxide (K_2O), in the case of N:P:K respectively. CSTR Digestate is used widely throughout the world as an organic fertilizer (see e.g. Table 1).

Example	Notes	Online Reference
Use of Digestate in the UK	Various examples of digestate usage in the UK	http://www.biogas-info.co.uk/index.php/using-digestate-agri.html
James Hart and Jeremy Iles' Anaerobic Digester	Located in in Gloucestershire, UK - electricity is exported to the grid and digestate is used on their arable land.	http://smartstore.bpex.org.uk/articles/dodownload.asp?a=smartstore.bpex.org.uk.9.3.2012.10.22.7.pdf&i=301948
Beelan Pig Farm	Located in North West Germany – digestate to fertilise maize crop.	http://www.fwi.co.uk/articles/27/01/2011/125242/learning-from-the-german-biogas-experience.htm
The Use of Digestate as an Organic Fertiliser		http://www.envirotech-online.com/articles/environmental-laboratory/7/susanna_litmanen_franz_kirchmeyr/the_use_of_digestate_as_an_organic_fertiliser/1593/
Fact Sheet: Nutrient Value of AD Digestate		http://www.biogas.org.nz/Publications/Resources/Biogas-Digestate-Factsheet_Renquist-Heubeck.pdf

Table 6: Examples of Digestate Fertiliser throughout the World

While climatic and soil conditions in the above examples may vary somewhat from those at Inverell comparison data and local examples such as the Berrybank Biodigester referred to earlier show that similar results would be achieved.

As noted above the CSTR digestate can be used as fertiliser without any further treatment after its removal from the digester. Should nutrient loadings and crop selection on the existing irrigated area allow, or should further non-grazing land be available on the Alsace property, or alternatively should additional property become available in the vicinity of the abattoir, the whole digestate from the CSTR would provide a valuable source of nutrient for additional cropping or hay production. Hay production in particular could offer a valuable replacement for existing bought-in feed and provide additional financial benefit to the operation.

Alternatively the digestate can be further dewatered producing a low nutrient liquid fraction (liquor), which could be returned to the UASB stream and a higher nutrient concentration solid fraction (fiber). Once dewatered, the fiber is low in volume and ideal for transporting by tractor and trailer to the farm from spreading on non-irrigated pastures.

Shallow injection or trailing-shoe application to pasture

Further dewatering and concentration of the digestate fiber would provide for more efficient transport off-site and the high nutrient material could be sold as a semi-solid fertiliser. If required, the dewatered fiber can be further conditioned to enhance its quality and marketability through drying and pelletizing to produce a more solid fertiliser product.

We recommend that Bindaree include facilities for post separation and drying of the digestate to provide for maximum flexibility in the management of the CSTR high nutrient stream in addition to conducting further analysis and market research to determine the optimal onsite and/or offsite use of the CSTR digestate.

7. EXISTING PILOT PLANT

The existing pilot plant at Bindaree provides an ideal opportunity to carry out further testing in order to prepare a new farm management plan that can be initiated as soon as the digester plant is operational. Ongoing analysis of actual output from the digester can then be used to enhance the farm management plant.

Utilitas recommends that Bindaree recommence operation of the pilot plant as soon as practical.

8. MONITORING PROGRAM

Bindaree Beef has an existing monitoring program, which is implemented as part of its EPA Licence conditions. As part of this existing monitoring program Utilitas recommends that Bindaree Beef introduce as part of its Digestate Management Plan a Digestate Monitoring Program to ensure digestate is regularly analysed and management practices tailored to suit soil conditions, weather events and crop requirements. Commensurate water balance calculations should be incorporated in the Farm Management Plan to determine the maximum volume of digestate that can be applied each period to ensure the requisite amount is applied at the right times to meet the crop requirements while ensuring increases in runoff and percolation are minimised.[7] Nutrient application should be predicted using a nutrient balance model where the amount of the specific nutrient [i.e. NPK] assumed to be applied each period is compared with the amount taken up by the biological or physical processes of the crop-soil system to achieve a sustainable outcome. The Farm Management Plan should also incorporate the need for metering digestate for irrigation and the on-going sampling of both digestate and soil nutrient levels.

Other considerations

It is also important that any digestate management plan also considers the importance of animal health and ensures the safety of food for human consumption. The plan should address the risk management of potential cross-contamination where digestate (effluent) is used for irrigation or fertilisation of grazing pastures. Refer to section 5.7 of the Environmental Guidelines.

9. RECOMMENDATIONS

Utilitas recommends:

1. Recommence operation of the pilot plant to gather further data on the digestate output based on the design parameters of the full-scale biodigester system

2. Conduct further analysis to identify additional areas on the Alsace property which maybe suitable for cropping or hay production using the nutrient rich digestate

3. Investigate the opportunity to access additional land adjacent to the facility suitable for high-nutrient uptake crops

4. Finalise digestate use strategy and develop a ***Digestate Management Plan*** as a key document that supplements the Bindaree Biogas Plant Operating and Maintenance Manual and the Farm Management Plan. The following is draft table of contents for this plan:
   - Scope
   - Terms and definitions
   - Quality management system (QMS)
   - Input materials analysis
   - Process management, separation and storage
   - Process equipment
   - Process output monitoring and analysis
   - Sampling, Testing and Analysis of irrigation and solid fertiliser streams
   - Use of whole digestate
   - Digestate conditioning
   - Agronomic Validation

5. That the existing ***Farm Management Plan*** be updated to reflect the use of digestate from the biodigester and identify where possible crops with higher nutrient take-up requirements.

[7] Environmental Guidelines – Use of Effluent by Irrigation, Dept. of Environment and Conservation (NSW) p36

10.SUGGESTED TIMING SCHEDULE

Table 5 shows the proposed schedule for actions and implementation of a new farm management plan.

Actions	By Whom	By When
1. EPA Discussions – as part of DA process	MHC/Utilitas	May 2014
2. Recommence Operation of Pilot Plant	Utilitas	July – Dec 2014
3. Investigate irrigation and cropping options for Alsace	Agronomist/BB & Utilitas	Oct – Dec 2014
4. Investigate Additional land availability	Bindaree Beef	Oct – Dec 2014
5. Prepare Digestate Management Plan	Utilitas	Jan – Mar 2015
6. Prepare New Farm Management Plan	Utilitas/BB	Apr – Jun 2015
7. Analyse digestate from operating plat and refine digestate fertiliser model	Utilitas/BB	Dec 2015
8. Refine Farm Management Plan	Utilitas/BB	Jan – Feb 2016

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