BIOENERGY SUPPORT PROGRAM - DAF TRANSITION

Project 4C-116

Final Report prepared for the Co-operative Research Centre for High Integrity Australian Pork

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Business Cooperative Research Centres Programme

Executive Summary

The project described in this report provided funding for Mr Alan Skerman, Department of Agriculture and Fisheries (DAF) to deliver the technical extension role of the Bioenergy Support Program (BSP) from July 2015 to June 2018. Dr Stephan Tait, Advanced Water Management Centre (AWMC), University of Queensland (UQ) continued to deliver and coordinate the research component of the program during this period, in addition to supporting Mr Skerman with the delivery of the extension service.

Biogas systems are currently operating at 21 piggery units across Australia, representing 15 separate businesses. Approximately 15% of the total Australian pig herd (42,700 sows ≈ 427,000 SPU) is currently housed in piggeries where the effluent is directed to a biogas system. This is equivalent to 29% of the national herd housed in accommodation currently considered 'suitable' for biogas system adoption (excluding deep litter housing, outdoor production and piggery units with capacities less than 500 sows farrow to finish). The existing piggery biogas systems include 14 covered anaerobic ponds (CAPs), 4 heated/stirred in-ground hybrid CAPs and 3 above-ground engineered vessel digesters.

Producers with existing biogas systems have reported significant financial benefits resulting from a combination of energy cost savings, additional income from the sale of surplus electricity to the grid, and returns from the sale of Australian Carbon Credit Units (ACCUs) and renewable energy certificates (RECs). In several cases, farm energy costs for the supply of electricity, LPG and diesel (for electricity generation) have been eliminated. Capital expenditure payback periods less than three years have been reported, however, returns from biogas systems do vary, depending on a range of site-specific factors.

Since the commencement of the emission reduction fund (ERF) in 2012/13, 372,143 ACCUs have been issued to 8 of the 14 registered piggery operators, indicating substantial abatement of greenhouse gas emissions by the piggery biogas installations. Based on average prices recorded at twice-yearly auctions, the total value of these ACCUs is approximately $4 M, providing noteworthy financial benefits to the participating producers.

The BSP has assisted producers, industry service providers and consultants by addressing numerous ad hoc enquiries regarding planning, design, and even construction, commissioning and operation of piggery biogas systems. Ten site-specific, preliminary piggery biogas feasibility reports were also prepared for producers. While only one of these piggeries has proceeded to install an on-farm biogas system, it is anticipated that other producers may proceed with biogas developments within the next few years, depending on industry profitability.

A national biogas survey indicated a substantial lack of awareness of on-farm biogas system adoption, particularly by producers operating smaller piggeries. The survey respondents indicated that further information regarding topics such as system costs and benefits, site-specific viability (particularly for smaller piggeries), funding options, compatibility with deep litter systems and ongoing operation and maintenance costs, would assist them in deciding whether or not to proceed with the installation of a biogas system. The greatest concerns identified by producers with existing biogas systems were depleted biogas production, red tape, sludge management in CAPs, lack of industry support personnel, and expensive generator maintenance. The majority of piggeries currently benefiting from biogas systems have capacities greater than 10,000 SPU, highlighting the need to continue

supporting the development and adoption of biogas systems technically and financially feasible for smaller piggeries.

The publications produced by the BSP (4 Talking Topics booklets, 8 Australian Pork Newspaper 'It's a gas' articles, a YouTube video, 5 peer-reviewed journal papers, 3 conference papers and several industry talks) have contributed substantially to the reference/extension material available to support the ongoing safe and technically-sound development of on-farm biogas systems. Scientific publications also evidenced the rigor of Pork CRC research in biogas.

There is considerable interest in smart strategies to maximise the financial benefits from biogas systems. Examples of such strategies include (1) co-digesting piggery effluent with various off-farm waste or by-products supplied by nearby industries, (2) upgrading excess biogas to bio-methane, to mobilize the biogas energy for higher value applications, and (3) employing sophisticated electricity spot price monitoring technology to control on-farm generator operation and the sale of biogas-derived electricity during higher demand/spot price periods. Each of these options are worthy of further investigation to assess technical and economic feasibility.

Regulatory issues and the cost of compliance continue to disincentivise adoption of biogas systems. For example, in at least one Australian State, the treated manure residue from anaerobic digesters is not permitted to be applied to land as a bio-fertiliser, despite its widely recognised beneficial attributes. This makes it difficult to manage manure volumes at a piggery. In another state, the burden of an annual safety and health fee and the cost of engaging suitably qualified gas fitters, has caused a piggery to demolish their on-site biogas system and return to an uncovered pond arrangement. Other concerns include onerous gas safety standards and legislation, which do not realistically reflect the risks associated with operating relatively small-scale, on-farm biogas systems, at low pressure. Inconsistencies between state gas safety legislation and standards also continue to impede the adoption of standard and modular biogas system components nationally.

Notwithstanding the above compliance issues, it is of vital importance for workers at piggeries with operating biogas systems to understand the significant health and safety risks associated with the biogas systems and how these risks can be safely managed.

The benefits of piggery biogas to date have been clear, and the Pork CRC Bioenergy Support Program played an instrumental role in facilitating uptake and benefits. Accordingly, it is recommended that a similar on-going industry extension and support role be funded into the future. This is because the demand for biogas systems will likely ramp up again when the pork industry recovers from its current downturn. Future developments will need adequate support. This is especially needed because of an apparent market failure in a lack of available suppliers that could successfully deliver the range of biogas technology and services required by producers in the long term. This initiative will ensure that producers can continue benefiting from biogas into the future.

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Glossary

ACCU	Australian carbon credit unit
AM2MA	Australian methane to markets in Agriculture
AMPTS	Automated methane potential test system
APL	Australian Pork Limited
AWMC	Advanced water management centre
BMP	Biochemical Methane Potential
BSP	Bioenergy support program
CAP	Covered anaerobic pond
CHP	Combined heat and power
CNG	Compressed natural gas
DAF	Department of Agriculture and Fisheries
ERF	Emissions reduction fund
GAC	Granulated activated carbon
HDPE	High density polyethylene
HLA	Heavily loaded anaerobic (pond)
HRT	Hydraulic retention time
Hybrid CAP	Mixed, heated, in-ground covered anaerobic pond
IEA	International energy agency
kWe	Kilowatt – electric: Electrical output of a generator.
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
MJth	Megajoule thermal
PCAP	Partially covered anaerobic pond
PPE	Personal protective equipment
REC	Renewable energy certificate
SPU	Standard pig unit
t CO2-e	Tonnes of carbon dioxide equivalents
UQ	University of Queensland
USQ	University of Southern Queensland
VS	Volatile solids

1. Introduction

Prior to the commencement of this project in July 2015, the BSP had already encouraged extensive uptake of biogas technology by the Australian pork industry and had also coordinated the development of a research program specifically addressing industry needs, as outlined in Pork CRC Milestones 4.5.2, 4.5.3, 4.5.5, 4.5.6 and 4.5.7. The present project provided funding for Mr Alan Skerman (DAF) to take over the Program's technical extension role, to promote the outcomes of relevant Pork CRC research, keep existing biogas extension materials up-to-date, and to offer ongoing technical support for adoption of biogas technology at Pork CRC demonstration piggeries. This project continued for the three-year period, commencing on 1 July 2015 and ending on 30 June 2018. Dr Stephan Tait (AWMC, UQ) continued to deliver and coordinate the research component of the program during this period, in addition to supporting Mr Alan Skerman with the delivery of the extension and technical support service.

2. Methodology

In part, the project activities were dictated by requests for assistance from producers, consultants and biogas service providers. Consequently, the types of assistance provided evolved over the course of the project in response to the needs identified by these main client groups. This flexibility in project delivery ensured that outputs were relevant to industry needs. The main methods of project delivery are described in the following section of this report.

Addressing ad hoc enquiries

Both Mr Alan Skerman and Dr Stephan Tait spent considerable time addressing ad hoc enquiries from producers, service providers and consultants. These enquiries were generally received via email or telephone calls and were addressed by:

- Telephone discussions.
- Emailing existing extension material or references to the client.
- Carrying out further investigation of the issue before responding by phone or email.

Preparing preliminary piggery biogas feasibility reports

Preliminary biogas feasibility reports were prepared in response to pork producer enquiries seeking information regarding the practical and economic feasibility of establishing on-farm biogas systems.

In all cases, the PigBal 4 model was run to estimate the volatile solids (VS) loading entering a potential covered anaerobic pond (CAP), based on site-specific pig herd, diet, feed consumption and shed flushing/cleaning data, provided by the producer, whenever possible. When site-specific data were not available, more generalised data or typical industry values were entered into the model, which was used to produce a schematic design for a possible CAP, based on a selected VS loading rate and hydraulic retention time (HRT). PigBal also includes provision for a nominal sludge storage period within the CAP.

An example of a CAP schematic drawing produced by the PigBal model is provided in Figure 1, below.

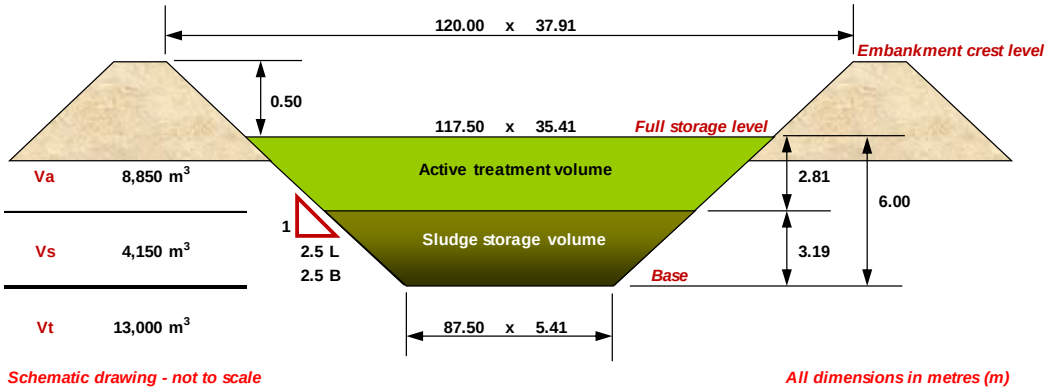

Figure 1. An example of a schematic CAP drawing included in preliminary piggery biogas feasibility reports.

An internal Department of Agriculture and Fisheries (DAF) spreadsheet, Piggery Biogas Energy Calculator (Skerman, 2016), was then used to estimate the CAP biogas yield and the resulting electrical and thermal energy which could be produced from using the available biogas to run an on-farm boiler or combined heat and power (CHP) system. The potential economic value of the resulting energy was also estimated based on replacing existing grid electricity and LPG consumption.

A standard reporting template, which included the following section headings, was developed for consistency and efficiency of reporting:

- Introduction
- Piggery details
- Effluent and biogas production
- Covered anaerobic pond
- Odour emission mitigation
- Flaring
- Hot water boiler option
- Combined heat and power (CHP) system option
- Carbon emission abatement
- Estimated biogas system cost

A summary of the completed biogas feasibility reports is provided in Section 3 of this report.

Preparing and maintaining a listing of biogas equipment suppliers and service providers

A listing of businesses supplying equipment or services to the biogas industry was compiled and maintained as a service to pig producers interested in developing, operating or maintaining on-farm biogas systems. This list, which is provided in Appendix 1, was not intended to be exhaustive and the majority of businesses included in this list had proactively requested that their details be made available to prospective customers in the pork industry. Also, inclusion in this list did not imply any warranty or recommendation with regard to the quality or suitability of the products or services provided by these businesses, neither were there any stated preferences. Lastly, while this listing provided some initial contacts, it was recommended that producers make their own enquiries before selecting businesses providing particular products or services. A disclaimer clause was inserted into the supplier list to highlight these limitations and assertions.

This supplier listing was commonly forwarded to producers who requested preliminary biogas feasibility reports, to assist in obtaining quotations for the supply of equipment or services.

Preparing standard drawings

Standard drawings showing typical schematic designs for CAP cover anchoring, inlet and outlet structures and desludging pipes were prepared based on experience gained at BSP demonstration piggeries and recommendations previously published by the Pork CRC and NIWA (NZ). These drawings were

prepared to assist producers planning new CAP developments and were generally provided to producers on request and/or attached to preliminary biogas feasibility reports. Copies of these drawings are included in Appendix 2 of this report. Again, a disclaimer was inserted to assert that these drawings were of a general nature, and to recommend separate detailed investigations by the producers themselves.

Compiling biogas system uptake data

A listing of Australian piggery biogas projects was prepared providing data on the status of existing and proposed biogas projects, including details of the piggeries and estimates of the potential biogas and energy production. This listing was updated as we became aware of new biogas projects or major changes to existing developments. The collection of all uptake data relied on the goodwill and cooperation of producers, and so may not necessarily be entirely complete. A summary of the current biogas uptake data is provided in Section 3 of this report.

Preparing and publishing 'Talking Topic' booklets

Four 'Talking Topic' extension booklets were prepared by Dr Stephan Tait and Mr Alan Skerman and published on the Pork CRC website. These booklets were intended to provide producers and industry service providers with an overview of principles involved in safely establishing and operating on-farm biogas systems. Hard copies of the Talking Topic booklets were also produced for distribution at industry forums. Further details of the completed 'Talking Topic' booklets are provided in Section 3 of this report.

Preparing Australian Pork Newspaper 'It's a gas' articles

Several articles were prepared for publication in the monthly Australian Pork Newspaper (APN) which is distributed free of charge to anyone involved in the Australian pork industry. It has a very wide readership of both producers and industry service providers. These articles provided an effective means for raising awareness of biogas technology and developments across a wide cross-section of the pork industry. Further details of the completed 'It's a gas' articles are provided in Section 3 of this report.

Preparing a 'Biogas Benefits for your piggery' video

Dr Stephan Tait coordinated the production of a YouTube video entitled 'Biogas Benefits for your piggery' (Figure 2) during 2016. The text for this video was prepared by Dr Tait and Mr Skerman and the video was produced by a commercial media production company, Range Media, based in Toowoomba, Queensland. This video highlighted the benefits of using biogas in Australian piggeries and showed real life examples of biogas technologies, systems, equipment and uses at BSP demonstration piggeries, including interviews with a producer and a Pork CRC researcher. This video was published on YouTube on 19 August 2016 with a link hosted on the Pork CRC website.
https://www.youtube.com/watch?v=4BASwiMclJE

Figure 2. The opening screen of the 'Biogas Benefits for your Piggery' video published on YouTube.

Preparing conference and journal papers and industry talks

Several conference papers, journal papers and industry talks were prepared, presented and published. Publication of research papers ensures that the valuable research outcomes are made available to a wide audience, while the peer review process enhances the credibility and value of the completed work. These papers and talks also publicised the valuable work completed under Pork CRC and related APL research and development projects. Further details and references for these publications are provided in Section 3 of this report.

On-farm R&D

Experimental floating pontoon on a heavily loaded anaerobic pond

Volume and composition of biogas collected by a small, experimental floating cover (pontoon) deployed on a highly loaded anaerobic (HLA) pond, at a 530-sow farrow to finish piggery near Dalby (Queensland), was monitored during 2017. The HLA pond operating at this piggery was previously described by Skerman *et al*. (2008). The rectangular pontoon, which covered a pond surface area of 2.7 m x 5.7 m = 15.4 m^2, was fabricated using 300 mm diameter high density polyethylene (HDPE) pipes (ex-mines) installed around the perimeter to provide flotation, with 1.5 mm thick HDPE sheeting heat welded onto the perimeter pipes to provide a continuous floating cover. The HLA pond at this piggery is not typical of CAPs designed specifically for biogas capture because of the higher VS loading rate and the presence of a thick crust over the pond surface most of the time. Consequently, this trial was intended to assess whether the crust inhibited methane emission sufficiently to compromise the feasibility of installing a larger cover on the existing HLA pond at the piggery. If economically and practically feasible, the producer was primarily interested in using biogas to offset current grid electricity usage of approximately 900 kWh/month, supplying the piggery and associated on-farm feed mill. Meter readings indicated an average biogas collection rate of 4.5 m^3 biogas/day from the cover deployed on the HLA pond.

Because considerable anaerobic activity had been observed visually in the secondary pond, the experimental pontoon was later moved from the HLA pond to the secondary pond during April 2017. The second phase of the trial was intended to meter biogas collection from the secondary pond for comparison with the data recorded for the HLA pond. The average daily biogas collection rate (4.6 m^3/day) was similar to the rate recorded for the HLA primary pond, and the much less prominent crust on the secondary pond would therefore suggest that it is better to recover biogas from the secondary pond. Photographs of the floating pontoon deployed on the primary HLA pond and secondary pond are provided in Figures 3 and 4, respectively.

Figure 3. The experimental floating pontoon deployed on the heavily loaded anaerobic (HLA) pond.

Figure 4. The experimental floating pontoon deployed on the secondary pond.

A preliminary biogas feasibility report was provided to the producer along with interpretations of the data collected in the on-farm trials and recommendations for possible biogas systems. Alan Skerman attended an on-farm meeting with Mr Alex Pannekoek (Managing Director East Coast Diesel & Gas) to discuss biogas electricity generation options. Mr Skerman also accompanied the producer and Mr Pannekoek on an inspection of ex-coal seam gas (CSG) gensets being auctioned in Dalby (Queensland) to assess their suitability for running on piggery biogas.

The producer is still considering various biogas options; with the current industry downturn likely delaying plans to proceed with the system installation.

Experimental biogas chemisorption treatment column

An experimental biogas treatment column was fabricated at the DAF Toowoomba workshop and installed at a 700-sow breeder piggery, located near Grantham (Queensland) during June 2017. The column was designed to reduce the time and labour required to change the iron oxide pellets used to remove hydrogen sulphide from biogas by chemisorption (See Talking Topic 4). The new column was installed on a tipping frame to enable the spent pellets to be easily removed from the column. Piggery employees were trained in safe use of the improved treatment column, which is shown in Figure 5.

Figure 5. The experimental biogas chemisorption treatment column installed at the Grantham piggery.

Potential use of ex-coal seam gas engines for piggery biogas applications

Several 60, 100 and 150 kVA gensets, originally designed for use at Surat Basin coal-seam gas plants, were offered for sale through a Dalby (Qld) machinery business during 2017. Most had little or no previous use and were being offered at relatively low prices in comparison to new biogas engines having similar electrical output. Enquiries were made to determine whether it would be feasible to deploy these gensets, with minimal modification, at smaller piggeries. At least one of these gensets was subsequently purchased by a Victorian pig producer for use in an on-farm biogas electricity generation system currently being commissioned.

Remote monitoring of biogas systems

A need was identified for the installation of instrumentation and communication equipment to allow real-time, remote monitoring of biogas composition and other operational data at on-farm piggery biogas plants. This resulted in the submission of an application to the Pork CRC for funding to provide incentives for producers to install the required monitoring instrumentation at up to three commercial piggeries with existing on-farm biogas systems. An agreement between the Pork CRC, DAF and UQ was subsequently signed on 17 July 2017 for the delivery of Pork CRC Project 4C-122 *Installation of instrumentation for remote monitoring of biogas composition and operational data at commercial piggeries*.

Following an expression of interest process, three producers were invited to submit detailed quotations for the supply and installation of the relevant instrumentation. Due to unforeseen circumstances outside the control of the project team, only one of these producers was able to successfully source quotes, sign contracts and, with grant assistance, install the intended monitoring instrumentation within the project timeframe. The current difficult financial circumstances being experienced in the Australian pork sector may have contributed to the disappointing producer participation in this project.

The high quality data available through this installation could potentially be used for:

- a better quantification of the risks of hydrogen sulphide and flammable methane in piggery biogas;
- Early diagnosis of operational irregularities or system faults.
- Evaluation of a range of operating strategies and biogas treatment methods.
- Managing changes in biogas composition resulting from co-digestion feed stock variations.
- Validating the energy and economic value of the biogas systems.
- Assessing short and long-term seasonal variations in biogas production and quality.
- Managing biogas use options to maximise economic benefit.

This data is readily accessible to the piggery managers for daily biogas system management purposes and was made available to Pork CRC BSP researchers to enable the evaluation of system performance and for carrying out strategic applied research. This initial installation will also provide a pilot resource for long-term evaluation and possible modification prior to more widespread adoption of similar instrumentation across the industry. Detailed monitoring results will be provided in the Final Report for Project 4C-122.

Laboratory analysis capability

Automated Methane Potential Test System

Project funds were used to purchase an Automated Methane Potential Test System (AMPTSII – Bioprocess Control, Sweden) which was supplied by Royce Water Technologies Pty Ltd (Brisbane) and set up in the DAF Toowoomba laboratory (Figure 6). This apparatus was initially used to evaluate the effect of different levels of feed wastage on the potential for methane production from piggery

waste streams (APL Project 2015-010). It has also been used to determine the Biochemical Methane Potential (BMP) of a range of sludge samples collected from a covered and several uncovered piggery anaerobic ponds under APL Project 2016-085.

This apparatus was predominantly set up to support on-going biogas research activities of the Pork CRC and will now become available for broader testing to support the pork industry, likely on a fee-for-service basis. It is anticipated that this apparatus could be used for further evaluation of the energy potential from proposed co-digestion feedstocks (i.e. other waste products added for digestion together with pig manure).

Figure 6. AMPTSII system operating in the DAF Toowoomba laboratory.

Laboratory chemisorption testing apparatus

The laboratory chemisorption test rig (Figure 7), previously fabricated for use in Pork CRC Project 4C-104, was used to carry out a series of laboratory trials to assess the hydrogen sulphide (H_2S) removal performance of two types of commercial Granulated Activated Carbon (GAC) media. These trials were carried out in response to a request for assistance from a central Queensland producer to address biogas quality issues at an existing digester facility where abattoir paunch was being co-digested along with piggery effluent. This chemisorption testing equipment will likely be decommissioned.

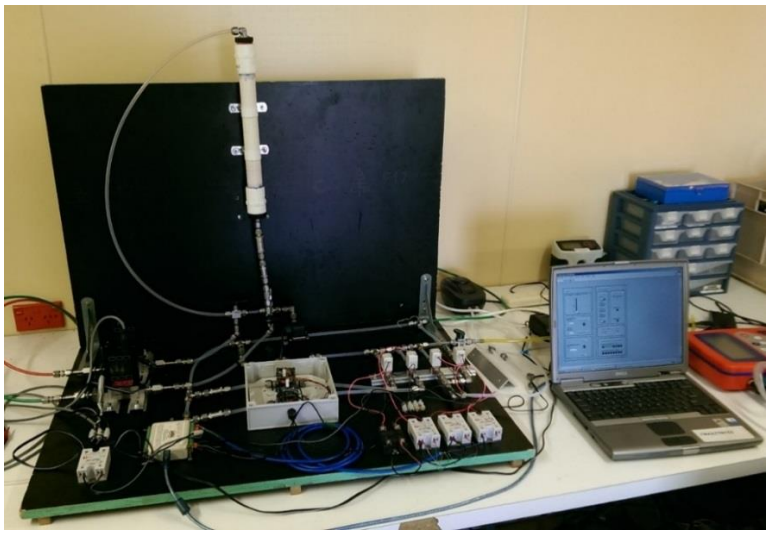

Figure 7. The chemisorption test rig fabricated for use in Pork CRC Project 4C-104 was used to assess biogas treatment media at the DAF Toowoomba laboratory.

Workplace Health and Safety

Respiratory personal protective equipment (PPE) requirements were researched to assist a commercial piggery that was experiencing OHS difficulties when carrying out changeovers of commercial iron oxide pellets used to remove hydrogen sulphide from biogas at the piggery. This research responded to an enquiry from the producer and recommendations were forwarded in confidence to the producer.

Project and report reviews

Reviews of the following reports and methodologies were carried out to support a range of industry initiatives:

- Mr Alan Skerman carried out a peer review on the pig manure and deep litter estimation method used by Dr Stephan Tait for preparing data for the Australian Biomass for Bioenergy Assessment (ABBA) initiative.
- Dr Stephan Tait and Mr Alan Skerman contributed to the International Energy Agency (IEA) Bioenergy Task 37 – 'Australian Success Story' document that was prepared by National Team Leader, Dr Bernadette McCabe (USQ). This document, which outlined the successful adoption of biogas systems by the Australian pork industry, was published on-line during February 2018. http://task37.ieabioenergy.com/case-studies.html
- Mr Alan Skerman peer reviewed the Final Report for Pork CRC Project 4C-109 (Tait et al., 2017) entitled 'Enhanced methane production from pig manure in covered lagoons and digesters'.

National piggery biogas survey

With the approaching conclusion of the Pork CRC and the BSP, Mr Alan Skerman used SurveyMonkey to prepare a survey to evaluate ongoing producer interest in, and attitudes relating to, on-farm biogas, and to help compile more accurate estimates of current adoption. Requests to participate in the survey were distributed to approximately 1000 producers by APL via their own survey email list on 16 March 2018. A reminder email was sent by APL to the same list of producers

on 5 April 2018. The survey was anonymous by default, and where producers chose to disclose their own names and locations, these details were kept strictly confidential.

Ninety-one responses were received during the period from 15 March 2018 to 13 April 2018. This represents an approximate response rate of 9%. The survey results are summarised in Section 3 of this report and results that are more detailed are provided in Appendix 3, WITHOUT any piggery names or locations.

The survey results will allow better planning of future research and technical support to facilitate ongoing adoption of biogas systems across the pork industry.

BSP Steering Committee meeting

A teleconference meeting of the Pork CRC BSP Steering Committee was convened on 30 May 2017. Four producers, two consultants and representatives of APL and the Pork CRC participated in the meeting, which was chaired by Pork CRC Program 4 Leader, Dr Stephan Tait. This teleconference provided a valuable opportunity for participants to share knowledge and experience gained in establishing and operating on-farm biogas systems over recent years. Recommendations from this teleconference provided direction for developing future research and work priorities. The minutes of this meeting are provided in Appendix 4 of this report.

3. Outcomes

This section of the report summarises the project outcomes.

Preliminary piggery biogas feasibility reports

Table 1 provides a summary of the ten preliminary biogas feasibility reports prepared for pork producers as part of this project. While only one of these producers has proceeded to install an on-farm biogas system, based on the advice provided in the report, it is anticipated that some of the other producers may proceed with biogas developments within the next few years, depending on industry profitability. Unfortunately, the industry has been facing severely depressed economic conditions, particularly over the past 12 months, due to low pig prices and high feed prices. Consequently, many producers are struggling to survive the current downturn and are unable to commit to major capital expenditure.

Table 1. Summary of preliminary piggery biogas feasibility reports issued.

Piggery size (SPU)	Locality	State	Est biogas production (m^3 biogas/d)	Carbon emission abatement (t CO_2-e/yr)	Status
546 sows f to f (6,121 SPU)	Trafalgar	Vic	477	1613	Operating
300 sows f to f (3,294 SPU) + broilers	Riverton	SA	235 (conv) 122 (dl)	1990	Feasibility
1200 sows f to f (13,130 SPU)	Munyabla	NSW	560 (conv)	2741	Feasibility
2250 sows f to f (14,183 SPU)	Grong Grong	NSW	1811	8874	Feasibility
533 sows f to f (5,011 SPU)	Dalby	Qld	491	1660	Onsite R&D
3100 sow breeder 11,000 pig grower (18,546 SPU)	Warwick	Qld	1576	5331	Feasibility
11,846 pig grower (13,170 SPU)	Warwick	Qld	1067	3607	Feasibility
960 sows f to f (4,655 SPU conv)	Lake Bolac	Vic	366 (conv)	1795	Feasibility
2500 sow breeder 4,500 pig grower	Dublin	SA	999 (conv)	3381	Feasibility
1244 sow f to f (12,755 SPU)	Tiaro	Qld	1392	4708	Feasibility

dl – deep litter, conv – conventional; f to f – farrow to finish.

Biogas system uptake data

On-farm biogas systems are currently operating at 21 piggery units, representing 15 separate businesses. At least three additional producers are currently seriously considering or planning new biogas projects. There is currently approximately 427,000 SPU housed in piggeries where the effluent is directed to a biogas system. This represents approximately 15% of the total Australian pig herd and 29% of the 'suitable' component of the national herd. (The 'suitable' component of the herd excludes the estimated 30% housed in deep litter sheds and outdoor production systems, and pigs housed in piggeries having capacities less than 500 sows farrow to finish, (5000 SPU) which are currently considered economically unviable for biogas system development). These estimates are based on an assumed total pig population of 279,085 sows ≈ 2,790,850 SPU.)

Figure 8 shows the rate of biogas system development since the construction of the first biogas system at Berribank Farms in Victoria in 1989. This graph clearly shows the rapid adoption of biogas systems between 2011 and 2015 when several larger piggeries recognised the potential benefits of biogas systems. Up until relatively recently, there has been considerable producer interest in the installation of on-farm biogas systems. As noted previously, there has been a noticeable decline in producer requests for information regarding the technical and economic feasibility of biogas systems over the past year, as the profitability of the industry has been adversely affected by depressed pig prices and high feed prices.

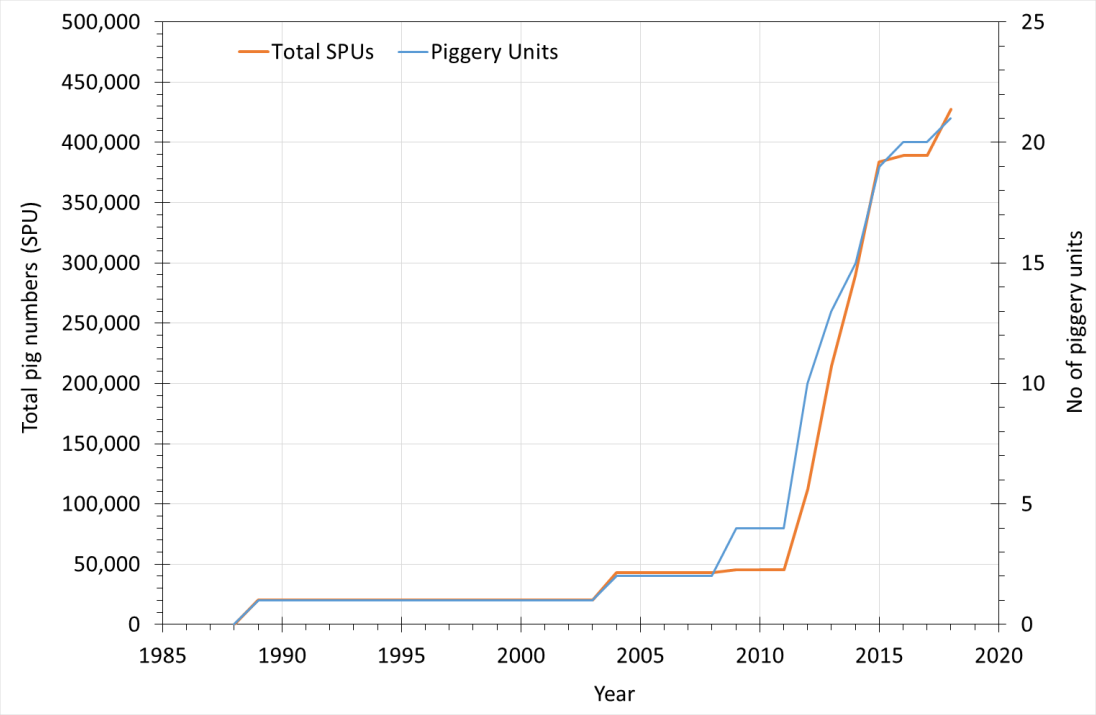

Figure 8. Rate of adoption of biogas systems at Australian piggeries expressed in terms of total standard pig units accommodated in units contributing effluent to biogas systems.

The existing piggery biogas systems include 14 simple CAPs, which are neither heated nor stirred, four in-ground hybrid CAPs, which are heated/stirred, and 3 aboveground stirred-tank (engineered) digesters. Approximate locations of existing piggery biogas systems are shown in Figure 9.

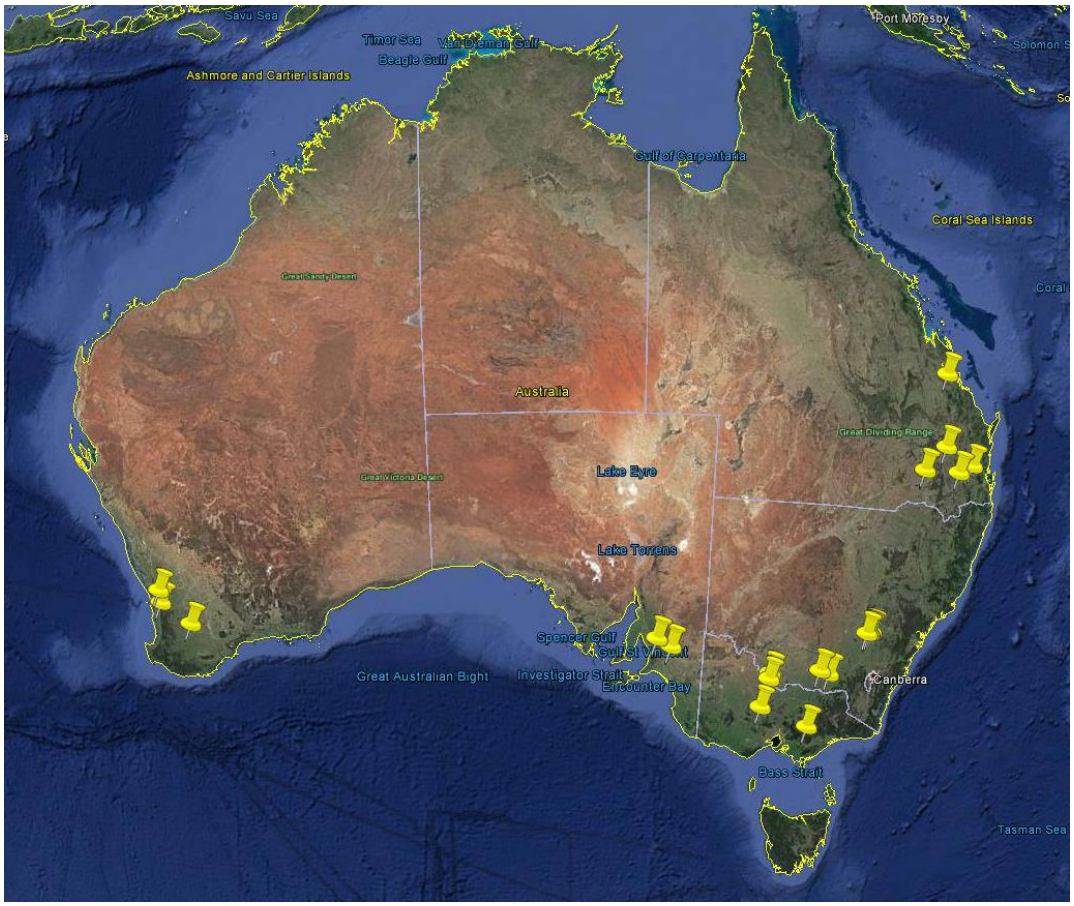

Figure 9. Locations of existing piggery biogas systems (Image from Google Earth).

Table 2 provides data showing the status of existing Australian piggery biogas projects, including piggery details and estimates of the potential biogas and energy production. This table also includes details of two piggery biogas systems, which have now been terminated. One of these was located at a state government research facility in Western Australia while the other one was installed at a commercial breeder piggery in southern Queensland, which was used extensively for some of the early biogas research projects funded under the Australian Methane to Markets in Agriculture (AM2MA) program.

Table 3 lists the Australian Carbon Credit Units (ACCUs) issued to pig producers up to June 2018, under the Carbon Credits (Carbon Farming Initiative) (Destruction of Methane Generated from Manure in Piggeries-1.1) Methodology Determination 2013. Since the commencement of the emissions reduction fund (ERF) in 2012/13, 372,143 ACCUs have been issued to eight of the 14 registered piggery operators indicating substantial avoidance of greenhouse gas emissions (1 ACCU = 1 t CO_2-e avoided). Figure 10 provides a graphical representation of the ACCUs issued annually to the various registered entities.

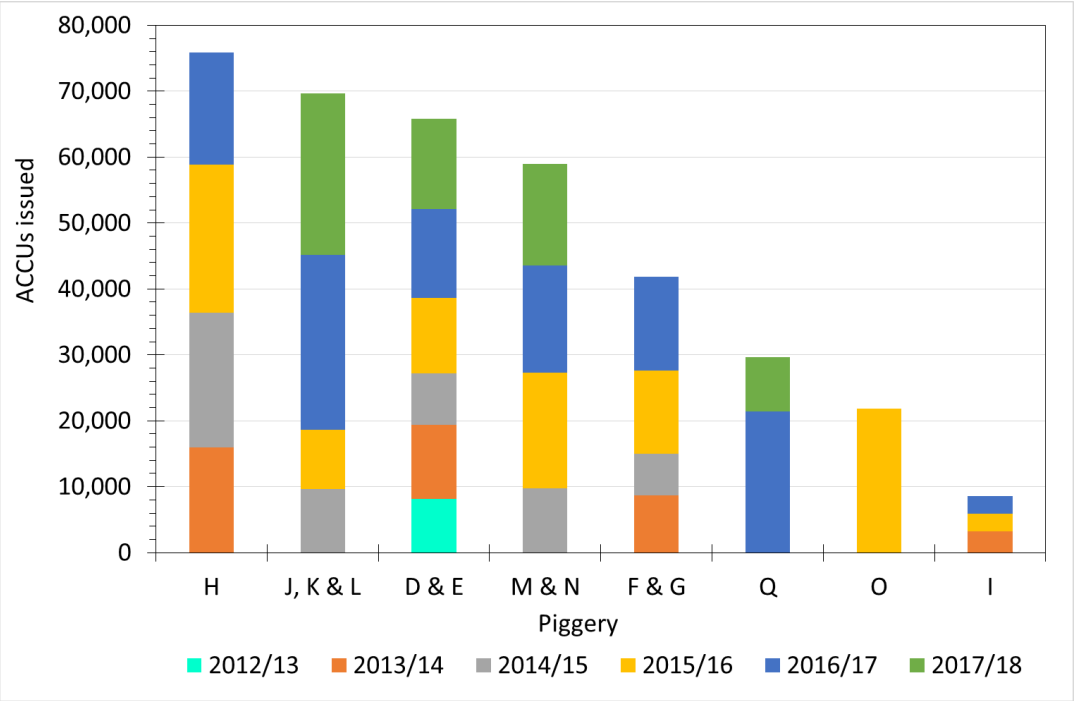

Figure 10. Australian Carbon Credit Units (ACCUs) issued under the Carbon Credits (Carbon Farming Initiative) (Destruction of Methane Generated from Manure in Piggeries-1.1) Methodology Determination 2013.

ACCUs may be sold at auctions, which have been held twice-yearly since April 2015. The average price per ACCU sold at these auctions has ranged from $10.23 to $13.95, resulting in total returns to pig producers of approximately $4 M, and providing significant financial benefits to individual producers. However, it should be noted that mandatory monitoring and auditing costs have reduced the net income from the Emissions Reduction Fund (ERF).

Table 2. Current and terminated piggery biogas system summary data.

Piggery	Locality	State	Year estab	Status	System type	Piggery type	Piggery capacity (sows SPU)	Est biogas prodn (m^3/year)	Est CH_4 prodn (m^3/year)	Biogas use	Est elec gen capacity (kWe)	Est CHP elec energy (kWh/year)	Est CHP thermal energy (MJt/year)	GHG emissions avoided (t CO_2-e/year)	ERF ACCUs issued (ACCU)
A	Windemere	Vic	1989	Operating	Mixed tank	Farrow to finish	2,000 20,000	580,500	377,325	Flare CHP	128	1,125,686	6,754,118	6,399	0
B	Bears Lagoon	Vic	2004		CAP	Grower	0 23,000	667,575	433,924	Flare	148	1,294,539	7,767,235	7,359	0
C	Grantham	Qld	2009	Terminated	PCAP	Breeder	700 1,400	54,180	35,217	Flare Boiler	12	105,064	630,384	597	0
D	Young	NSW	2012	Operating	CAP	Breeder	2,138 4,529	175,272	113,927	Flare CHP	39	339,882	2,039,293	1,932	65,830
E	Young	NSW	2012	Operating	CAP	Grower	0 20,817	805,618	523,652	Flare CHP	178	1,562,227	9,373,364	8,881	
F	Young	NSW	2012	Operating	CAP	Breeder	2,800 18,000	696,600	452,790	Flare CHP	154	1,350,824	8,104,941	7,679	41,852
G	Young	NSW	2012	Operating	CAP	Grower	1,200 12,000	464,400	301,860	Flare CHP	103	900,549	5,403,294	5,120	0
H	Corowa	NSW	2013	Operating	CAP	Farrow to finish	5,500 55,000	2,128,500	1,383,525	Flare Genset	471	4,127,516	24,765,098	23,465	75,812
I	Bungowannah	NSW	2012	Operating	CAP	Breeder	6,000 12,000	464,400	301,860	Flare	103	900,549	5,403,294	5,120	8,593
J	Yarrawalla	Vic	2013	Operating	CAP	Grower	0 15,000	580,500	377,325	Flare CHP	128	1,125,686	6,754,118	6,399	69,641
K	Yarrawalla	Vic	2015	Operating	CAP	Breeder	2,000 6,000	232,200	150,930	Flare CHP	51	450,275	2,701,647	2,560	
L	Yarrawalla	Vic	2016	Operating	CAP	Grower	0 5,000	193,500	125,775	Flare CHP	43	375,229	2,251,373	2,133	
M	Lundavra	Qld	2014	Operating	Hybrid CAP	Breeder	**0** **15,000**	391,838	254,694	Flare CHP	87	759,838	4,559,029	4,320	58,933
N	Lundavra	Qld	2013	Operating	Hybrid CAP	Grower	**0** **32,000**	609,525	396,191	Flare CHP	135	1,181,971	7,091,823	6,719	

Piggery	Locality	State	Year estab	Status	System type	Piggery type	Piggery capacity (sows SPU)	Est biogas prodn (m^3/year)	Est CH_4 prodn (m^3/year)	Biogas use	Est elec gen capacity (kWe)	Est CHP elec energy (kWh/year)	Est CHP thermal energy (MJt/year)	GHG emissions avoided (t CO_2-e/year)	ERF ACCUs issued (ACCU)
O	Warra	Qld	2014	Operating	Hybrid CAP	Grower	0 60,000	1,741,500	1,131,975	Flare CHP	385	3,377,059	20,262,353	19,198	21,790
P	Biloela	Qld	2015	Operating	Mixed tank	Farrow to finish	2,000 20,000	580,500	377,325	Flare CHP	128	1,125,686	6,754,118	6,399	0
Q	Ellangowan	Qld	2015	Operating	Hybrid CAP	Grower	0 42,000	1,625,400	1,056,510	Flare CHP	360	3,151,922	18,911,529	17,918	29,692
R	Medina	WA	2009	Terminated	CAP	Research station	78 780	22,640	14,716	Flare	5	43,902	263,411	250	0
S	Netherby	SA			CAP	Educate facility	8 35	1,016	660	Flare	0	1,970	11,820	11	0
T	West Pinjarra	WA	2018	Operating	CAP	Breeder	2,500 6,400	185,760	120,744	Flare	41	360,220	2,161,318	2,048	0
U	Brinkley	SA	2015	Operating	CAP	Grower	2,440 26,503	768,690	500,049	Flare	195	1,711,280	8,800,871	7,124	0
V	Trafalgar	Vic	2018	Operating	CAP	Farrow to finish	550 6,100	193,500	125,775		43	375,229	2,251,373	2,133	0
W	Boscabel	WA	2018	Commission-ing	Mixed tank	Grower	0 28,000	1,083,600	704,340	Flare Genset	240	2,101,281	12,607,686	11,946	0

CAP – covered anaerobic pond; PCAP – partially covered anaerobic pond; Hybrid CAP – mixed, heated, in-ground covered anaerobic pond;
Mixed tank – mixed tank (above-ground) engineered digester; kWe – kilowatt electric; MJt – Megajoule thermal; CHP – combined heat and power system;
t CO_2-e – tonnes of carbon dioxide equivalents; ACCU – Australian carbon credit unit.

Table 3. Australian Carbon Credit Units (ACCUs) issued to June 2018, under the Carbon Credits (Carbon Farming Initiative) (Destruction of Methane Generated from Manure in Piggeries-1.1) Methodology Determination 2013.

http://www.cleanenergyregulator.gov.au/ERF/project-and-contracts-registers/project-register

Year	Rivalea Corowa	Kia Ora	Blantyre	Enviropower	Wonga Templemore	Cefn	Tong Park	Rivalea Bungo	ACCUs/year	Total ACCUs issued
Piggery:	H*	J, K & L	D & E	M & N	F & G	Q	O	I		
2012/13	0	0	8,169	0	0	0	0	0	8,169	8,169
2013/14	15,989	0	11,176	0	8,679	0	0	3,224	39,068	47,237
2014/15	20,441	9,590	7,885	9,761	6,298	0	0	0	53,975	101,212
2015/16	22,372	9,000	11,416	17,516	12,610	0	21,790	2,728	97,432	198,644
2016/17	17,010	26,521	13,508	16,311	14,265	21,395	0	2,641	111,651	310,295
2017/18	0	24,530	13,676	15,345	0	8,297	0	0	61,848	372,143
Totals:	75,812	69,641	65,830	58,933	41,852	29,692	21,790	8,593	372,143	

*Refer Figure 10 for corresponding bar graph representation

Publications

As described in Section 2 of this report, the following publications were produced.

'Talking Topic' extension booklets

The following 'Talking Topic' extension booklets were published on the Pork CRC website:
http://porkcrc.com.au/research/program-4/bio-energy-support-program/

- Talking Topic 1 – Collecting the biogas benefits of pig manure – provides a good introduction/overview.
- Talking Topic 2 – Biogas Safety – the essentials – talks about compliance with biogas safety.
- Talking Topic 3 – Covered lagoons – looks at designing a covered lagoon for biogas.
- Talking Topic 4 – Cleaning piggery biogas – the why and how of cleaning biogas before using it.

Australian Pork Newspaper 'It's a gas' articles

The following 'It's a gas' articles were published in the Australian Pork Newspaper and may be accessed at the following website:
http://porknews.com.au/index.php/past-editions/

- December 2016: Cleaning Piggery Biogas
- March 2017 Co-digestion – waste not, want not
- April 2017: Is biogas a viable option for smaller piggeries?
- June 2017: Anaerobic digestion – keeping bugs in the system
- September 2017: Taking biogas system monitoring for granted
- November 2017: Avoiding the big biogas bang
- December 2017: Pork CRC boosts biogas systems across Australia
- March 2018: Biogas survey time

Video - 'Biogas Benefits for your piggery'

This video was published on YouTube on 19 August, 2016 with a link hosted on the Pork CRC website. Up until June 2018, it had received 637 views.
https://www.youtube.com/watch?v=4BASwiMclJE

Peer-reviewed journal papers

The following peer-reviewed journal papers were published based on research carried out under Pork CRC Program 4 and related APL funded research projects:

- Skerman, A.G., Heubeck, S., Batstone, D.J. and Tait, S. (2018) On-farm trials of practical options for hydrogen sulphide removal from piggery biogas, Process Safety and Environmental Protection, 117, 675–683. https://doi.org/10.1016/j.psep.2018.06.014.

- Skerman, A.G., Willis, S., Batstone, D.J., Yap S.D. and Tait S. (2017) Effect of feed wastage on piggery effluent characteristics. Animal Production Science 57(12) 2481-2481. APSA abstract. https://doi.org/10.1071/ANv57n12Ab024.
- Skerman, A.G., Heubeck, S., Batstone, D.J. and Tait, S. (2017) Low-cost filter media for removal of hydrogen sulphide from piggery biogas, Process Safety and Environmental Protection, 105, 117-126. http://dx.doi.org/10.1016/j.psep.2016.11.001.
- Skerman, A.G., Willis, S., McGahan, E.J., Borgognone, M.G., and Batstone, D.J. (2016) Validation of PigBal model predictions for pig manure production, Animal Production Science, 56, 1081–1090. http://dx.doi.org/10.1071/AN14702.
- Skerman, A.G., Heubeck, S., Batstone, D.J. and Tait, S. (2015) Alternative low-cost solid media for scrubbing of hydrogen sulphide from piggery biogas, Animal Production Science, 2015, 55, 1461, CSIRO publishing. APSA abstract. http://dx.doi.org/10.1071/ANv55n12Ab051.

Conference Papers

The following peer-reviewed conference papers were published based on research carried out under Pork CRC Program 4 funded research projects:

- Skerman, A.G. and Tait, S. (2016) Update on biogas use at Australian piggeries and recent research and development, Bioenergy Australia 2016 Conference – Regional growth in a sustainable biofuture, Brisbane Qld, 14 – 16 Nov 2016.
- Skerman, A.G., Heubeck, S., Tait, S. (2014a) Poster presentation: Alternative biogas purification media for farm installations, International Conference: Progress in Biogas III – Biogas production from agricultural biomass and organic residues, Stuttgart, Germany, 10-11 September 2014.
- Skerman, A.G., Heubeck, S., Tait, S. (2014b) Developing low cost options for on-farm biogas cleaning at piggeries, Bioenergy Australia 2014 Conference – Developing the economy through sustainable biomass, Glenelg, Adelaide, SA, 1-3 Dec 2014.

Industry / educational talks

In August 2016, Mr Alan Skerman prepared a 20 minute talk and PowerPoint slides providing a general overview of the potential for Australian pork producers to establish on-farm biogas collection, treatment and use systems, specifically for the purpose of offsetting on-farm energy costs. These talks were presented remotely at a series of workshops organised by Mr Nick Bullock of 'The Energy Guys' (Port Macquarie, NSW), under APL Project 2012/2407 – 'Establishing energy usage on Australian piggeries to enable implementation of energy reduction strategies'. The workshops were held in Young (NSW), Echuca (Vic) and Murray Bridge (South Australia). Unfortunately, workshops planned for Mandurrah (WA) and Toowoomba (Qld) were cancelled due to low attendee registration numbers. Mr Bullock indicated a strong interest in the biogas presentations and Mr Skerman answered numerous questions from the producers and industry stakeholders who attended the workshops.

A talk highlighting Bioenergy Support Program progress was prepared and presented at the APL Researchers' Forum, held in Canberra during February 2017.

In March 2018, Mr Alan Skerman prepared and delivered a guest lecture to final year vet students at the University of Queensland (Gatton), providing an overview of intensive livestock environmental management, including a segment on anaerobic effluent treatment and biogas production and use in Australian piggeries.

From 2016 to 2018, Dr Stephan Tait prepared and presented talks on piggery effluent management at the annual 'Science and Practice of Pig Production' course held at the University of Adelaide's Roseworthy Campus in South Australia. This course is attended by pork industry employees, and by undergraduate and post-graduate students undertaking industry research projects.

Laboratory analysis capability

Automated Methane Potential Test System

Figure 11 is an example of the data outputs from the AMPTSII system at the DAF Toowoomba laboratory. This figure shows the cumulative methane volumes produced over time from four piggery effluent samples containing various levels of simulated feed wastage. These results were used in APL Project 2015-010 which investigated the effect of feed wastage on biochemical methane potential and other effluent characteristics.

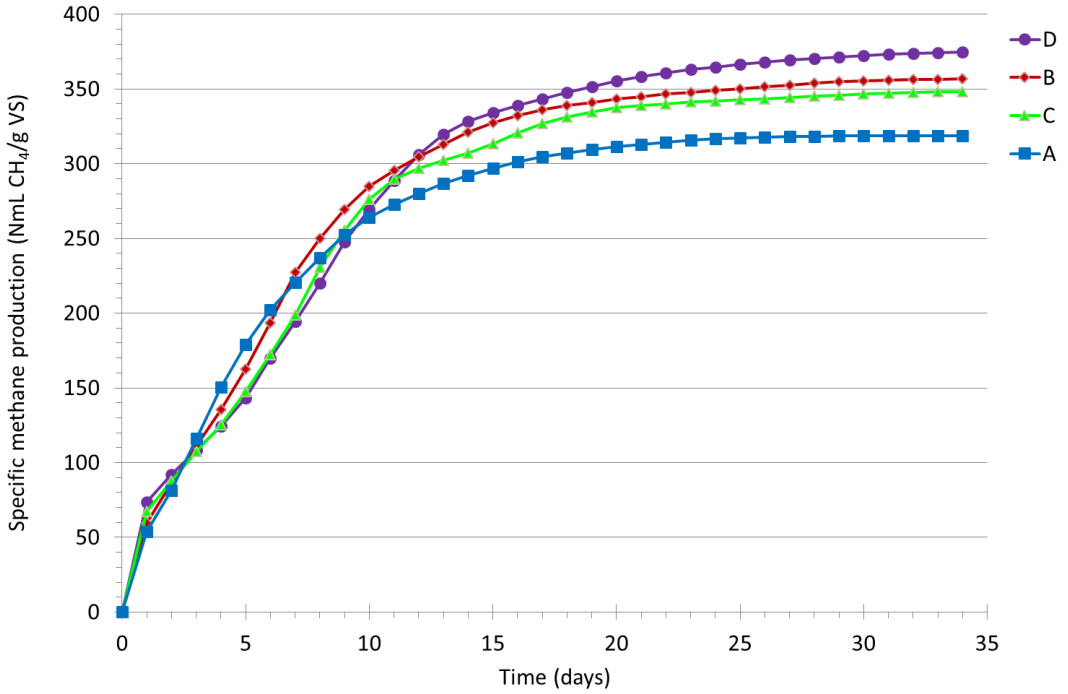

Figure 11. Biochemical methane potential curves for four piggery effluent samples (A to D) containing increasing levels of simulated feed wastage (0% to 15%) produced for APL Project 2015/010 using the AMPTS II system in the DAF Toowoomba laboratory.

Laboratory chemisorption testing apparatus

Examples of the output from the laboratory chemisorption test rig are provided in Figures 12 and 13. Figure 11 shows the H_2S breakthrough curve for a commercial Granulated Activated Carbon (GAC) medium used to remove H_2S from the biogas stream produced at a central Queensland piggery. Figure 12 compares the S sorption performance of various samples of granulated activated carbon.

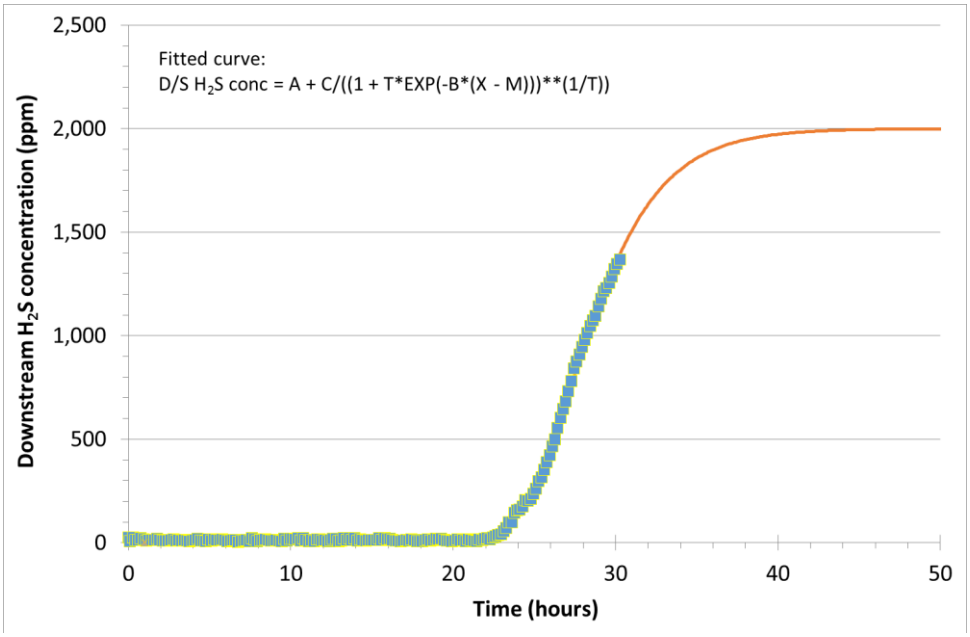

Figure 12. Breakthrough curve produced using the chemisorption testing rig at the DAF Toowoomba laboratory for the granulated activated carbon (GAC) media used to treat biogas at a central Queensland piggery.

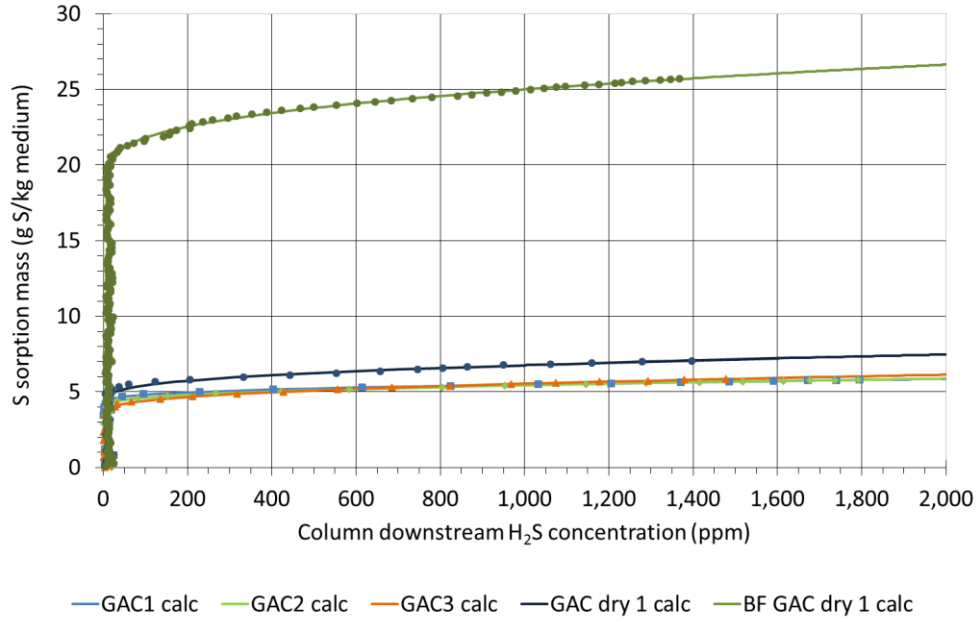

Figure 13. Comparison of S sorption capacities of various granulated activated carbon (GAC) media determined using the chemisorption testing rig at the DAF Toowoomba laboratory.

Biogas survey results

Survey responses were received from 91 producers, representing approximately 6% of producers nationally. NSW producers had the highest response rate compared to the other states. 76% of respondents had farrow to finish piggeries.

69% of the respondents operated some combination of conventional flushed, pull plug or static pit sheds, which could potentially supply liquid effluent to a CAP. The remaining 31% of respondents were operating a combination of deep litter, outdoor rotational or outdoor (fixed or non-rotational) piggeries. This latter group of piggeries would not be suitable for operating a conventional CAP and there are currently no anaerobic digestion technologies proven to be economically viable for deep litter or solid piggery waste in Australia.

Survey responses were received for a wide range of piggery capacities, from 14 SPU to 90,000 SPU. 76% of the 74 responses were received for relatively small piggeries, having capacities up to 5000 SPU, to some extent highlighting an on-going interest from smaller producers in biogas. Unfortunately, piggeries having capacities in this range have previously been considered marginal in terms of their economic viability for biogas system establishment.

59% of the respondents indicated that they were aware of the progressive adoption of on-farm biogas systems by Australian pig producers over the past decade. The most common information sources were Australian Pork Newspaper articles, industry workshops and word-of-mouth.

Seven of the 74 respondents indicated that they were operating existing on-farm biogas systems while 5 respondents were planning to install a system. A further 31 producers indicated that they were not planning to install any on-farm biogas systems, while a similar number indicated that they were undecided.

The most common reasons given for not installing an on-farm biogas system were that the piggery was either too small or an outdoor or deep litter operation, or that biogas systems were too costly.

Two producers indicated that they were planning to install biogas systems within two years, while two additional producers indicated that they were planning to install biogas systems within two to five years. Most notably, these responses were received in the midst of an industry downturn. One further producer indicated that the decision to install a biogas system would depend on system costs / returns and industry profitability.

The capacities of the six piggeries with existing biogas systems ranged from 2,000 to 90,000 SPU. All of these systems were CAPs, with volumetric capacities from 4 ML to 48 ML.

Of the four respondents that answered the biogas treatment question, all employed biological scrubbers to remove hydrogen sulphide (H_2S), and chillers to remove moisture from the biogas. Two respondents also used iron-oxide pellets, presumably following treatment of the biogas in a biological scrubber.

All of the six existing biogas systems burn some biogas in a flare. Three of these systems are used to run combined heat and power (CHP) engines, while two

systems supply engines driving electrical generators, and one system supplies a boiler.

Annual biogas production ranges from 175,000 to 1,900,000 m^3/year. The electricity generation capacity ranges from 50 to 500 kWe. One of the respondents also exports 788,568 kWh/year of electricity to the supply grid.

The respondents with existing biogas systems identified recovering energy, reducing or eliminating power costs, reducing odour emissions, generating carbon credits, and 'saving the world' (greenhouse gas reduction) as the greatest benefits resulting from their systems.

The greatest issues and concerns that they identified were minimal biogas production, red tape, sludge management in their covered lagoons, lack of industry support personnel, and expensive generator maintenance.

The survey respondents indicated that the following information or support would assist in deciding whether or not to install a biogas system:

- Costs and expected benefits.
- Site specific viability.
- Funding options and possible assistance.
- Economic viability for smaller piggeries.
- Design information and plans.
- Compatibility with solids composting.
- Pig numbers for viability and long term gains from the system.
- Availability of viable systems for smaller piggeries.
- Systems for both deep litter and conventional slurry effluent.
- Time commitment and cost of system operation and maintenance.

The respondents also provided a range of general comments regarding on-farm biogas systems. Many of these comments were consistent with the information requirements listed above.

Comprehensive details of the survey results are provided in Appendix 3, without piggery names or locations.

4. Application of Research

Benefits of biogas systems
Producers who have adopted biogas systems have reported significant financial benefits resulting from a combination of energy cost savings, additional income from the sale of surplus electricity to the grid, and returns from the sale of ACCUs and renewable energy certificates (RECs). In several cases, farm energy costs for the supply of electricity, LPG and diesel (for electricity) have been completely eliminated. Capital expenditure payback periods less than three years have been reported. However, returns from biogas systems will vary substantially depending on a range of site-specific factors. These include the type of piggery (e.g. farrow to finish, breeder, grower), local climate (heating and cooling requirements), shed design (naturally ventilated vs. climate controlled), existing energy use (e.g. the presence of an on-site feed mill), current energy tariffs, and the proximity of the piggery to grid electricity infrastructure suitable for receiving exported electricity.

Biogas system adoption
As noted in Section 3, the majority of piggeries currently benefiting from the adoption of biogas systems have capacities greater than 10,000 SPU. While approximately 60% of the national herd is housed in piggeries within this size range, it will be important to support the development and adoption of biogas systems which are technically and economically viable at smaller piggeries. Provided the recent installation of a biogas system at a 550 sow farrow to finish unit in Victoria proves to be successful, further similar-sized developments may follow, subject to improved industry profitability.

A number of producers have taken a 'hands on' approach to biogas system development. While they have utilised the knowledge of industry-funded BSP personnel and have employed contractors and/or consultants to carry out some of the more specialised system design and installation tasks, they have personally managed the overall project implementation, making use of on-farm labour resources wherever possible. This approach has proved to be successful for some of producers; however, a major investment of time and practical business and entrepreneurial skills is typically required.

Other producers have opted to employ professional service providers to coordinate the entire planning, design, construction and commissioning of the biogas project. These producers generally prefer to concentrate on their core business (producing pigs) and have insufficient time (and money) available for managing development projects, securing the required statutory approvals and gaining specialised technical knowledge regarding biogas systems.

Biogas system types
Another issue, which must be carefully considered by a producer before embarking on a biogas system project, is the type of system to be installed. Most of the earlier biogas systems installed at Australian piggeries employed unheated, unstirred CAPs, which generally entail the lowest capital investment. Currently, there are four hybrid CAPs (heated, stirred, in-ground CAPs) and three above-ground, engineered vessel digesters. Hybrid CAPs and engineered digesters require higher levels of capital investment and there is currently insufficient data available to validate that they would, on-average, have superior performance to lower cost CAP installations.

Industry service providers
Industry experience over the past decade suggests that there may be a market failure in terms of the capability of single companies to provide the whole range of services required for planning, design, construction and commissioning of a piggery biogas project (i.e. a one-stop-shop for turn-key style project delivery). In some cases, companies which specialise in supporting large-scale biogas developments for other industries (e.g. municipal waste treatment, food processing, landfill or abattoirs) may also not have sufficient knowledge or experience with piggery operations and typical piggery waste treatment methods. It is also typically difficult to estimate anticipated biogas yield for a particular piggery effluent, to design a biogas project, resulting in inappropriate designs.

Co-digestion
Recent enquiries have highlighted producer interest in maximising returns from biogas systems. More specifically, producers have requested support with co-digestion of piggery effluent along with various off-farm waste or by-products from nearby industries, e.g. whey from dairy processing, paunch from abattoirs and a range of food waste products. In many cases, the additional co-substrates have a higher methane potential than the piggery effluent, resulting in higher biogas production and more efficient use of the on-farm anaerobic digestion infrastructure. Furthermore, the diversion of otherwise waste materials away from landfill may attract the payment of gate or tipping fees to the pig producer, resulting in an additional income stream and improved environmental outcomes. Further information regarding co-digestion is provided in the Final Reports prepared for Pork CRC Projects 4C-109 (Tait et. al., 2017) and 4C-113 (Tait et al., 2018), available on the Pork CRC website. The former report includes a comprehensive evaluation and guidance on various waste products typically co-digested with pig manure.

There are some additional costs involved in setting up and operating co-digestion facilities, including the provision of facilities for receiving and stockpiling the co-substrates, and in some cases, for pre-mixing, homogenising and/or pre-treating the combined digester influent stream. The specific requirements will vary depending on the type of co-substrate (e.g. liquid slurry or solid materials). Again, see the Final Report for Pork CRC Projects 4C-109 (Tait et. al., 2017).

Other potential issues which should be considered with co-digestion, include potential inconsistencies of the co-substrate supply and composition, odour control during co-substrate delivery, storage and handling, and satisfying biosecurity protocols to protect the health of the pigs accommodated on the farm. Again, see the Final Report for Pork CRC Projects 4C-109 (Tait et. al., 2017).

Providing co-digestion systems are carefully planned, designed and operated, there is considerable potential to make more effective use of the on-farm AD infrastructure, turning otherwise waste products into additional valuable energy, while improving environmental outcomes.

Biogas upgrading
Even without adopting co-digestion, some piggeries are currently producing excess biogas, which is being flared in lieu of any other economically viable uses. This has resulted in considerable interest in biogas upgrading to bio-methane, most likely in compressed (CNG) form. While this gas could potentially be used for on-

farm transport or farming applications, (e.g. pig transport trucks, tractors, farm vehicles) it may have significant value for off-farm sale as a portable fuel source. The viability of biogas upgrading will be investigated more thoroughly in a proposed APL research project commencing later in 2018.

Spot price electricity sales
Other options for maximising returns from biogas systems include employing sophisticated monitoring technology to sell electricity, generated on-farm, onto the wholesale electricity market, when it is most profitable to do so. This option would involve maximising returns by managing biogas generator output based on electricity spot prices, which vary widely on a daily basis.

Regulatory standards
Inconsistencies between state gas safety legislation and standards also result in difficulties for service providers working across multiple states. Gas train components and operating systems, which comply with the legislation in a particular state, may not be acceptable in other states. This makes it difficult to develop standard or modular systems for deployment across the industry, nationally. The *Code of Practice for on-farm biogas production and use at piggeries* (APL, 2015) has addressed this anomaly in part. However, in some states, the gas safety standards applied to relatively small-scale on-farm biogas systems operating at low pressure in rural areas, are identical to those applied to much larger-scale industrial plants storing significantly larger quantities of gas at much higher pressure, despite the disparity between the resulting risks.

This issue highlights the need to maintain constructive communications with relevant regulatory authorities and to ensure that the officers responsible for regulating piggery biogas projects are aware of the relevant risks and industry initiatives to address those risks in a practical, cost-effective manner.

Biogas safety
While some gas safety standards may appear to be onerous, it is vitally important for all piggery employees to understand the significant risks to the health and safety of humans and livestock associated with working near biogas systems. The major risks resulting from the flammability and toxic nature of the biogas must be understood and thoroughly managed. This generally requires the development of risk assessments, standard operating procedures, installation of appropriate signage, use of appropriate personal protective equipment (PPE) and providing ongoing training for workers. Regular system checks and maintenance are also important for ensuring the safety and well-being of piggery workers (Talking Topic 2 and Australian Pork Limited, 2015).

5. Conclusions

Biogas systems are currently operating at 21 piggery units across Australia, representing 15 separate businesses, with at least three additional producers currently seriously considering or planning new on-farm biogas projects. There is currently approximately 427,000 SPU housed in piggeries where the effluent is directed to a biogas system. This represents approximately 15% of the total Australian pig herd and 29% of the national herd housed in accommodation currently considered 'suitable' for biogas system adoption. The existing piggery biogas systems include 14 CAPs, 4 heated and stirred in-ground hybrid CAPs and 3 above-ground stirred-tank (engineered) digesters.

Producers who have adopted biogas systems have reported significant financial benefits resulting from a combination of energy cost savings, additional income from the sale of surplus electricity to the grid, and returns from the sale of ACCUs and renewable energy certificates (RECs). In several cases, farm energy costs for the supply of electricity, LPG and diesel (for electricity generation) have been eliminated. Capital expenditure payback periods less than three years have been reported. However, returns from biogas systems vary substantially, depending on a range of site-specific factors, including on-site energy demands.

Since the ERF program commenced in 2012/13, 372,143 ACCUs have been issued to eight of the 14 registered piggery operators. This indicates that piggery biogas projects have avoided total emissions of 372,143 t CO_2-e. Based on average ACCU prices from $10.23 to $13.95 recorded at twice-yearly auctions, the total value of these ACCUs is approximately $4 M, indicating some significant returns to individual producers.

The BSP has assisted producers, industry service providers and consultants by addressing numerous ad hoc enquiries regarding piggery biogas system planning, design, construction, commissioning and operation. Ten site-specific preliminary biogas feasibility reports were also prepared for pork producers. While only one of these piggeries has proceeded to install an on-farm biogas system, it is anticipated that other producers may proceed with biogas developments within the next few years, depending on industry profitability.

The publications produced by the BSP (4 Talking Topics, 8 APN 'It's a gas' articles, a YouTube video, 5 peer-reviewed journal papers, 3 conference papers and several industry talks) have contributed substantially to the reference/extension material and scientific literature available to support the ongoing safe and technically sound development of on-farm biogas systems.

A national biogas survey indicated that there were a substantial number of smaller producers (>40%) who were unaware of the progressive adoption of on-farm biogas systems by Australian producers. The survey respondents indicated that further information regarding the following topics would assist them in deciding whether to install a biogas system: system costs and benefits, site-specific viability (particularly for smaller piggeries), funding options, compatibility with deep litter systems and ongoing operation and maintenance costs. The greatest concerns identified by producers with existing biogas systems were depleted gas production, red tape, sludge management in CAPs, lack of industry support personnel, and expensive generator maintenance.

The majority of piggeries currently benefiting from biogas systems have capacities greater than 10,000 SPU highlighting the need to continue supporting the development and adoption of systems, which are technically and economically viable at smaller piggeries.

Other issues identified during the course of the BSP, which should be addressed in ongoing research and development projects include:

- The relative long-term economic viability of the various biogas system options (CAP vs hybrid-CAP vs engineered digester), with regard to biogas yield, capital and operating costs, and the expected life of the infrastructure.
- Apparent market failure in terms of the capability of service providers to deliver the whole range of services required for planning, designing, constructing, commissioning, and operating piggery biogas projects.
- The viability of employing co-digestion of piggery effluent with various off-farm waste or by-products supplied by nearby industries to maximise returns from biogas systems.
- Upgrading excess biogas to bio-methane, most likely in compressed (CNG) form, for on-farm transport or farming use (e.g. pig transport trucks, tractors, farm vehicles), or export off-farm for more profitable uses.
- Employing sophisticated monitoring technology to sell electricity, generated on-farm, through the wholesale electricity market, to maximise returns by managing biogas generator output, based on electricity spot prices.
- Inconsistencies between state gas safety legislation and standards creating difficulties for developing standard or modular systems for deployment across the industry, nationally.
- Onerous gas safety standards and legislation which do not realistically reflect the risks associated with operating relatively small-scale, on-farm biogas systems, at low pressure in rural areas.
- The regulatory status of digestate with regard to land application as a bio-fertiliser.
- The vital importance for all piggery employees to understand the significant risks to the health and safety of humans and livestock associated with biogas systems. These risks must be addressed by developing risk assessments and standard operating procedures, installing appropriate signage, using suitable personal protective equipment (PPE), ensuring that workers receive adequate ongoing training, and by carrying out regular system checks and maintenance.

6. Limitations/Risks

The following factors are potential risks/limitations to further uptake of biogas systems by the Australian pork industry:

- **Industry profitability:**
  Further biogas system development is likely to be curtailed, particularly at smaller piggeries, until the profitability of the industry improves.
- **Compliance costs:**
  Compliance costs have resulted in the termination of one piggery biogas project in Queensland where the *Petroleum and Gas (Production and Safety) Regulation 2004 Schedule 9, Part 8* prescribes an annual safety and health fee of $4,429 per site. This is a significant disincentive for the installation of small-scale, on-farm biogas systems. Other compliance costs include costs associated with engaging suitably qualified gas fitters to carry out system servicing and maintenance in rural areas.
- **Inconsistent and onerous regulatory standards:**
  Issues regarding gas safety standards were discussed in the previous section. Another regulatory issue facing Western Australian producers is the status of digestate (produced by anaerobic digestion of piggery effluent) which is not permitted to be directly applied to land, despite being widely recognised as a highly valuable bio-fertiliser (Lukehurst *et al.*, 2010).
- **Service provider market failure:**
  There is an apparent scarcity of experienced and competent service providers, with sufficient knowledge of the industry, to successfully provide the whole range of services required for planning, designing, constructing and commissioning a piggery biogas project. Continuity of service has also been an issue, as companies appear to enter and exit the industry at regular intervals.
- **Availability of small-scale biogas infrastructure:**
  There is a need to develop and promote the adoption of biogas systems which are robust, simple to operate, cost effective and suitable for deployment at relatively small-scale piggeries (< 500 sows farrow to finish or 5,000 SPU).
- **Failure to adequately address biogas safety issues:**
  A major event resulting in loss of life, significant injury or damage to property could have tragic or devastating consequences for the industry and may result in the imposition of more stringent regulatory standards and the severe curtailment of further biogas system development.

7. Recommendations

Based on the outcomes in this study, the following actions are recommended:

- Investigate options for funding the provision of ongoing, independent technical support to assist producers with evaluating the site-specific feasibility of biogas projects, and to assist with the detailed planning, design, construction, commissioning and operation of on-farm biogas systems.
- Continue investigating options for maximising returns from biogas systems, including: (1) co-digesting piggery effluent with various off-farm waste or by-products supplied by nearby industries, (2) upgrading excess biogas to bio-methane, for on-farm transport or farming use, or export off-farm as CNG, and (3) employing sophisticated electricity spot price monitoring technology to control on-farm generator operation and the sale of electricity through the wholesale market
- Continue communicating with regulatory agencies to encourage the adoption of more consistent standards across Australian states which realistically reflect the risks associated with operating relatively small-scale, on-farm biogas systems, at low pressure in rural areas.
- Continue promoting the vital importance for workers to understand the significant health and safety risks associated with biogas systems and how these risks can be safely managed.

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Appendix 1

Biogas equipment suppliers and service providers

Biogas equipment suppliers and service providers

Note: The following list of businesses has been compiled as a service to Australian pig producers interested in developing, operating or maintaining on-farm biogas systems. It is not intended to be an exhaustive listing of all businesses that supply equipment or services to the biogas industry. The majority of businesses included in this listing have proactively requested that their details be made available to prospective customers in the pork industry. Consequently, inclusion in this listing does not imply any warranty or recommendation with regard to the quality of the products or services provided by these businesses. Furthermore, in compiling this listing, the businesses are not listed in any particular order and the Pork CRC is not endorsing any individual business or product over any other business providing similar products or services. While this listing provides some initial contacts, it is recommended that producers make their own enquiries before selecting businesses providing particular products or services.

Shepelec Instrumentation

Henk Büchner

Technical Manager

Shepelec Instrumentation

Phone: (03) 5831 8181

Fax: (03) 5831 3540

Email: sales@shepelecinstrumentation.com

Website: www.shepelecinstrumentation.com

Biogas metering, Sage and other brands

Biogas flare temperature and flowrate monitoring.

Thermo Fisher Scientific

Tim Brewer, Sales Specialist

Environmental Assessment Technologies

Thermo Fisher Scientific

Unit 2, 5 Ross Street | Newstead, QLD 4006

Mobile: 0403 222 557 | Customer Service: 1300 735 295

tim.c.brewer@thermofisher.com

www.thermofisher.com.au

Geotech gas analysers, GE flowmeters.

ALS Group Qld

Scott Miller

Business Development -Australasia

Units 3 & 4, 32 Premier Circuit,

WARANA, QLD. 4575

ALS GROUP QLD

T +61 7 5413 4343

F +61 7 5413 4333

E info@alsgroupqld.com.au

http://alsgroupqld.com.au/

Storage tanks

Envirofix Erosion Control Pty Limited

Richard Hurley

Envirofix Erosion Control Pty Limited

PO Box 2177

Carrum Downs Vic 3201

Phone +61 3 9773 2049

info@envirofix.com.au

www.envirofix.com.au

Biogas flares, blowers, flow meters.

East Coast Diesel & Gas

Engineering Consultants & Services - Currumbin Waters, QLD

Alex Pannekoek - Managing Director

8 Boom Ct, Currumbin Waters QLD 4223

Phone: (07) 5521 0304

Mob: 0488 048 662

Email: alexpannekoek@bigpond.com

Biogas engine retrofits and troubleshooting relating to biogas engines.

Bulk iron-oxide pellets (cg5) imported from China for removing H_2S from biogas .

Evo Industries Australia

Travis McNeill

General Manager

Phone: 1300 85 99 33

After Hours: 0419 136 772

Address: 18 Hasp Street

Seventeen Mile Rocks QLD 4073

Email: info@evoheat.com.au

Website: http://www.evoet.com.au/contact-us/

2G Biogas CHP systems, GM/Efficiency & Powergen Specialist at Evo Energy Technologies

Evo Industries supplies a range of heat pump equipment to the market. Evo's product range is designed to lower energy usage and running costs of various areas such as space heating/cooling, water heating and chilling and applications which use hot or cold liquids in any process.

Energy 360 Pty Ltd

Samantha LAMOND | Energy 360 Pty Ltd

Chief Financial Officer

2/2 Access Way CARRUM DOWNS, VIC.3201

Ph: +613 9770 8545 | Fax: +613 9770 8546 | Mobile: 0428 397 837

web: www.energy-360.com.au

email: samantha.lamond@energy-360.com.au

Energy 360 Pty Ltd has been established by the key stakeholders of ABM Combustion, Australia's most experienced and respected biogas handling equipment engineering firm. Energy360 has built upon ABM Combustion's experience in biogas systems to bring our biogas handling expertise into a formal partnership with a leading German biogas company - Oekobit - to offer turn-key biogas systems to the Austrlain market. Energy360 will take responsibility and Project Manage the system design and implementation to provide sites which have an organic waste stream, a competitively priced biogas solution. Energy 360's turn-key biogas systems aim to maximise the amount of biogas obtainable from the current organic waste stream. We work with our clients to make minimal upstream (plant located) modifications. This reduces the upfront project cost, whilst delivering valuable renewable energy savings.

Total Lining Systems

Dax Knight

Total Lining Systems

Address: 14 Waine St Freshwater NSW 2096

T. (02) 9938 3858

F. (02) 8916 6173

M. 04 28 135 139

Email: enquiries@totalliningsystems.com.au

www.totalliningsystems.com.au

Total Lining Systems (TLS) specialises in the design, supply and installation of engineered geosynthetic systems.

Waterlogic Environmental Systems

Colin Jones

Mob: 0425 326 916

Warehouse: Shed1, 344 Annangrove rd, Rouse Hill, 2155.

Enquiries@waterlogic.com.au

Postal Address: 141 Hanckel Road, OAKVILLE NSW 2765, Australia

Street Address: NGINA, 344 Annangrove Road, ROUSE HILL NSW 2155, Australia

Phone: (02) 9627 3861

Email: colin@waterlogic.com.au; Website: www.waterlogic.com.au

Waterlogic is an experienced and well-established company, in the plastic geomembrane industry. With extensive experience in the civil, agricultural and mining sectors, Waterlogic can offer a wide range of products, delivering dynamic and practical solutions to suit all small and large scale projects.

Liner applications Include:

- Environmental Ground water protection
- Lining of dams and ornamental Lakes
- Floating covers
- Biogas Covers
- Evaporation ponds and canals
- Sewage ponds
- Water storage
- Reservoir liners
- Heap leach pads
- Damp proof membranes
- Agricultural sheeting and covers

AMOCO Group Chengdu Company

Address: B-1403. Huaxi Building, No.5 Linyin Street. Chengdu, China P.C.:610041

TEL:(86-28)85431144 Ext. 120

FAX:(86-28)85436644

Mobile: +86 135 4104 2268

Email: camila@amoco.com.cn

Skype: jincai8881

Http://www.amoco.com.cn

Camila, Marketing Director

The main function and parameter our membrane biogas holder:

1. Capacity: Volume from 10-20000 cubic meter.
2. Stable pressure: We do stable pressure adjustment by auto-control system, in general it is 3000Pa, or you can choose another data.
3. Another additional device can do help: Such as, over-pressure protection, the display of capacity,pressure and temperature, dewatering system, observation window, etc.
4. The other function can be customized according to customer demand.

Bio-Gen Solutions Pty. Ltd.

Locked Bag 5010

Caloundra DC QLD 4551

07 5413 9240

info@bio-gensolutions.com.au

http://www.bio-gensolutions.com.au/index.php

BIO-GEN SOLUTIONS

Bio-Gen Solutions supply and install modular bolted storage tanks, bioenergy digesters, odourless storage covers and mixing agitators.

We offer a variety of services including tank maintenance, repairs, insulation and cleaning. We can design and engineer water management solutions to meet the requirements of a wide range of applications.

Finnbiogas

Jason Hawley B.E(Mech)

Engineering Director

Phone: +61 407 823 161 Email: jasonh@finnbiogas.com

Skype: Jason_g_hawley Web: www.finnbiogas.com

I run a small Brisbane-based engineering consulting company that specialises in the design, construction management, commissioning and rectification of biogas plants throughout Australia and South East Asia. I've worked previously for a Brisbane-based biogas company, but have since gone out on my own on a consulting basis, and am working on projects in Costa Rica, the Philippines and China. We work across a range of different technologies (tanks, lagoons, hybrid systems), and aim to provide smart sustainable solutions that meet the true needs of our clients. I personally am a Chartered Professional Engineer (CPEng), and Registered Professional Engineer of QLD (RPEQ).

Cipatex

William Rogerio Nicolau

Exports Manager

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Fone +55 (15) 3288-4330

Cel: +55 (15) 99132-2143

Fax +55 (15) 3284-9056

www.cipatex.com.br

skype: rogeriofacilis

I have developed a partner in Australia who has a deep knowledge about waterproofing systems and also about the materials we commercialize. In fact, one of his associates is located in Brisbane and may help us a lot in developing this relationship with you at UQ and somehow contribute to your project. They are copied in this e-mail. The owner of SGS is Mr. Wayne Alexander and Ms. Zehra Kaya is his team member in Brisbane. As I have introduced before we have a reasonable knowledge in biodigestors and Cipatex is commited to employ all the efforts necessary to have a solid presence in Australia. We look forward to partnering with you and have you consider us as one of your certified suppliers of geomembranes for your projects.

Southern Geosynthetics Supplies Pty Ltd (ABN: 31 766 785 395).

QLD contact:

Zehra Kaya BSc Engineering (Textiles), Master of International Business

Business Development Manager

Southern Geosynthetics Supplies

Mobile: +61 409 953 136

Email: zehra@geosynthetics.com.au

Internet: www.geosynthetics.com.au

VIC and other states contact:

Wayne Alexander

Mobile: 0419 478 238

Email: Wayne Alexander wayne@geosynthetics.com.au

Local geomembrane suppliers with regards to lining and capping of biodigesters.

Quantum Power Limited

Richard Brimblecombe

Level 1, 9 Gardner Close

Milton Qld 4064

Phone: 07 3721 7500

Email: info@quantumpower.com.au

Internet: http://www.quantumpower.com.au/

We're the leaders in anaerobic digestion systems and biogas fuelled power station installations, offering complete, end-to-end service.We've completed many successful installations in the pig, poultry and food processing industries. We offer two different project delivery models, depending on what works best for your business:

Build, own and operate system – We build, fund, own, operate and maintain the biogas to energy system and sell electricity to you at a discount to your grid supplied cost under a long-term power purchase agreement.

Turnkey solution – We build the entire biogas to energy system including the digester and generator/boiler and you purchase and operate the completed system. We also provide maintenance services to our turnkey clients.

RCM Digesters

P.O. Box 4716

Berkeley, CA 94704

PH: 510-834-4568

www.rcmdigesters.com

contact@rcmdigesters.com

Analysis, design, construction and operation of a range of biogas systems.

BioBowser

Ron Lakin

89 Pinjarra Road

Pinjarra Hills

Brisbane QLD 4069

info@biobowser.com.au

+61 422 872 586

An exciting Australian innovation, BioBowser® offers a range of packaged biogas plants and modules designed to be installed quickly and integrate with existing waste handling procedures at minimal cost with minimal disruption. BioBowser® can treat between 50 kgs and 20,000 kgs (feed-in volume at max 8% Total Solids) of organic waste per day. Suitable waste streams include animal manures, effluent, abattoir residues or food waste from processing facilities such as kitchens, canteens, holiday resorts, mining camps and retirement villages.

UTILITAS

Fiona Waterhouse, CEO

Suite 12, London Offices, 30 Florence Street

Teneriffe I Queensland 4005 I Australia

Phone: +61 7 3105 2819

Website: www.utilitas.com.au

Brisbane based Utilitas Pty Ltd is a biogas energy developer. We scope, design and deliver process plants for solid organic wastes and wastewater using “European Style” tank based digester systems, ‘tier1’ equipment and experienced local contractors.

We do the process engineering for each of the projects this includes using our internal knowledge to design the biogas plant. We design, specify and integrate both solid and liquid waste biogas treatment equipment into our plants (traditionally most biogas companies specialise in either liquid or solid).

Compressed Air and Gas Systems Specialist

AJ Stack Solutions P/L

John DEWAR - Compressed Air and Gas Systems Specialist

7 Arnold Street, Cheltenham. VIC Australia 3192

Office: +61 3 8820 3119 Mobile: +61 4 0234 6284 Email: compressors@ajss.com.au,

Website: http://ajss.com.au/

A J Stack Solutions P/L represent Airpack NL which has recently released a modular package system for treatment of biogas to clean the gas and convert the other waste streams into usable products. This innovative product reduces the service requirements compared with other cleaning processes (such as iron oxide absorbtion). The packages can be engineered to suit any required size and gas quality.

Refer: http://www.gazpack.nl/ and http://www.gazpack.nl/nieuws/

Livestock Environmental and Planning (LEAP)

Livestock Environmental and Planning (LEAP)

Robyn Tucker, Principal Consultant

Private Bag 260 (110 Natimuk Road)

Horsham Vic 3400

M: 0419 787 137

P: 03 5381 0709

E: robyn@leap-consulting.com.au

www.leap-consulting.com.au

Intensive livestock planning permit applications typically include information about the proposed site, the development, the potential environmental impacts and how the facility will be managed to prevent these. Detailed information about effluent treatment and reuse is needed; this can include a covered anaerobic pond with or without a generator or combined heat and power or a biodigester. A comprehensive Environmental Management Plan (EMP) is also essential. Livestock Environmental and Planning staff have over 20 years' experience in preparing planning permit applications for all types of intensive livestock developments in all mainland states.

Fox Generation

Brad Fox

Principal Engineer

Mobile: 0409 365 477

Email: foxgeneration@outlook.com

Design and installation of biogas control and monitoring systems.

Gas Advisory Services

John Fleming

Mobile: 0431 533 252

Post: PO Box 31, Scarborough Qld 4020

Email: GAS@johnfleming.com.au

Projects to date include:

Safety Managment Plans, Accident Investigations, Gas Safety Training, Safety and Compliance Audits, Government Submissions, Risk Assessments including unodourisd gas, Gas Advice to Major Projects including SMS, Technical and Safety Reviews, Type B Certification (Small and special devices), Assistance with Standards and Codes of Practice, Advice on gas issues to large and small industries, Expert Witness in legal cases, Review of experimental procedures, University Lectures, Design and undertaking Emergency Exercises.

Advanced Energy Australia

Peter VanderWeyde

28 Marillana Court, Shailer Park Qld 4128

Mob: 0413 084 098

advancedenergyaustralia@gmail.com

Design and installation of biogas generators, control and monitoring systems.

Earthlee Onsite Organic Waste Reduction & Energy Solutions

Our goal is to deliver innovative services and products in the field of Onsite Waste Management for SMEs by working with global partners in the development and delivery of waste-to-energy technologies, including anaerobic digestion of organic waste and slurry.

Australian distributors of Qube small-scale and modular anaerobic pond covers and CHP systems.

Adam Odeh, Managing Director

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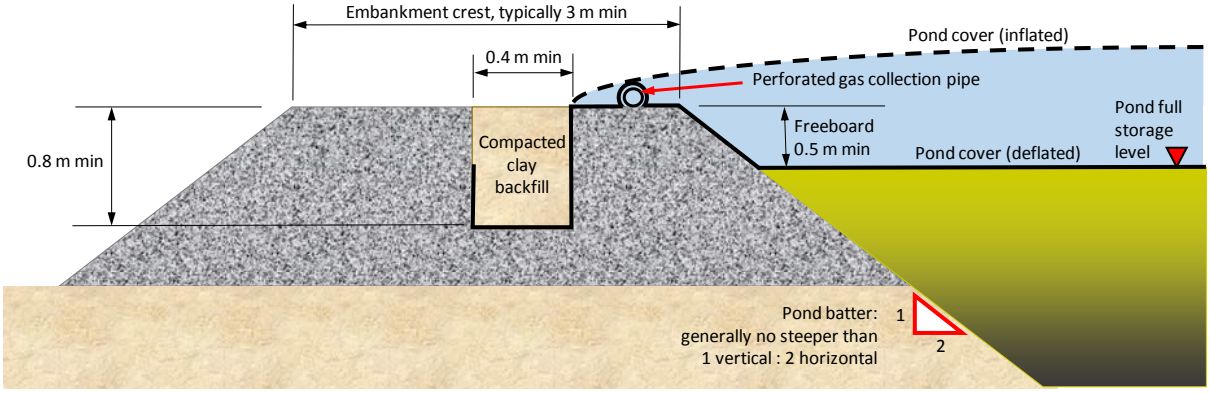
A: Suite 313, 23 Milton Parade, Malvern Vic 3144

Appendix 2
Standard drawings

Securing pond cover in perimeter anchoring trench

Schematic drawing - not to scale



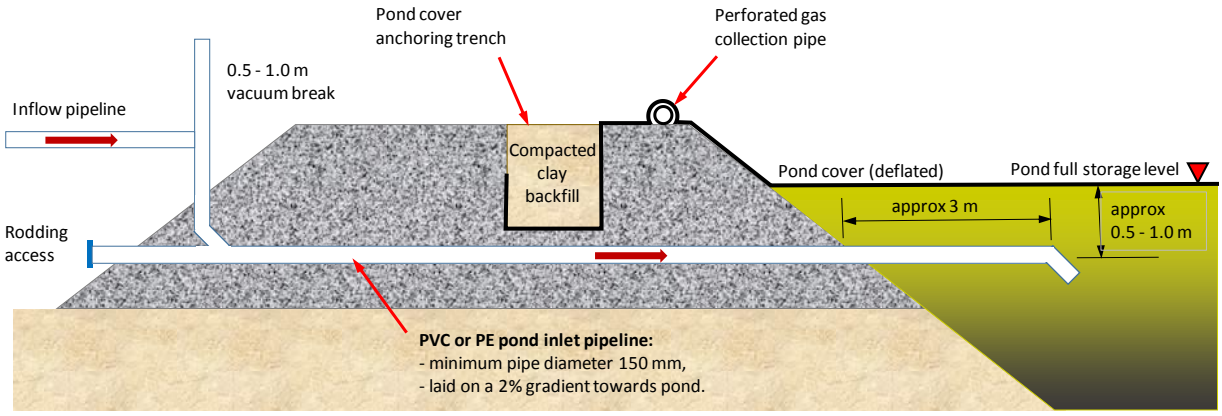
Notes:

1. Pond covers may be secured in an anchor trench excavated around the perimeter of the pond embankment crest.
2. The trench should be at least 0.4 m wide x 0.8 m deep. The cover material should extend down the inner trench wall, across the base of the trench and approximately halfway up the outer trench wall.
3. The trench should be backfilled with clay, in layers not exceeding 200 mm in thickness. Each layer should be thoroughly compacted to form a gas-tight seal.
4. Synthetic pond liners may also be secured in the same trench used to secure the pond cover.

This drawing is based on current best practice adopted within the Australian and New Zealand pork industries and incorporates recommendations previously published by the Pork CRC and NIWA (NZ). It should be noted that these drawings are schematic only and therefore general in nature. Consequently, it is recommended that producers planning the installation of covered anaerobic ponds should seek professional advice to ensure that their proposed systems meet all relevant site-specific limitations and regulatory requirements.

Pond inlet structure

Schematic drawing - not to scale



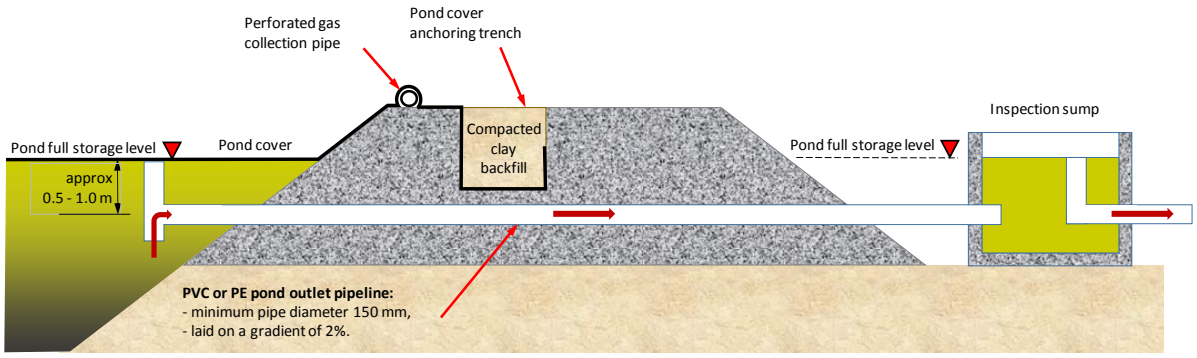
Notes:

1. Inlet pipelines are generally installed through the pond embankment, below the cover anchoring trench.
2. Pond inlet pipelines generally use PVC or PE pipes. The pipe diameter will depend on the delivery flowrate, either directly from the sheds or from an effluent collection or solids separation sump; however, a minimum diameter of 150mm is recommended to minimise the risk of blockages.
3. The inlet pipeline should discharge effluent approximately 0.5 to 1.0 m below the pond full storage level, with a 45° bend on the discharge end, to minimise the likelihood of the fresh, in-coming effluent flow 'short-circuiting' across the pond surface, to the pond outlet.
4. The inlet pipeline should extend approximately 3 m out from the pond batter to provide adequate clearance above any accumulating coarse solids deposited near the pond inlet.
5. Inlet pipelines are generally laid on a constant gradient of 2% towards the pond, to minimise the risk of solids settlement impeding the effluent flow.
6. For ease of removing any blockages, rodding access should be provided on the upstream end of the inlet pipeline. If practical, the inlet pipeline could be installed on a steeper slope so that the rodding access point, on the the upstream end of the inlet pipeline, is above the pond full storage level. This would avoid the need for partial emptying of the pond during inlet pipeline blockage removal operations.
7. A vertical riser (vacuum break) may be required on the upstream end of the inlet pipeline to prevent siphoning of pond effluent back to an effluent collection sump located at a lower elevation.
8. A 45° 'Y' piece and 45° bend is recommended where the vertical riser meets the inlet pipeline to provide better rodding access through the vertical riser and to avoid a sharp (90°) tee where solids may accumulate.

This drawing is based on current best practice adopted within the Australian and New Zealand pork industries and incorporates recommendations previously published by the Pork CRC and NIWA (NZ). It should be noted that these drawings are schematic only and therefore general in nature. Consequently, it is recommended that producers planning the installation of covered anaerobic ponds should seek professional advice to ensure that their proposed systems meet all relevant site-specific limitations and regulatory requirements.

Pond outlet structure

Schematic drawing - not to scale



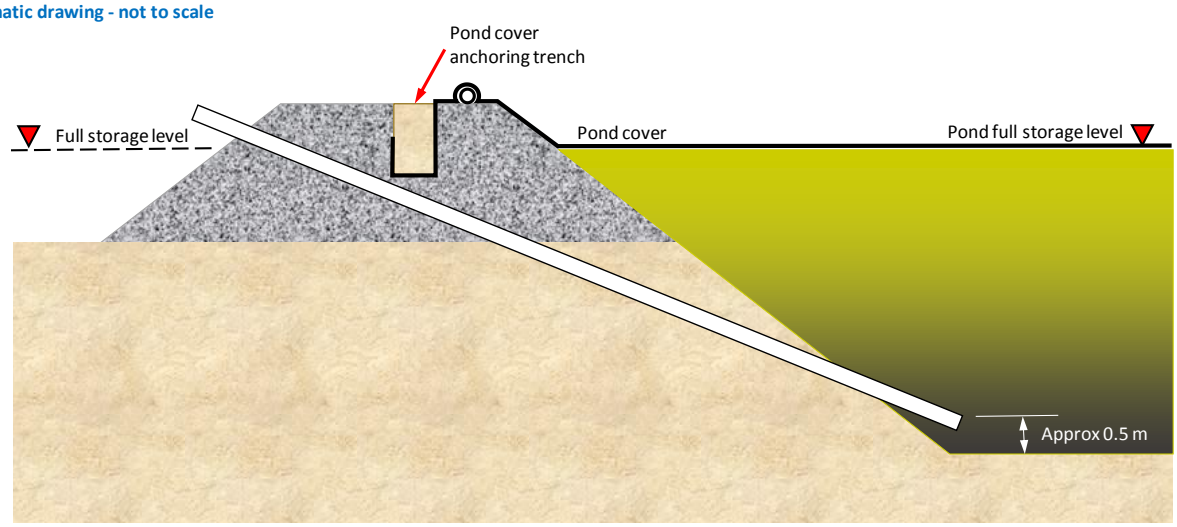
Notes:

1. The pond outlet pipeline should be installed approximately 0.5 to 1.0 m below the pond full storage level, with a tee installed on the inlet, extending up to the pond full storage level, to minimise the liklihood of any floating crust material entering the outlet pipeline.
2. An inspection sump may be installed downstream from the pond embankment to provide access for removing any blockages from the outlet pipeline and for regulating the pond full storage level (by adjusting the angle of the elbow on the inspection sump outlet).
3. A suitable cover should be installed on the inspection sump to minimise the risk of human or livestock injury or exposure to hazardous gases or liquid effluent.

This drawing is based on current best practice adopted within the Australian and New Zealand pork industries and incorporates recommendations previously published by the Pork CRC and NIWA (NZ). It should be noted that these drawings are schematic only and therefore general in nature. Consequently, it is recommended that producers planning the installation of covered anaerobic ponds should seek professional advice to ensure that their proposed systems meet all relevant site-specific limitations and regulatory requirements.

Covered anaerobic pond (CAP) desludging pipes

Schematic drawing - not to scale



Notes:

1 Desludging pipes should be installed to draw sludge from a depth of approximately 0.5 m above the base of the pond, extending to above the pond full storage level. These pipes are typically approximately 16 m long, based on a pond effluent depth of 5 m and a batter gradient of 1 vertical : 2 horizontal.

2 Desludging pipes may be directly connected to pumps or vacuum tankers. Polyethylene (PE) or PVC pressure pipe, having a minimum diameter of 150 mm, may be suitable in this application; however, the suction pressure limitations of the selected pipe material should be considered. The minimum recommended pressure rating is PN 9 (0.9 MPa maximum working pressure at 20°C).

3 Alternatively, flexible pump or vacuum tanker suction pipes may be inserted through the desludging pipes. In this case, larger diameter desludging pipes (minimum 225 - 300 mm) are recommended.

4 Desludging pipes are generally spaced at 10 to 15 m intervals along one or both long sides of the the covered anaerobic pond.

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Appendix 3

Piggery biogas survey

Piggery biogas survey

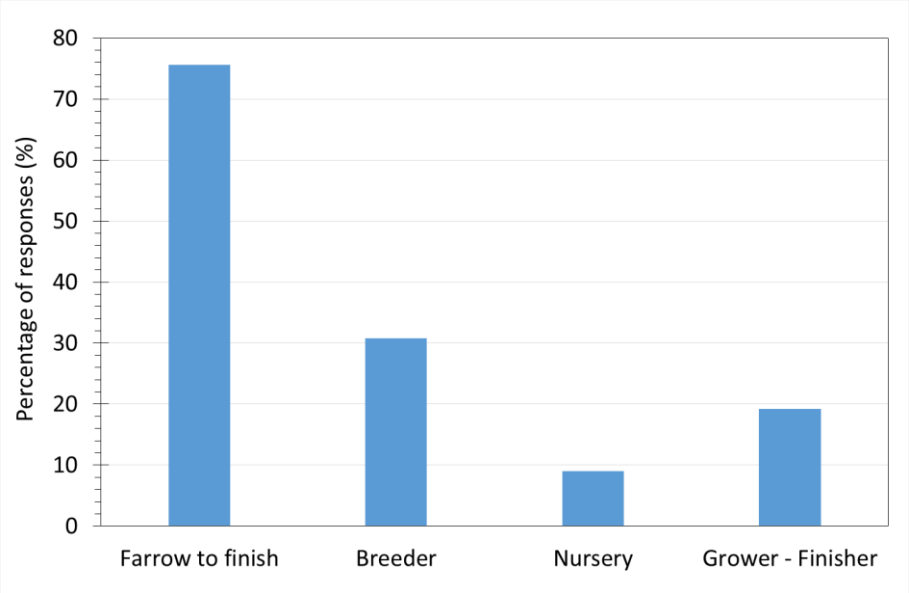
Detailed responses to the survey questions are summarised below:

Australian state where your existing piggery (or piggeries) is located:

Answer Choices	Responses	
Queensland	16.67%	15
New South Wales	27.78%	25
Victoria	23.33%	21
South Australia	17.78%	16
Western Australia	11.11%	10
Tasmania	3.33%	3
Australian Capital Territory	0.00%	0
Northern Territory	0.00%	0
	Answered	**90**
	Skipped	**1**

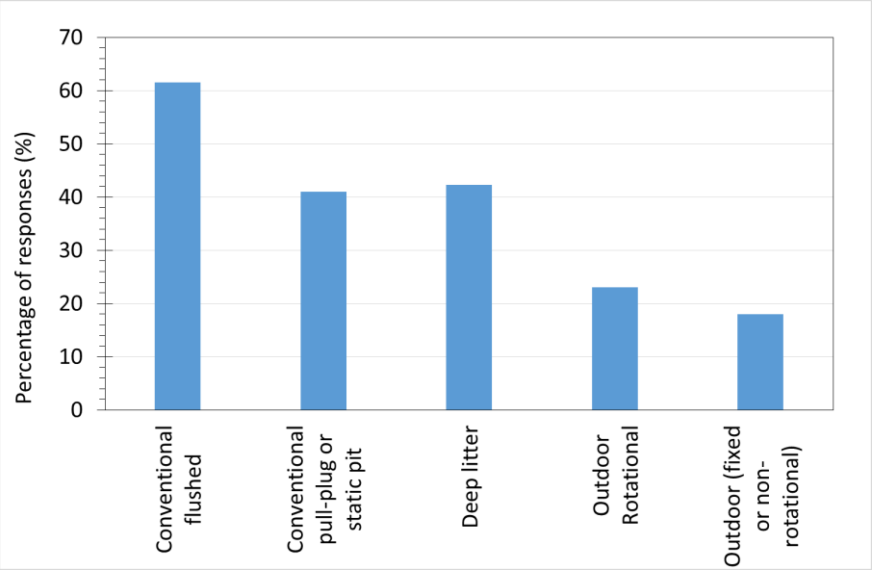
Types of piggery units that you currently operate (tick all relevant boxes):

Answer Choices	Responses	
Farrow to finish (accommodating pigs from birth to finishing weight within the same unit)	75.64%	59
Breeder (accommodating pigs from birth to weaning)	30.77%	24
Nursery (accommodating weaner pigs)	8.97%	7
Grower - Finisher (accommodating pigs from weaning to finishing weight)	19.23%	15
	Answered	78
	Skipped	13



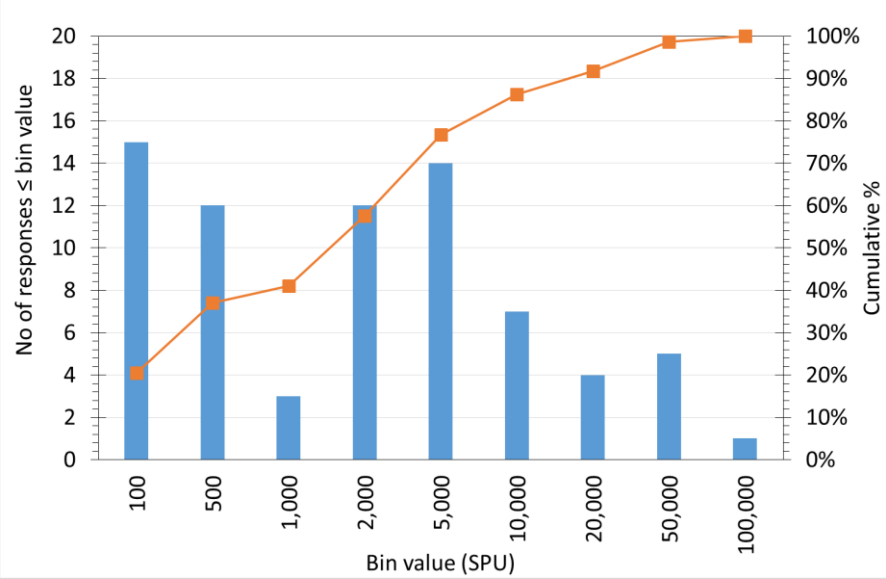
Production system(s) employed at your current piggery unit(s) (tick all relevant boxes):

Answer Choices	Responses	
Conventional flushed sheds	61.54%	48
Conventional pull-plug or static pit sheds	41.03%	32
Deep litter	42.31%	33
Outdoor Rotational	23.08%	18
Outdoor (fixed or non-rotational)	17.95%	14
	Answered	78
	Skipped	13



Total capacities of your current piggery unit(s):

Range		SPU	Frequency	Cumulative %
1	–	100	15	20.55%
101	–	500	12	36.99%
501	–	1,000	3	41.10%
1,001	–	2,000	12	57.53%
2001	–	5,000	14	76.71%
5,001	–	10,000	7	86.30%
10,001	–	20,000	4	91.78%
20,001	–	50,000	5	98.63%
50,001	–	100,000	1	100.00%
Answered			74	
Skipped			17	

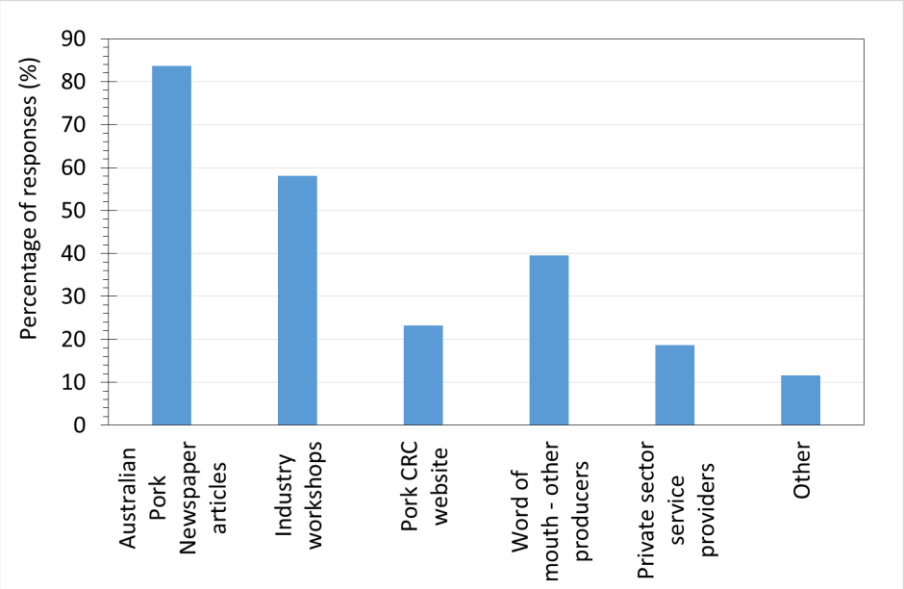


Are you aware of the Australian pork industries' progressive adoption of on-farm biogas systems over the past decade?

Answer Choices	Responses	
Yes	58.67%	44
No	41.33%	31
	Answered	75
	Skipped	16

How did you hear about the adoption of biogas systems by the pork industry (tick all relevant boxes)?

Answer Choices	Responses	
Australian Pork Newspaper articles	83.72%	36
Industry workshops	58.14%	25
Pork CRC website	23.26%	10
Word of mouth - other producers	39.53%	17
Private sector service providers	18.60%	8
Other	11.63%	5
	Answered	43
	Skipped	48



Do you have an existing on-farm biogas system?

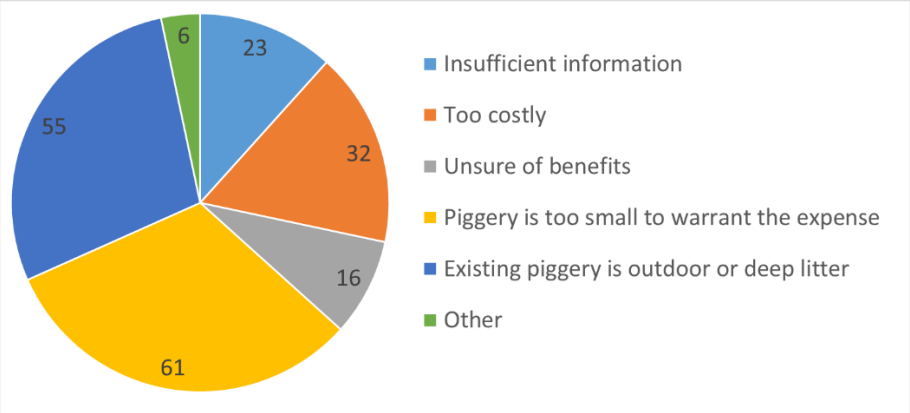
Answer Choices	Responses	
Yes	9.46%	7
No	90.54%	67
	Answered	74
	Skipped	17

Are you planning to install an on-farm biogas system?

Answer Choices	Responses	
Yes	7.46%	5
No	46.27%	31
Undecided	46.27%	31
	Answered	67
	Skipped	24

Reason(s) for not considering biogas system installation:

Answer Choices	Responses	
Insufficient information	22.58%	7
Too costly	32.26%	10
Unsure of benefits	16.13%	5
Piggery is too small to warrant the expense	61.29%	19
Existing piggery is outdoor or deep litter	54.84%	17
Other	6.45%	2
	Answered	31
	Skipped	60



When are you planning to install an on-farm biogas system?

Answer Choices	Responses	
Within 2 years	40.00%	2
2 to 5 years	40.00%	2
5 to 10 years	0.00%	0
Depends on system costs / returns and industry profitability	20.00%	1
	Answered	5
	Skipped	86

Type(s) of piggery unit(s) contributing effluent to the existing biogas system (tick all relevant boxes):

Answer Choices	Responses	
Farrow to finish (accommodating pigs from birth to finishing weight within the same unit)	50.00%	3
Breeder (accommodating pigs from birth to weaning)	66.67%	4
Nursery (accommodating weaner pigs)	33.33%	2
Grower - Finisher (accommodating pigs from weaning to finishing weight)	66.67%	4
	Answered	6
	Skipped	85

Capacity of piggery unit(s) contributing effluent to the existing biogas system:

Respondent No	Sows	Standard pig units (SPU)	Pigs
1	2,200	(22,000)	24,000
2	200	(2,000)	
3	2,040	(20,400)	24,000
4	9,497	(90,000)	
5	550	5,500	
6	2,000	(20,000)	23,000

Existing biogas system type:

Answer Choices	Responses	
Covered anaerobic pond (not heated or stirred)	100.00%	6
Hybrid in-ground heated, stirred covered pond / digester	0.00%	0
Above-ground mixed tank digester	0.00%	0
	Answered	6
	Skipped	85

Volumetric capacity of existing covered anaerobic pond / digester (megalitres - ML):

Respondent No	Responses (ML)
1	20
2	4
3	48
4	48
5	6
6	20

Biogas treatment method(s) (tick all relevant boxes):

Answer Choices	Responses	
Iron-oxide pellets	50.00%	2
Biological scrubber	100.00%	4
Chiller to remove condensed moisture	100.00%	4
	Answered	4
	Skipped	87

Biogas is currently used to operate (tick all relevant boxes):

Answer Choices	Responses	
A flare	100.00%	6
A boiler producing hot water	16.67%	1
A biogas engine (or engines) driving an electrical generator(s)	33.33%	2
One or more combined heat and power (CHP) systems generating electricity and hot water	50.00%	3
	Answered	6
	Skipped	85

Average annual biogas production (cubic metres / year):

Respondent No	Responses (m^3/y)
1	1,286,228
2	?
3	1,900,000
4	1,410,000
5	175,000

Rated electrical output of biogas-fuelled generator(s) (kilowatts - kW):

Respondent No	Responses (kWe)
1	280
2	0
3	50
4	500

Average annual electricity exported to the grid (kilowatt hours / year - kWh/y)

Respondent No	Responses (kWh/y)
1	788,568
2	0
3	0 (so far)
4	0

What have been the greatest benefits from having a biogas system?

Respondent No	Responses
1	Eliminated power bill
2	Reduced odour
3	So far, carbon credits. Near future, power cost reduction.
4	Carbon Credits. Recovered energy. Reduced Odour
5	Only half way through project
6	Power costs saved, Carbon credits earned, Odour reduction, Saving the world!

Please list any major issues or concerns regarding your biogas system.

Respondent No	Responses
1	none
2	minimal gas produced
3	Red F*%#ing tape
4	Sludge removal is the major issue with covered lagoons. Difficult to measure and remove.
5	Lack of support personnel in industry
6	Technical expertise for generator maintenance can be expensive.

What further information or support would assist you in deciding whether to install a biogas system?

Respondent No	Responses
1	Costs, Viability for our site, Benefits
2	investigating feasibility for install in 2 years
3	Money
4	size of piggery needed to be cost effective
5	more information and plans on how they can and are built
6	Whether a biogas system works in conjunction with composting
7	pig numbers for viability and long term gains from the system
8	?
9	If biogas units were available for smaller units
10	Is there a system that accommodates deep litter and conventional slurry effluent?
11	Full investigation of same
12	Costs, Returns, analysis on risks and rewards
13	Cost and efficiencies gained.
14	Knowing what the biogas system is?
15	Time poor, waiting for viable scaled down versions
16	We love the concept. We just need to find a way to make it viable for a small piggery such as ours. If this can be achieved, please contact me
17	Design cost effective?
18	It is a time factor for us
19	Any information
20	More details on what is involved...cost, process, benefit, etc.?
21	We looked into biogas and was going to cost $450,000.00. Not viable for our business at present
22	More information
Answered	22
Skipped	69

Comments:

Respondent No	Responses
1	installed to reduce odour, we have produced more energy with solar panels
2	This piggery is on a flood prone site which doesn't lend itself for setting up Biogas Collection. Have heard varying stories about the amount of maintenance that is required to run biogas generating plant. Not encouraging. We use all our piggery waste across our grain farming operation of the business. Covered ponds make it harder to access the effluent for spreading purposes. The amount of red tape required in order to get a biogas system up & running (local govt approval, gas compliance regulations, contracts with energy suppliers to feed back into the grid, govt rebates, Carbon credit system, etc) seems to be too much effort for a small operation. Solar energy becoming more attractive.
3	you people seem to push the political correctness wheelbarrow, not understanding that people who have pigs are trying to scratch a living from selling their pigs, and are not interested in the stupidity of government and ridiculous biogas.
4	Perhaps there should be some form of rebate eg. solar gov rebate for farmers. The pig industry in Australia is struggling so there would be no funds to adopt such a major expense.
5	Do not have enough information to make an informed decision
6	need to research low cost systems applicable for inclusion with straw based pig systems also
7	Never price a on-farm bio gas system. Happy to be informed
8	Utilising waste and disposal of it and reducing odours are really more of concern to us
9	Not suitable to my setup
10	how many pigs are required to make the system economically viable and total cost of a unit and who are the end users of the gas produced ...
11	We had feasibility study done for our farm but because we are multi-sited the concentration of pigs in the biggest grower area (to collect gas) is too far away from the breeder site where the gas could be utilised (kms away !)
12	it is very expensive to install
13	no comment
14	In general a productive plan
15	I would like more info on deep litter models and what the minimum amount of liquid effluent is needed to make it worthwhile
16	We investigated this a few years ago & were advised that because we couldn't feed back into the grid it wouldn't warrant the expense.
17	Covering anaerobic lagoons is good value if the energy recovered can be profitably used onsite.
18	dissemination of information is inadequate/not effective
19	Great for heating sheds floors, where straw is not an option
20	important for neighbour relations and obviously needs to be financially viable
21	Great idea. Please develop an economical SMALL system.
22	We are interested in using biogas for domestic supply if possible and maybe rotating boar and sows through concrete yard.
23	We can all improve our farming operations
24	For intensive indoor piggeries I believe this would be very practical and valuable!

25	**We are of the opinion that 400 sow is no big enough for such system**
26	**Difficulty in managing and up keeping such a system, outweigh the benefits for our farm at this point in time.**
27	**I am continually surprised uptake has not been faster. Pig farmers have the ability to save on their cost of production, do not out the work in & then complain when prices are high.**
Answered	**27**
Skipped	**64**