INSTALLATION OF INSTRUMENTATION FOR REMOTE MONITORING OF BIOGAS COMPOSITION AND OPERATIONAL DATA AT COMMERCIAL PIGGERIES

Project 4C-122:

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

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June 2018

Pork CRC

Australian Government
Department of Industry, Innovation and Science

Business Cooperative Research Centres Programme

Executive Summary

Three Australian piggeries with existing biogas systems were offered opportunities to utilise funding provided by this project for purchasing and installing instrumentation to monitor biogas production, composition and system operation. These piggeries were selected following an expression of interest and evaluation process. Unfortunately, only one of the selected piggeries (Piggery A) was able to purchase and install the required instrumentation within the project timeframe.

A quotation for the supply of suitable monitoring instrumentation came to a total of $47,200 (incl GST). However, because Piggery A already had some monitoring instrumentation in place, the total cost for supplying and installing the additional monitoring instrumentation, required to meet the project objectives, was $18,404 (incl GST). Following installation of the additional instrumentation, the operation of the existing hybrid covered anaerobic pond (hybrid CAP) at Piggery A was closely monitored over a three-month period, from April to June 2018.

The hybrid CAP at Piggery A received unscreened effluent from flushing and pull-plug sheds housing a total capacity of 38,200 SPU. The average biogas production from the hybrid CAP was 5,601 m^3/d over the three-month monitoring period. The resulting biogas and methane yields were 523 m^3 biogas and 287 m^3 CH_4, respectively, per tonne of VS discharged into the hybrid CAP. The recorded methane yield indicated that the hybrid CAP was achieving a high methane recovery of 88% of the biochemical methane potential (BMP).

Approximately two-thirds of the biogas produced by the hybrid CAP was used to run two 250 kWe Camda combined heat and power (CHP) generator units while the remaining third of the biogas was burnt in a shrouded flare. The substantial consumption of excess biogas in the flare suggests that there is considerable potential for adopting additional, more productive biogas use options on the farm.

The two CHP units generated an average of 6,490 kWh/day over the monitoring period (average output 270 kWe). Thirty-six percent of the electrical power generated by the CHP units was used in the pig sheds, predominantly running cooling fans, lights and heat lamps, 26% of the power was used to operate the on-site feed mill, and 26% was exported to the electricity grid. The remaining 12% (34 kWe) was used to run the hybrid CAP and onsite biogas production and use infrastructure.

The average power generated per cubic metre of biogas was 1.73 kWh/m^3 biogas. Based on the average biogas methane content of 55%, the average electrical efficiency of the generator engines was 34%, which is typical for biogas engines operating at piggery installations.

The H_2S concentration in the biogas extracted from the hybrid CAP (average 223 ppm H_2S) was much lower than typically observed in raw piggery biogas and only marginally higher than the typically recommended maximum of 200 ppm for generator engines. However, this reduction in H_2S concentration which was achieved by biological oxidation inside the hybrid CAP headspace, was not sufficiently consistent for safe operation of the generator engines. Further biogas treatment in the external biological scrubber reduced the H_2S concentration measured downstream of the biological scrubber to very low levels (average 18 ppm) which rarely exceeded 200 ppm. This showed that the combined biological oxidation in the hybrid CAP and external biological scrubber was effective at removing H_2S from the biogas.

It may be preferable to inject air into the biogas delivery line, upstream from the external biological scrubber, rather than into the CAP headspace. Excess O_2 in the CAP headspace can result in further oxidation of H_2S to form sulphate instead of elemental sulphur. The resulting sulphuric acid (H_2SO_4) produced by this reaction, can cause severe corrosion of exposed metal or concrete surfaces in the CAP headspace. Supplying excess O_2 upstream from a separate biological scrubber may be advantageous, by avoiding the deposition of elemental sulphur on the scrubber packing elements. In this case, the scrubbing liquid should not be recycled back to the CAP.

High levels of balance gas and relatively low levels of CH_4 and CO_2 measured by the MRU SWG 100 biogas analyser, in comparison to readings taken using portable analysers, suggested that the MRU SWG 100 biogas analyser installed at Piggery A may require re-calibration. Alternatively, the air dosing rate may be higher than expected, resulting in higher N_2 concentrations in the biogas.

The three-month monitoring period at Piggery A has provided considerable useful data regarding the biogas system performance and operation. However, there was insufficient data to conclusively identify issues which warrant any major changes to system operations. Consequently, it is recommended that the detailed monitoring program be continued.

Installation of monitoring instrumentation, similar to that installed at Piggery A, has considerable potential for improving the management of on-farm biogas systems. More specifically, the high quality, real-time data provided by such installations will assist piggery managers to promptly diagnose operational irregularities and system faults, and thereby avoid costly damage to system components such as generator engines. The output data can also be used in evaluating a range of operating strategies and biogas treatment methods to maximise economic benefit.

The initial installation of monitoring instrumentation at Piggery A has improved the knowledge and experience of researchers, service providers and piggery managers with regard to the available monitoring technology and its practical application in the Australian pork industry. It also provides a model for the further development and more widespread deployment of similar systems across the industry.

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1. Introduction

The composition of biogas produced by anaerobic digestion of piggery effluent can have a major effect on safe and efficient operation of biogas use equipment. For example, high levels of hydrogen sulphide (H_2S) can damage biogas use equipment and is very dangerous for piggery workers and livestock. Prior Pork CRC research (Project 4C-104, Skerman, 2016) developed cost-effective and practical methods to remove H_2S and other recalcitrant contaminants from piggery biogas prior to use. However, the on-going performance of such treatment methods at Australian piggeries was uncertain, and incorrect operation of such treatment methods could result in unsafe scenarios. For example, a small amount of air is added to biogas pipelines when removing H_2S with a biological scrubber. However, if too much air enters a biogas system, explosive biogas mixtures or melting of plastic biogas pipelines can result, as the air reacts with iron-based filter media also commonly used for final removal of trace amounts of H_2S from the biogas (Project 4C-115, Tait, 2017).

To confirm on-going safe performance, the current project funded installation of real-time monitoring and communication instrumentation on relevant biogas treatment systems at Australian piggeries.

In addition, the project encouraged voluntary participation of Australian producers operating piggeries with a suitable profile (e.g. biogas systems in place, using Pork CRC suggested or similar treatment methods) by offering:

- grant funding in partial payment for the supply and installation of the instrumentation; and
- analysis of the resulting monitoring data to provide recommendations for possible improvements to the operation of the biogas treatment systems.

Lastly, the instrument installations provided for in this project also provided a template for future instrumentation/monitoring system installations which may be adopted at other piggery biogas installations.

2. Methodology

2.1 Specification of required instruments

It was important to ensure that the instrumentation installations were able to provide high quality data. As such, a brief specification was prepared, describing the minimum requirements necessary to secure the grant funding (Appendix 1). In summary, the instrumentation needed to be capable of monitoring the following parameters:

- The total flowrate of biogas delivered from the digester or covered anaerobic pond (CAP) to each of the biogas treatment systems, engines, boilers or flares.
- The concentrations of methane (CH_4), carbon dioxide (CO_2), oxygen (O_2) and hydrogen sulphide (H_2S) in the raw biogas, and following one or more respective biogas treatment steps. (Ideally, the instrumentation should have been capable of monitoring biogas quality before and after each successive treatment step; e.g. following both biological primary treatment and iron-based chemisorption secondary treatment).

Initial quotations were also obtained for reference price comparison (Appendix 2), and a list of known suppliers was made available to interested producers (Table 1).

Table 1. Makes, models and Australian suppliers of three possible biogas analysers which may be suitable for this application

Analyser make and model	Australian supplier	Contact details
Geotech Biogas 3000 United Kingdom. https://www.geotechuk.com/products/biogas-3000/	Thermo Fisher Scientific http://www.thermofisher.com.au/	Tim Brewer, Sales Specialist, Brisbane; Ph: 0403 222 557 tim.c.brewer@thermofisher.com
SWG 100 biogas, MRU, Germany https://www.mru.eu/en/products/detail/swg-100-biogas/	Phoenix Instrumentation Pty Ltd http://phoenix-inst.com.au/	15/19-21 Central Road MIRANDA NSW 2228 Ph: 02-9524-5955 icoulson@phoenix-inst.com.au
Sewerin, BioControl 4 and 8 Germany https://www.sewerin.com/cms/en/our-products/gas/landfill-and-biological-gas.html	Access Detection Pty Ltd http://www.accessdetection.com.au	Unit 11b The Leermont Centre 3-9 Kenneth Rd, Manly Vale NSW Australia 2093 Ph: 02 9999-0777 sales@accessdetection.com.au

2.2 Call for Expressions of Interest

A call was released inviting producers to participate in the project and to receive grant funding for the installations. This call was publicised using a flyer (Appendix 3) distributed through a Pork CRC producer email list, and by means of an "It's a gas" column titled, "Taking biogas system monitoring for granted" which was published in the Australian Pork Newspaper (Appendix 4). The call emphasised the potential beneficial uses of the high quality measurement data from the instrumentations, which included:

- Early diagnosis of operational irregularities or system faults.
- Evaluation of a range of operating strategies.
- 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.

2.3 Selection of Awardees and Grant Funding Approach

Four producers (Piggeries A, B, C and D) subsequently submitted expressions of interest, and these were evaluated objectively, against criteria agreed by the project team, which were:

- Financial ability to meet any shortfall in the cost of the instrumentation that is not covered by the grant funding.
- Ability to meet the specified instrumentation requirements.
- Research and collaboration history.
- Biogas technology types in place, and relevance to current project objectives.
- Occupational health and safety awareness and track-record.
- Potential for flow-on research and collaboration.
- Distance to travel to site, in terms of providing on-going support.

On each of the categories, submissions were given a rank from 1 (least desirable) to 4 (most desirable). From the total ranking scores, three piggeries (Piggeries A, B and C) were subsequently selected for participation in the project. The operators of these piggeries were informed of the outcome (October 2017) and were asked to source quotations for the supply and installation of the monitoring instrumentation, as soon as possible.

During November 2017, Piggery C advised that they no longer wished to proceed with the project, and the previously unsuccessful applicant, Piggery D, was contacted and offered an opportunity to participate.

Quotations for the supply and installation of suitable monitoring instrumentation were subsequently received from Piggeries A and B, a draft funding agreement was negotiated, and this agreement was signed by Piggery A on 13 February 2018. On 12 March 2018, a representative of piggery B advised that they had decided to discontinue their participation in the project. Following the late withdrawal of Piggery B, it was not possible to source additional expressions of interest and candidates within the remaining life of the project. Consequently, in accordance with the Pork CRC project header agreement, a decision was made to split the grant funding between the remaining Piggeries A and D, subject to their satisfactory installation and commissioning of the instrumentation by 30 June 2018.

Following advice from a Piggery A staff member, a site visit on 4 April 2018 by the project team confirmed that the required instrumentation was installed and operating satisfactorily. Subsequently, payment of an agreed $15,000 (excluding GST) grant was made to Piggery A following submission of a valid tax invoice.

Unfortunately, due to unforeseen circumstances, the manager of Piggery D was unable to source a suitable quotation within the project timeframe and therefore Piggery D was unable to participate further in the project. Consequently, it was agreed with the Pork CRC that an additional payment of $1,731 (excluding GST) be made to Piggery A to fully reimburse all 'out of pocket' expenses incurred during installation of the monitoring equipment required by the project.

Any unspent project funds will be either returned to the Pork CRC or used to fund on-going research and development projects supporting biogas system adoption in the Australian pork industry.

2.4 Post-Installation Support

Piggery A was visited following installation of the monitoring equipment as noted above, and again subsequently to check the calibration of biogas composition instruments.

The installed infrastructure at Piggery A included:

- A biogas analysis system capable of sampling biogas both upstream and downstream from an existing biological scrubber (MRU SWG 100 biogas·-stationary biogas-measuring system for continuous measurements, supplied by Phoenix Instrumentation).
- Two new ½" pneumatic valves with remote solenoids to control biogas flow from the sampling points to the analyser, including all connecting stainless steel tubing and incorporating a moisture bowl and j-trap to enable self-drainage of condensed moisture in the sampling line.

- A new ComAP Inteli AIN8 input module to communicate with the biogas analysis system.
- New 4-20mA signal cables from the two existing biogas flow meters to the ComAP controller.
- New control cables between the solenoid valves and analyser.

A quotation obtained from ThermoFisher for the supply of suitable instrumentation, which included a Geotech Biogas 3000 fixed analyser, a GE PanaFlow™ MV80 flowmeter and a data telemetry system, came to a total cost of $47,200 (incl GST). This quotation has been included in Appendix 2 of this report. However, because Piggery A already had significant instrumentation in place, the total cost for supplying and installing the additional monitoring instrumentation required to meet the project objectives was $18,404 (incl GST). The data analysis, technical recommendations and post-installation support provided by the project team were funded by the project, at no cost to the producer.

The existing biogas system operating at Piggery A consisted of an RCM-designed, heated, stirred, in-ground hybrid covered anaerobic pond (CAP), treating unscreened shed effluent from a 35,800 SPU grower unit and a separate 1,300 sow breeder unit (total = 38,200 SPU). Untreated effluent discharged from the flushing and pull-plug piggery sheds flowed to the hybrid CAP. Heat recovered from the generator engine blocks and exhaust systems is used to heat pond effluent which is circulated through the hybrid CAP to heat the stored effluent. Four submersible mixer stirrers, mounted near the base of the digester, were operated for approximately two hours per day (generally 2:00 am to 4:00 am). This stirring and mixing was said to keep sludge suspended in the hybrid CAP. Air was injected directly into the biogas headspace inside the hybrid CAP, at a rate of 8 cfm (13.6 m^3/h), through several ports, spaced evenly across the cover. This allowed some removal of H_2S inside the hybrid CAP, before extraction of the biogas. No additional air was injected into the biogas externally to the hybrid CAP. Biogas drawn from the digester was piped to a separate external biological scrubber to remove residual H_2S, and onto a chiller to remove residual moisture. A blower then boosted the treated biogas pressure to approximately 11 kPa before it was directed to two 250 kWe Camda generators onsite. The generators supplied electricity to the on-farm feed mill and the pig sheds, or exported electricity to the supply grid. Any additional excess biogas was burnt in a shrouded flare.

The photographs in Figures 1 to 9 depict some the major system components installed at Piggery A. Figure 10 is a schematic drawing of the biogas system operating at piggery A.

Figure 1. Upgraded biogas analysis system (MRU SWG 100 biogas) supplied by Phoenix Instrumentation.

Figure 2. Readout on the upgraded biogas analysis system (MRU SWG 100 biogas).

Figure 3. Pneumatically operated valves with remote solenoids to control biogas flow from the two sampling points to the analyser.

Figure 4. Sage Thermal Mass Flow meter measuring biogas flow to one of the 250 kWe generators.

Figure 5. Hybrid CAP cover showing the stirrer and air injection locations.

Figure 6. RCM-designed, heated, stirred, in-ground hybrid CAP.

Figure 7. Biological scrubber.

Figure 8. Data logging and communications panel incorporating the new ComAP Inteli AIN8 input module.

Figure 9. Camda 250 kWe generator units.

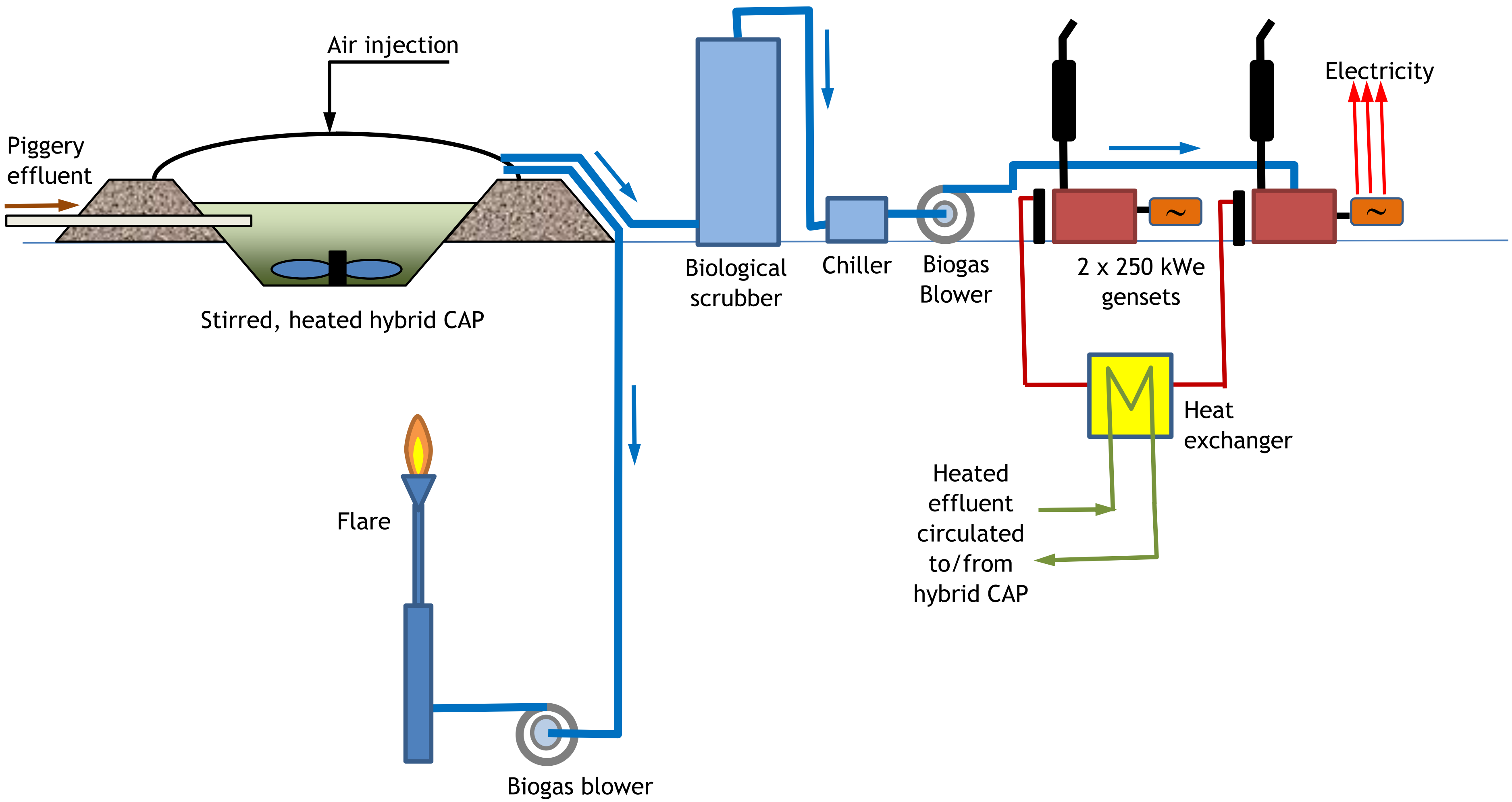

Figure 10. Schematic drawing of the biogas system operating at piggery A.

3. Outcomes

The Piggery A project coordinator provided the project team with monthly reports for a three month period, up to the end of June 2018, which included all biogas flow and composition data, and metered total electricity generated and separate metered electricity use onsite. The grid electricity export data was only available as monthly totals.

3.1 Biogas production

Table 2 summarises hourly and daily biogas flowrates to the onsite flare and generator engines over the project monitoring period. Figures 11, 12 and 13 show hourly, daily and monthly biogas consumption by the flare and generators.

An analysis of the biogas use data, which was recorded at one minute intervals, suggests that one generator was operating for 58% of the monitoring period (60 to 120 m^3/minute biogas flow) and two generators were operating for 41% of the monitoring period (3 to 5 m^3/minute biogas flow). Both generators were stopped on 17 separate occasions for a total duration of 17 hours, which is equivalent to 0.8% of the total monitoring period. These trends are clearly evident in the hourly data presented graphically in Figure 11. The piggery project coordinator advised that the generator stoppages were caused by grid failures which required disconnection of the generators from the grid. Some further difficulties were encountered restarting the generators without grid power and reconnecting the power output to the grid.

The data (Table 2, Figure 12) indicates that approximately two-thirds of biogas produced by the hybrid CAP at Piggery A was used by the generators and approximately one-third was burnt in the flare (no energy recovery). Biogas consumption by the flare was quite variable, as compared to the generators. The highest levels of biogas consumption by the flare occurred when just one of the generators was operating (Figure 12). The significant consumption of excess biogas in the flare suggests that there may be opportunities to implement additional, more profitable biogas use options.

Table 2. **Biogas flowrates (mean ± 95% CIs) supplying the flare and engines on an hourly and daily basis for the months from April to June 2018, and over the entire 3-month period.**

	April	May	June	April-June
Average Hourly Biogas Flow (m^3/h)				
Flare	94 ± 7	73 ± 7	80 ± 7	80 ± 4
Engines	161 ± 5	161 ± 5	148 ± 5	158 ± 3
Total	**255 ± 7**	**234 ± 7**	**228 ± 7**	**238 ± 4**
Average Daily Biogas Flow (m^3/d)				
Flare	2,212 ± 452	1,709 ± 487	1,901 ± 579	1,884 ± 283
Engines	3,790 ± 348	3,753 ± 447	3,491 ± 371	3,718 ± 211
Total	**6,001 ± 415**	**5,462 ± 510**	**5,392 ± 494**	**5,601 ± 258**

Standard Reference conditions: 60°F (15.6°C) and 29.92” Hg (1 atm)

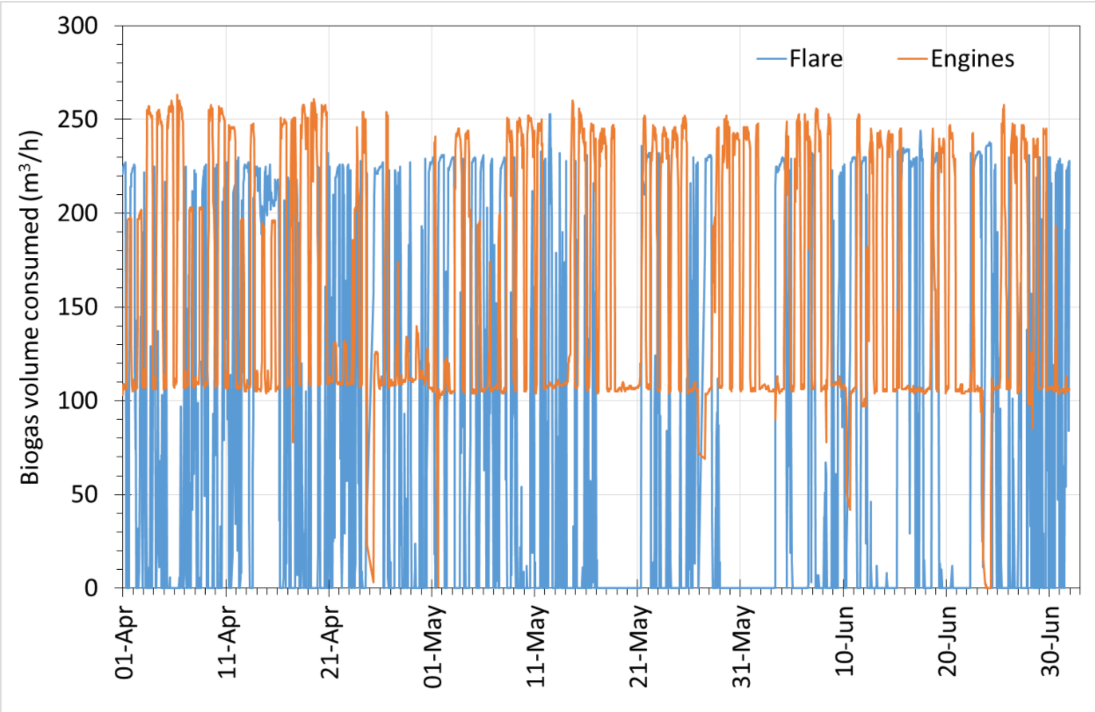

Figure 11. Hourly biogas consumption in the flare and engines.

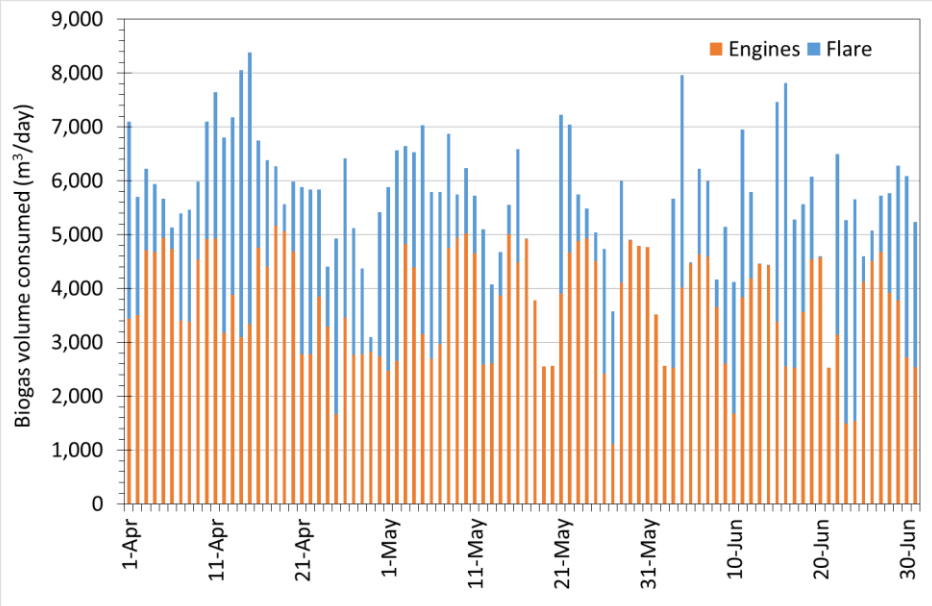

Figure 12. Stacked column graph showing daily biogas consumption in the flare and engines.

Figure 13 shows similar monthly total biogas flows to the flare and generators over the period April to June 2018, despite a significant fall in minimum and maximum ambient temperatures at the site. This relatively small variation in biogas production may be due to the benefits of heating of the hybrid CAP contents, sustaining more consistent biogas production; however, longer term monitoring data would be required to confirm this.

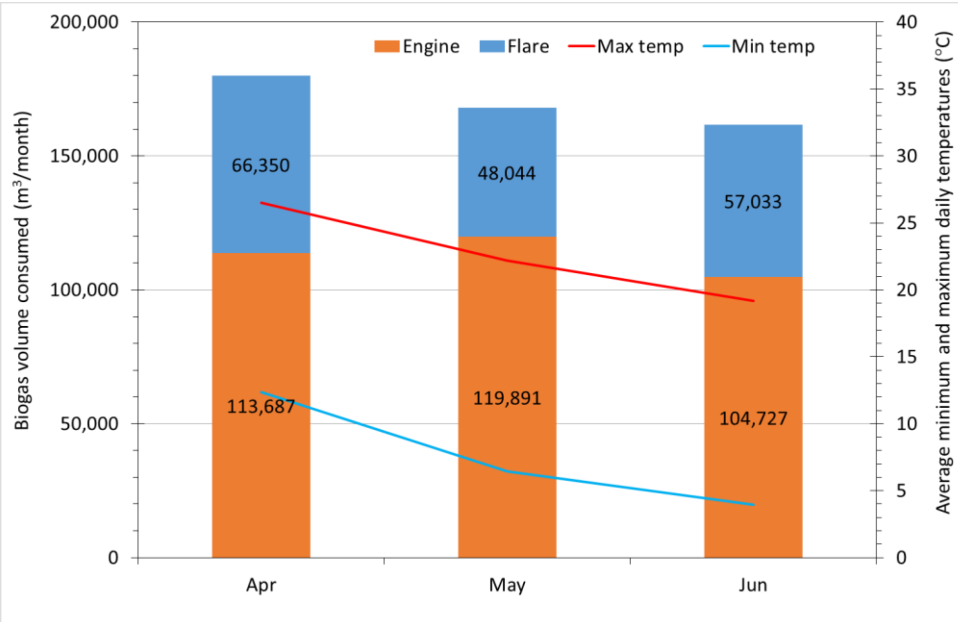

Figure 13. Stacked column graph showing monthly biogas consumption in the flare and engines plotted with average minimum and maximum daily temperatures (Station 41525 - Warwick).

Figure 14 shows that the flare at Piggery A burnt biogas, raising the flare temperature to approximately 900°C, whenever the meter on the flare biogas supply line registered a flowrate. These data are useful for verifying the operation of the flare and demonstrating that the flare appears to be igniting and effectively burning biogas whenever there is any significant biogas flow.

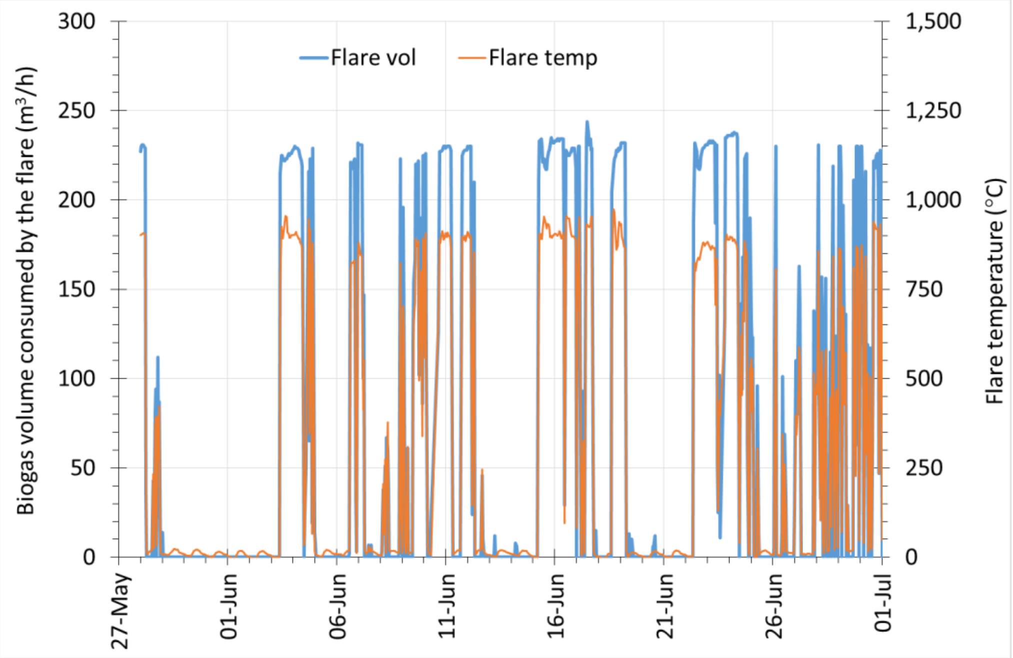

Figure 14. Hourly biogas volumes consumed in the flare and the corresponding flare temperatures recorded over part of the monitoring period.

3.2 Biogas yield

As noted in Section 2 of this report, the hybrid CAP operating at Piggery A currently receives raw effluent from a 35,800 SPU grower-finisher unit and a 1,200 sow breeder unit (Total: 38,200 SPU). Untreated effluent from the flushing and pull-plug piggery sheds is discharged directly into the hybrid CAP, without prior screening or solids separation.

PigBal modelling, using site-specific pig herd and diet data, suggested that the hybrid CAP treated a volatile solids (VS) loading rate of 10,709 kg VS/d during the monitoring period. From above, the average total biogas consumption in the flare and engines was 5,601 m^3 biogas/d. This suggests a biogas yield of 523 m^3 biogas/tonne VS fed and a methane yield of 287 m^3 CH_4/tonne VS fed, based on the measured biogas methane concentration of 54.96% (refer to Section 3.3 below). A previous biochemical methane potential (BMP) analysis carried out on an effluent sample from the grower-finisher shed at Piggery A suggested a biochemical methane potential (BMP) of 327 m^3 CH_4/tonne VS fed (Skerman et al., 2017), which indicates that the hybrid CAP is achieving a high methane recovery of 88% of the BMP, and so was performing as well as could be expected during the monitoring period.

3.3 Biogas composition and H_2S removal performance

Table 3 shows mean concentrations of CH_4, CO_2, O_2 and H_2S measured for biogas upstream and downstream of the biological scrubber, over the monitoring period April to June 2018. The balance gas concentrations given in Table 3 were calculated by subtracting the CH_4, CO_2, O_2 and H_2S concentrations from 100%. Figure 15 presents a time trend of the measured biogas composition, recorded at 24-min intervals.

Table 3. Biogas composition (means ± 95% CIs) measured upstream and downstream from the biological scrubber, using the MRU SWG 100 biogas analyser, for the months from April to June 2018, and over the entire 3-month period.

Sample point	April	May	June	April - June
Upstream CH_4 (%)	51.85 ± 0.06	52.90 ± 0.12	52.10 ± 0.09	52.29 ± 0.06
Downstream CH_4 (%)	54.96 ± 0.08	55.55 ± 0.09	54.35 ± 0.20	54.96 ± 0.08
Upstream CO_2 (%)	27.37 ± 0.03	26.66 ± 0.04	25.89 ± 0.04	26.64 ± 0.03
Downstream CO_2 (%)	28.91 ± 0.04	27.93 ± 0.03	26.91 ± 0.10	27.92 ± 0.04
Upstream O_2 (%)	1.30 ± 0.01	1.35 ± 0.02	1.47 ± 0.02	1.37 ± 0.01
Downstream O_2 (%)	0.45 ± 0.02	0.62 ± 0.01	0.92 ± 0.06	0.66 ± 0.02
Upstream Bal (%) [1]	19.47 ± 0.07	19.07 ± 0.14	20.51 ± 0.10	19.68 ± 0.07
Downstream Bal (%) [1]	15.68 ± 0.09	15.90 ± 0.11	17.81 ± 0.23	16.46 ± 0.09
Upstream H_2S (ppm)	125.5 ± 9.1	177.3 ± 7.3	367.9 ± 23.9	223.2 ± 9.1
Downstream H_2S (ppm)	6.2 ± 3.5	5.4 ± 2.4	42.1 ± 9.9	17.8 ± 3.5
% H_2S reduction [2]	95.03%	96.93%	88.56%	92.02%

[1] Bal = balance gas concentration; calculated by subtracting CH_4, CO_2, O2 and H_2S concentrations from 100%.

[2] Percentage change from upstream to downstream

Because air is being injected directly into the biogas stored in the hybrid CAP headspace, to support the biological oxidation of H_2S, the balance gas content seen in Table 3 would mostly consist of nitrogen (N_2) in the added air. However, based on the said air injection rate of 8 cfm (13.6 m^3/h) and an average biogas extraction rate of 238 m^3/h, the expected N_2 concentration in extracted biogas would be 4.5%, which is considerably lower than the calculated values presented in Table 3 (average 16.5%). Also, previous Australian research reported CH_4 concentrations in piggery biogas from 63 to 69%, with CO_2 making up the remaining 31 to 34% (Skerman et al, 2018, Skerman et al, 2013). These observations suggested that the MRU SWG 100 biogas analyser installed at Piggery A may have been reading biogas composition incorrectly.

Consequently, the project team again visited the site to cross-check the onsite instrument calibration using readings from two pre-calibrated portable biogas analysers (Geotech biogas check and Geotech biogas 5000). The portable analysers were separately calibrated with standard gas mixtures containing 60% CH_4 and 40% CO_2, and 2000 ppm H_2S in N_2. Comparison of the results between the two portable meters and the onsite MRU SWG 100 biogas analyser, showed the onsite meter was reading slightly lower CH_4 and CO_2 concentrations, with an offset of -3 to -5 volume percentage for CH_4 and an offset of -5 to -8 volume percentage for CO_2. This may indicate that the MRU SWG 100 biogas analyser at Piggery A requires re-calibration for CH_4 and CO_2 and partly explained the high balance gas concentrations in Table 3. In addition, the air dosing rate at Piggery A may be higher than expected, resulting in higher nitrogen concentrations in the biogas. This issue has been brought to the attention of the piggery project coordinator and has also been discussed with the supplier of the biogas analyser.

With biological oxidation, in general, specialised micro-organisms (Thiobacillus amongst others) use O_2 in added air to oxidise H_2S to form elemental sulphur (a solid), as described by Equation 1 (Ryckebosch et al., 2011).

$2H_2S + O_2 \rightarrow 2S + 2H_2O$ Equation 1.

Elemental sulphur forms a light yellow-whitish solid deposit on surfaces exposed to the biogas being treated. If air is directly added to a CAP or digester, these surfaces would be the pond cover, or any solid infrastructure exposed to the headspace gas. If biological oxidation occurs in an external scrubber vessel, the elemental sulphur accumulates on a packing medium inside the scrubber vessel.

The H_2S concentration in the biogas extracted from the hybrid CAP at piggery A (Table 3, upstream) was much lower than typically observed in raw piggery biogas (500–3000 ppm, Skerman *et al.* 2018). This suggests that biological oxidation was already occurring inside the headspace of the hybrid CAP, removing H_2S by reacting with oxygen in air added directly to the headspace. Literature reports similarly that micro-aeration of a digester headspace can reduce H_2S concentrations by up to 95% (Wellinger and Lindberg, 2005).

The average H_2S concentration in biogas extracted from the hybrid CAP (223 ppm, Table 3 - upstream) is only marginally higher than a typically recommended maximum of 200 ppm for generator engines (Camda website). However, H_2S concentrations in biogas extracted from the hybrid CAP exceeded 200 ppm over 32% (678 hours) of the total 3-month monitoring period and were periodically very high (Figure 15). The spikes in H_2S concentration generally coincided with generator stoppages which resulted in stoppages of the biological scrubber, biogas blower and air dosing pump. The high H_2S concentrations in the stagnant biogas stored in the hybrid CAP head space and delivery pipeline appear to be reduced to normal levels soon after the resumption of the generator operation. These results suggest that removal of H_2S by biological oxidation in the hybrid CAP headspace was inadequate and intermittently inconsistent, highlighting the importance of the separate external biological scrubber to remove the residual H_2S.

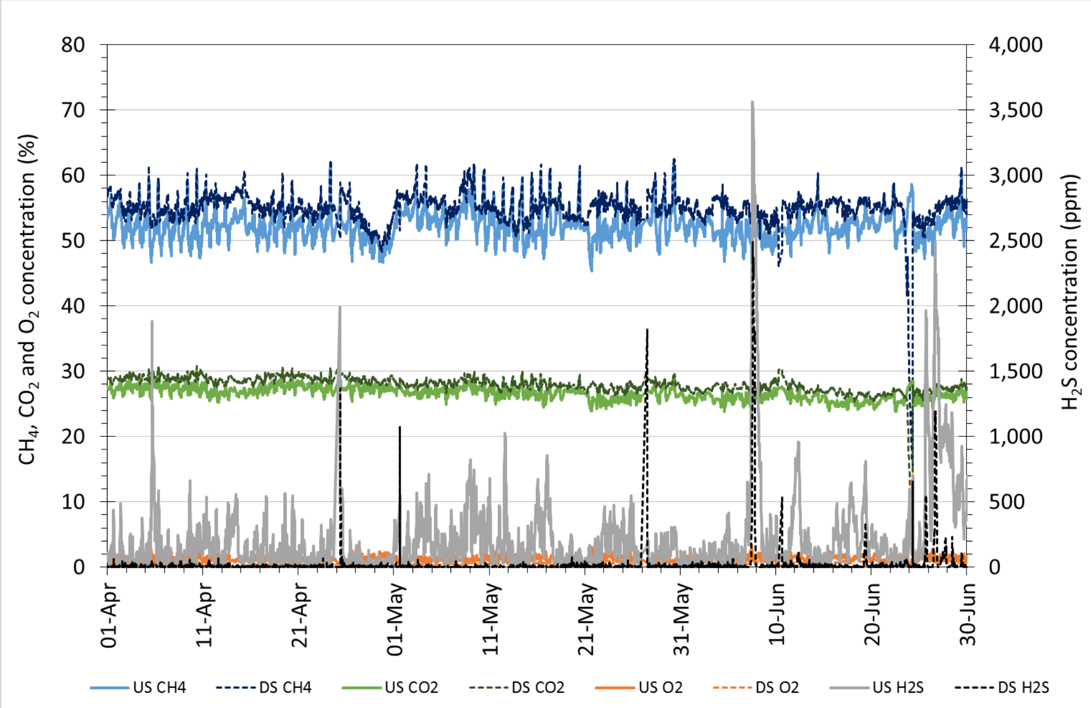

Figure 15. Biogas composition measured upstream (US) and downstream (DS) from the biological scrubber at Piggery A, using the MRU SWG 100 biogas analyser, over the three month monitoring period.

O_2 remaining in biogas extracted from the hybrid CAP headspace appeared to be adequate for biological oxidation in the external biological scrubber. This oxidation decreased the average O_2 content across the scrubber from 1.37% (upstream) to 0.66% (downstream). The average H_2S concentration measured downstream of the biological scrubber was very low (18 ppm, Table 3) and instantaneous H_2S concentrations rarely exceeded 200 ppm (1.3% or 29 hours of the total 3-month monitoring period). This showed that biological oxidation in the hybrid CAP and external biological scrubber was effective at removing H_2S from the biogas at Piggery A.

3.4 Biogas treatment system - Potential long-term performance issues

Elemental sulphur is chemically reactive under anaerobic conditions (as in a CAP or digester). This is important, because if sulphur solids form and deposit on surfaces exposed to headspace biogas inside a CAP or digester, these solids may be dislodged over time, and fall back into the liquid phase inside the CAP or digester. The liquid phase is anaerobic, so this sulphur is readily converted back into H_2S by biological activity in the liquid phase, producing more H_2S and progressively increasingly the load of H_2S on the subsequent biological oxidation treatment. An external biological oxidation system is preferred in this regard, because H_2S exits the CAP or digester before being deposited as elemental sulphur. It is commonly assumed that in well-mixed digesters, elemental sulphur which is dislodged and drops into the digester liquid, simply flows out with the treated outflow liquid. However, this has not been previously proven by research.

When air or O_2 is added in excess, such as by higher rates of air injection, further oxidation of H_2S can occur to form sulphate instead of elemental sulphur, as described by Equation 2.

$H_2S + 2O_2 \rightarrow H_2SO_4$ Equation 2.

Note that the sulphuric acid (H_2SO_4) produced by this reaction, is highly acidic and can cause severe corrosion of exposed metal or concrete surfaces. The pH of the digester or CAP liquid phase is not typically affected by this acid (Equation 2), because the alkalinity in the liquid phase is adequate to neutralise the acid (Staunton et al., 2015; Sell et al., 2011). However, metal and concrete surfaces exposed to headspace biogas and not to the bulk liquid phase, are eventually covered with aerosol moisture and acid formed by the reaction described in Equation 2. It seems that air is being added to the hybrid CAP at Piggery A in excess (average 1.37% oxygen remaining in extracted biogas). For this reason, acid attack of solid surfaces exposed to biogas headspace inside the hybrid CAP, is a key on-going concern.

If air is instead added directly to an external biological scrubber vessel (unlike at Piggery A), any sulphuric acid that forms is neutralised by CAP effluent trickled over the top of the packing medium (Tait and Skerman, 2016 - Talking Topic 4) and acid attack would be minimal. In fact, it may be desirable to encourage formation of sulphuric acid (which is soluble and joins the trickled CAP effluent) in an external scrubber vessel, to limit build-up of elemental sulphur on the packing media. In such cases, it is important that trickled CAP effluent not be recirculated back to the CAP or digester, because the sulphate carried with it will readily convert back into H_2S, causing similar issues to those described above for recycling of elemental sulphur inside a CAP or digester.

Comparing Equations 1 and 2 shows that 4 times more O_2 is required to convert H_2S into sulphate than to convert H_2S into elemental sulphur, so that amounts of O_2 that need to be added to the biological scrubber are much higher, thereby diluting the biogas with inert nitrogen.

3.5 Electricity generation and use

Table 4 summarises total electrical power generated by the biogas generator engines at Piggery A, and also presents the various uses of electricity. Figures 16, 17 and 18 show hourly, daily and monthly electricity generation and use data, respectively. The grid export data was only available on a monthly basis and the grid export values are included with the hourly and daily piggery use data. Over the 3-month monitoring period, 36% of the generated power was used at the pig sheds, 26% was used at the feed mill and 26% was exported to the grid. The remaining 12% (34 kWe) was used to run the hybrid CAP and onsite biogas production and use infrastructure. From Figure 16, it appears that one of the biogas generators provided a baseline electrical output of approximately 170 kWe increasing to 225 kWe for short periods. The two generators operating together produced a maximum output of 463 kWe.

Table 4. Mean hourly, daily and monthly electrical power generation and use for the biogas gensets at Piggery A, for individual months and the entire 3-month monitoring period.

	April	May	June	April-June
Hourly (kWh/h)				
Piggery	131.7	102.8	60.2	98.3
Mill	57.5	83.7	66.1	69.3
Plant	33.9	32.0	35.2	33.7
Grid export	48.9	66.9	91.7	69.1
Total	272.0	285.5	253.3	270.4
Daily (kWh/d)				
Piggery	3,161	2,468	1,445	2,359
Mill	1,380	2,009	1,587	1,662
Plant	813	769	846	809
Grid export	1,174	1,605	2,202	1,660
Total	6,527	6,851	6,079	6,490
Monthly (kWh/month)				
Piggery	94,834	76,520	43,343	71,566
Mill	41,403	62,264	47,604	50,423
Plant	24,376	23,840	25,380	24,532
Grid export	35,206	49,761	66,053	50,340
Total	195,819	212,385	182,379	196,861

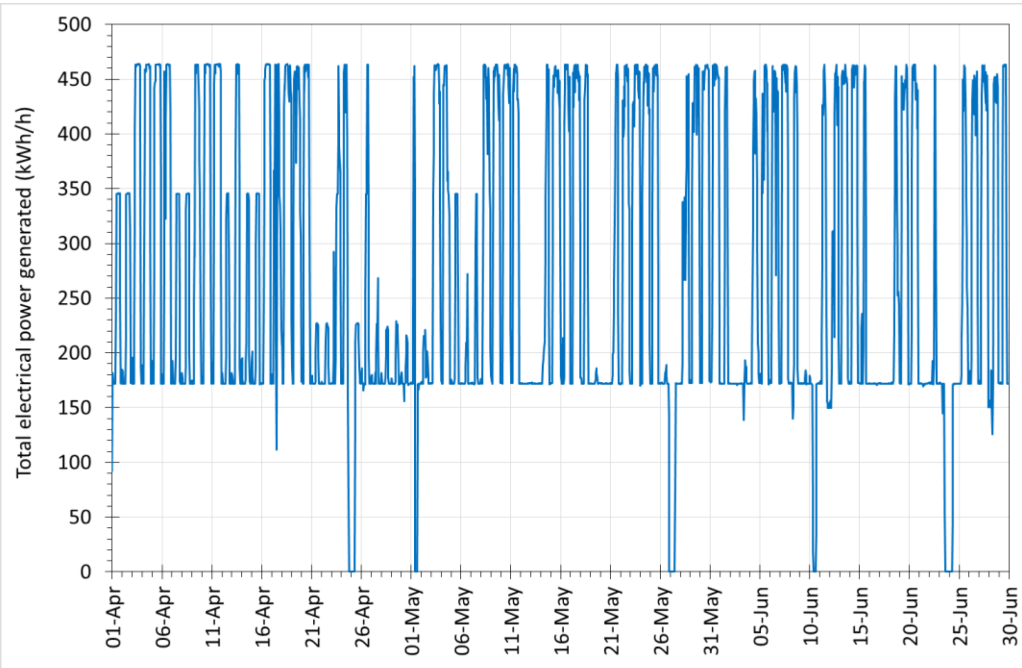

Figure 16. Total hourly power generated by the biogas gensets over the 3-month monitoring period.

Figure 17 shows daily variations in power consumption. The on-site feed mill was a major power user. Over weekend periods when the mill was not operating, one of the generators was typically shut down. Figure 18 shows decreasing power consumption in the piggery with the decreasing average daily maximum and minimum temperatures from April to June. This reflects the lower usage of the evaporative cooling fans, primarily in the piggery grow-out sheds. While there may have been some increase in electricity consumption by heat lamps and heat pads in the 1300 sow on-site farrowing sheds, as the ambient temperatures cooled, the cooling fan operation was the dominant electrical power consumer. As the piggery power consumption decreased from April to June, the export of power to the grid increased substantially. The power required to run the biogas plant remained relatively constant throughout the monitoring period.

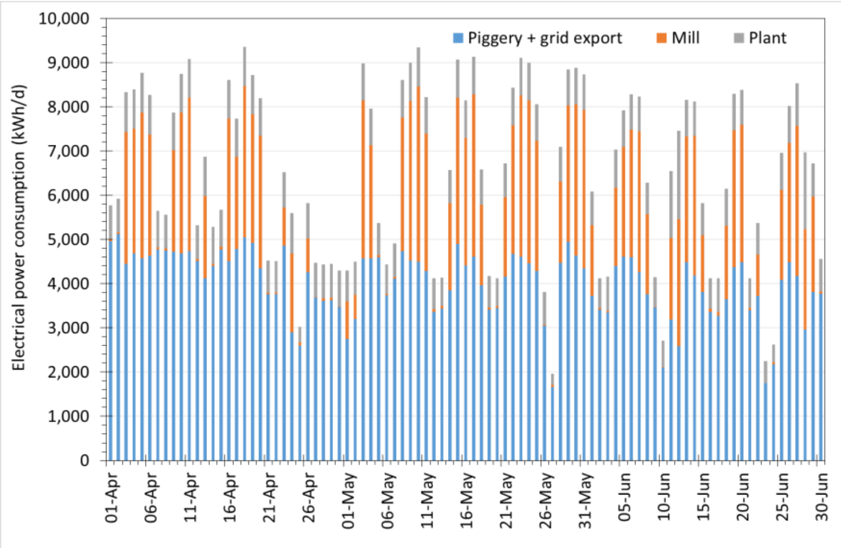

Figure 17. Stacked column graph showing daily power generation and use.

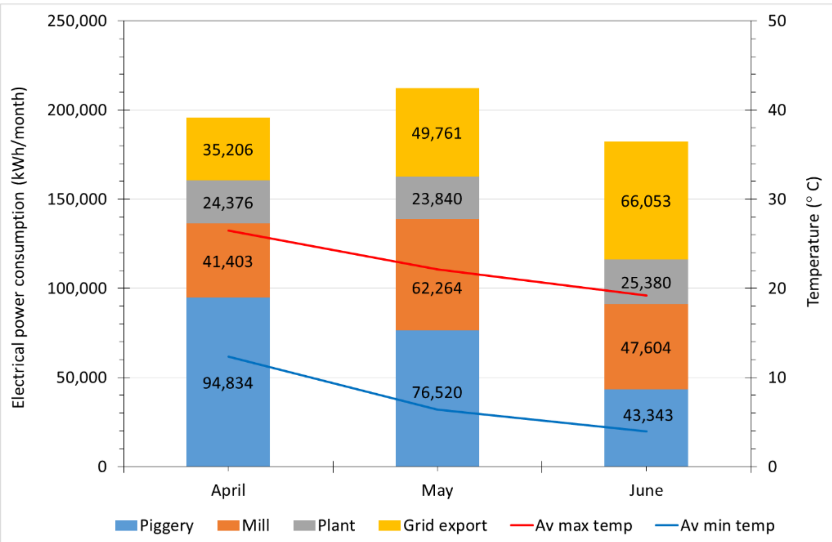

Figure 18. Stacked column graph showing monthly power generation and use and average daily maximum and minimum temperatures.

Figure 19 shows strong correlation between the daily biogas volume consumed by the generators and the total power generated. The power generated per unit volume of biogas is also plotted on this Figure. The average power generated per cubic metre of biogas was 1.73 kWh with a range from 1.51 to 1.87 kWh. The efficiency of biogas use appears to increase on the days of higher biogas consumption when both generator engines were operating at high outputs (approximately 460 kW = 92% of nominal rated power output). Based on the average biogas methane content of 54.96% measured using the MRU SWG 100 analyser and the lower heating value of methane (33.35 MJ/Nm^3 CH_4), the average electrical efficiency of the generator engines was 34%, which is regarded as typical for biogas engines operating at piggery installations.

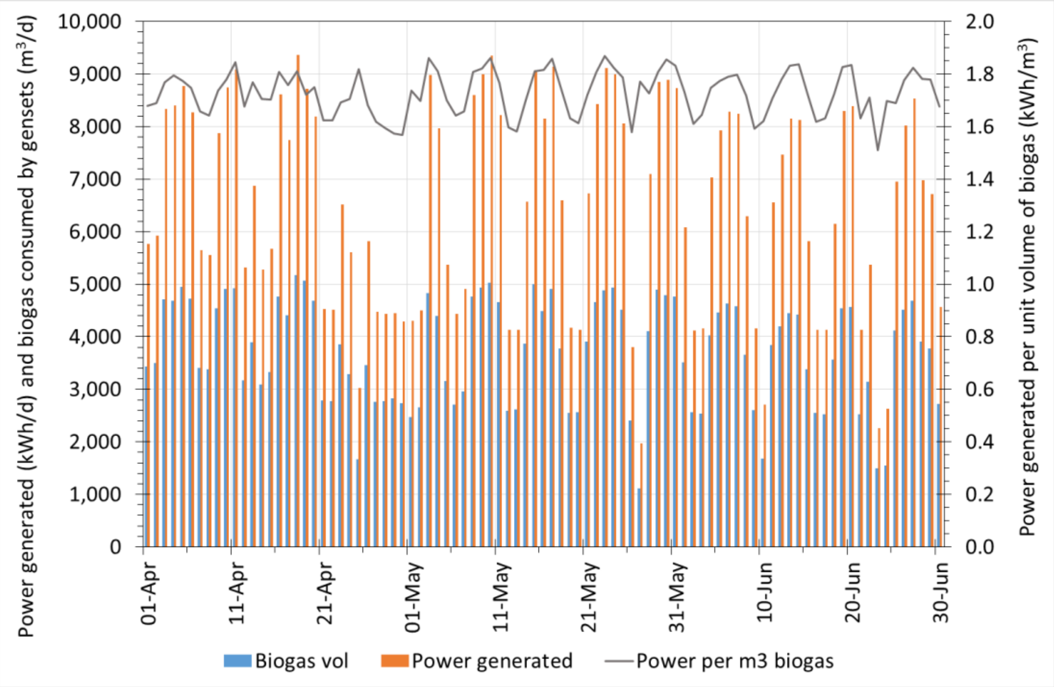

Figure 19. Daily biogas volumes consumed by the gensets, total genset power generation and power produced per unit volume of biogas over the 3-month monitoring period.

3.6 Recommendations for Piggery A

Based on the findings described above, the following recommendations are provided specifically for Piggery A:

- Continue monitoring to identify whether mitigation strategies should be employed to address the potential longer term performance issues highlighted in Section 3.4.
- Consider dosing air into the biogas pipeline, immediately upstream of the biological scrubber, rather than into the hybrid CAP headspace (as described in Talking Topic 4), to prevent accumulation of elemental sulphur inside the hybrid CAP and corrosion of solid surfaces exposed to the biogas headspace.

- If air is dosed into the biogas pipeline immediately upstream of the biological scrubber, a high dosage rate is recommended to minimise the accumulation of elemental sulphur on the packing inside the biological scrubber.

4. Application of Research

Installation of biogas system monitoring instrumentation, similar to that installed with the assistance provided by this project, has considerable potential for improving the management of these systems. More specifically, the high quality, real-time data provided by such installations could be used for:

- Early diagnosis of operational irregularities or system faults which may avoid costly damage to system components such as generator engines.
- Measuring biogas system operating efficiency and evaluating the effects of incremental management changes.
- 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 available biogas.
- Assessing short and long-term seasonal variations in biogas production and quality.
- Managing biogas use options to maximise economic benefit.

The initial installation at piggery A has provided a pilot resource for long-term evaluation and possible modification prior to more widespread deployment across the industry.

5. Conclusions

Over the three month monitoring period, from April to June 2018, the hybrid CAP at Piggery A received unscreened effluent from flushing and pull-plug sheds housing separate grower and breeder units (total capacity of 38,200 SPU). The average biogas production from the hybrid CAP was 5,601 m^3/d. There was a relatively small reduction in biogas production from April to June, despite falling maximum and minimum temperatures at the piggery site. The resulting biogas and methane yields were 523 m^3 biogas and 287 m^3 CH_4, respectively, per tonne of VS discharged into the hybrid CAP. Based on previous biochemical methane potential (BMP) testing results for this piggery (Skerman et al., 2017), the recorded methane yield indicated that the hybrid CAP was achieving a high methane recovery of 88% of the BMP, and was therefore performing as well as could be expected during the monitoring period.

Approximately two-thirds of the biogas produced by the hybrid CAP was used to run two 250 kWe Camda combined heat and power (CHP) generator units while the remaining third of the biogas was burnt in a shrouded flare. There was strong correlation between the measured flare temperature and metered biogas flow through the flare. The substantial consumption of excess biogas in the flare suggests that there is considerable potential for adopting additional, more productive biogas use options.

The two CHP units generated an average of 809 kWh/day over the monitoring period (average output 270 kWe). Sixty-two percent of the electrical power generated by the CHP units was used in the pig sheds, predominantly running cooling fans, lights and heat lamps, 26% of the power was used to operate the on-site feed mill, and the remaining 12% (34 kWe) was used to run the hybrid CAP and onsite biogas production and use infrastructure.

The average power generated per cubic metre of biogas was 1.73 kWh/m^3 biogas. Based on the average biogas methane content of 55% (measured using the MRU SWG 100 analyser, which was upgraded using funds provided through this project), the average electrical efficiency of the generator engines was 34%. This electrical efficiency is regarded as typical for biogas engines operating at piggery installations.

The average H_2S concentration in the biogas extracted from the hybrid CAP (223 ppm) was much lower than typically observed in untreated piggery biogas and was only marginally higher than the typically recommended maximum of 200 ppm for use in generator engines. This suggested that the O_2 in the air injected into the headspace effectively supported significant biological oxidation of H_2S inside the headspace of the hybrid CAP. However, the measured H_2S concentrations exceeded 200 ppm over 32% (678 hours) of the total 3-month monitoring period and were periodically very high, generally following generator stoppages. These findings demonstrate that removal of H_2S by biological oxidation in the hybrid CAP headspace was generally inadequate for safe operation of the generator engines, without further biogas treatment in the external biological scrubber.

The average H_2S concentration measured downstream of the biological scrubber was very low (18 ppm) and instantaneous H_2S concentrations rarely exceeded 200 ppm. This showed that the combined biological oxidation in the hybrid CAP and external biological scrubber was effective at removing H_2S from the biogas.

It may be preferable to inject air into the biogas line upstream from an external biological scrubber, rather than into the CAP headspace. This will prevent the formation of elemental sulphur in the CAP headspace and subsequent deposition in the CAP liquid phase, where it can be converted back into H_2S. This sequence of reactions can progressively increase the H_2S load on the subsequent biogas treatment processes. Based on the limited data acquired over the relatively short monitoring period, this sequence of reactions may be responsible for the general increase in biogas H_2S concentrations observed from April to June (Table 3); however, longer term monitoring would be required to more confidently attribute the observed increase to this process.

When excess air or O_2 is added to the CAP headspace, further oxidation of H_2S can occur to form sulphate instead of elemental sulphur. The resulting sulphuric acid (H_2SO_4) produced by this reaction, can cause severe corrosion of exposed metal or concrete surfaces. Supplying excess O_2 upstream from a separate biological scrubber may be advantageous, by reducing the deposition of elemental sulphur on the scrubber packing elements. In this case, the scrubbing liquid should not be recycled back to the CAP.

High levels of balance gas and relatively low levels of CH_4 and CO_2 measured by the fixed MRU SWG 100 biogas analyser, in comparison to readings taken using portable analysers, suggested that the MRU SWG 100 biogas analyser may require re-calibration. Alternatively, the air dosing rate may be higher than expected, resulting in higher N_2 concentrations in the biogas. This issue has been discussed with the analyser supplier and the piggery project coordinator.

The three-month monitoring period at Piggery A provided considerable useful data regarding the biogas system performance and operation. However, there was insufficient data to conclusively identify issues which currently warrant any major changes to system operations. Consequently, it is recommended that the detailed monitoring program be continued at Piggery A.

Installation of monitoring instrumentation, similar to that installed at Piggery A, with the assistance provided by this project, has considerable potential for improving the management of on-farm biogas systems. More specifically, the high quality, real-time data provided by such installations will assist piggery managers to promptly diagnose operational irregularities and system faults, thereby avoiding costly damage to system components such as generator engines. The resulting data will also assist in evaluating of a range of operating strategies and biogas treatment methods to maximise economic benefit.

The initial installation of monitoring instrumentation at Piggery A has improved the knowledge and experience of researchers, service providers and piggery managers with regard to the available monitoring technology and its practical application in the Australian pork industry. It also provides a model for the further development and more widespread deployment of similar systems across the industry.

6. Limitations/Risks

The monitoring data for Piggery A were recorded over a limited 3-month period, and so were not able to conclusively identify potential longer-term performance issues highlighted in Section 3.4 of the report.

Piggery A is representative of several large Australian piggeries which could potentially benefit from the adoption of biogas systems; however, it is not representative of many smaller Australian piggeries for the following reasons:

- The hybrid CAP at Piggery A receives effluent from a relatively large piggery by Australian standards (35,800 SPU grower unit + a separate 1,200 sow breeder unit; Total = 38,200 SPU).
- The herd composition at Piggery A is not representative of normal farrow to finish units because the grower unit at Piggery A receives the progeny from two separate off- site breeder units (total 3800 sows), in addition to the progeny from a 1,300 sow breeder unit, which was recently established on-the same site as the grower unit.
- A relatively large proportion of the electricity generated by the biogas system is used to power an on-site feed mill. This is atypical for many smaller farrow to finish piggeries.
- The hybrid CAP employed at Piggery A is one of only four similar systems currently operating in Australia. The majority of the remaining 21 biogas systems operating at Australian piggeries are unheated, unstirred CAPs.

While monitoring systems deployed at smaller piggeries would measure smaller biogas flows, they would provide similarly useful analysis and troubleshooting assistance, as for Piggery A in the present report.

Piggeries are increasingly considering co-digestion of pig manure with by-products and wastes imported from other industries, to boost methane production and to receive gate fees for diverting wastes away from landfill. Co-digestion of other wastes together with pig manure can change biogas composition, either increasing or decreasing CH_4 concentration and/or increasing or decreasing H_2S concentration. Therefore, the biogas composition at piggeries that co-digest may be dissimilar to monitoring results observed at Piggery A in the present study.

Unlike the majority of piggery biogas installations in Australia to date, Piggery A uses a hybrid heated, mixed CAP to produce biogas. Unfortunately Piggery D, which operated an unmixed and unheated CAP, was unable to source suitable quotations within the project period and as such could not participate in the project. The project results therefore did not permit a cross-comparison of performance of a CAP and a hybrid CAP, to quantify the net performance benefits of heating and mixing. Heating and mixing requires considerable additional capital investment, so such a cross-comparison and relative cost-benefit analysis would have been particularly useful for further industry consideration.

7. Recommendations

The data collected and analysed for Piggery A, provided a very good understanding of current performance, and also highlighted some key issues to consider in the longer-term with respect to biogas treatment (Section 3.4). Clearly, there is value in being able to monitor and troubleshoot on-farm biogas systems, using similar monitoring infrastructure to that installed at Piggery A, with assistance from this project.

As a result of the outcomes of this study it is recommended that:

- Piggery A regularly recalibrate monitoring instrumentation and continue to monitor longer term performance of onsite biogas production and use;
- Other piggery biogas installations in Australia use the suggested instrumentation specifications provided in this report, and install similar infrastructure onsite to monitoring system performance.

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Appendix 1 - Monitoring instrumentation specifications

The following specifications were provided to producers to assist in obtaining quotations for the required instrumentation:

Pork CRC Project 4C-122:
Installation of instrumentation for remote monitoring of biogas composition and operational data at commercial piggeries

The following minimum requirements are applicable for instrumentation to be installed at existing on-farm biogas plants under the grants program associated with the above project:

Monitoring Parameters

The instrumentation must be capable of monitoring the following parameters:

1. The total flowrate of biogas delivered from the digester or covered anaerobic pond (CAP) to each of biogas treatment systems, engines, boilers or flares.
2. The concentrations of methane (CH_4), carbon dioxide (CO_2), oxygen (O_2) and hydrogen sulphide (H_2S) in the raw biogas, and following one or more respective biogas treatment steps. (Ideally, the instrumentation should be capable of monitoring biogas quality before and after each successive treatment step; e.g. following both biological primary treatment and iron-based chemisorption secondary treatment.
3. The raw biogas temperature and the temperature and moisture content of the biogas following treatment.

It is recognised that program participants would currently have some existing instrumentation in place. Consequently, it will be important for all participants to ensure that the new instrumentation installed under this grant program is compatible with the existing instrumentation (wherever possible) and that the new instrumentation can be integrated into the existing system in the most practical and cost-effective manner.

Remote Monitoring

The monitoring system must include provision for recording (logging at regular intervals), and remotely accessing data relating to each of the parameters described above. Individual participants may also choose to install monitoring systems that incorporate alarms to alert key personnel when the data indicates potential safety hazards or equipment faults.

Data access

The data recorded by the monitoring system must be made available in a timely manner for remote access by the Pork CRC Bioenergy Support Program (BSP) Program Leader and Technical Support Officer, until the scheduled program termination date (30 June 2018). This data will be used for industry research purposes only, and the release of any of such data will be subject to privacy conditions negotiated with the participants.

Instrumentation and installation standards

All instrumentation procured and installed under this program must comply with the APL Code of Practice for on-farm biogas production and use (piggeries) (2015) and any relevant local, state or federal legislation or standards.

Appendix 2 - Monitoring instrumentation quotations

The following quotation was obtained from ThemoFisher Scientific for supply of two sets of the required instrumentation:

Product code, Description & Availability	Pack size	Qty	Unit Price, excl GST	Nett Value, excl GST
<u>Gas Analyser</u>				
Item: GTIBG3KPLUSD-25000 GEOTECH IECEx Fixed BIOGAS 3000 Fixed Analyser with 2 sample points with H2S 200ppm & H2S 5000ppm (**MISCCONS-Q-EA)** **Availability: 2 - 4 weeks**	EA	Qty: 2	**$21,800.00**	**$43,600.00**
Item: GTIADR GA3000 Auto Drain option **Availability: 2 - 4 weeks**	EA	Qty: 2	**$2,300.00**	**$4,600.00**
<u>Flow Meter</u>				
Item: GPAMV80VTP24S150LDDAC3AHSTP1CC **MV80 -** In-line multi-variable Vortex Flow Meter **VTP -** Mass measurement with pressure and temperature compensation **24-S-**150 - 3-inch (80mm) ANSI 150 lb Flanged, 316L **L -** Local Electronics NEMA 4X Enclosure Mounted on Meter **DD -** Digital Display and Programming Buttons **AC -** 100-240 VAC, 50-60Hz Line Power, 2 Watts maximum, 1AH, 1AM, 3AH, 3AM output options **3AH -** Three Analog Outputs (4-20mA), three alarms, one pulse, HART communication protocol - Requires DC4 or AC inout power **ST -** Standard Temperature -400 to 500°F (-400 to 205°C) **P1 -** Maximum 30 psia (2 bara), Proof 60 psia (4 bara) **CC -** MV80/MV82 Certificate of Conformance **(MISCPANA)** **Availability: 8 - 10 weeks**	EA	Qty: 2	**$11,241.00**	**$22,482.00**
<u>Data Telemetry System</u>				
Item: Data Logger and 3G Telemetry DataTaker DT80M with 3G modem 240V powered Wall mount enclosure Audible and visual alarm beacon DataTaker programing Data service – Web hosted data	EA	Qty: 2	**$7,563.00**	**$15,126.00**

Appendix 3 - Expression of interest flyer

The following flyer was distributed to producers by Dr Roger Campbell through a Pork CRC email distribution list on 18 September 2017. Additional emails with this flyer attached were also sent directly to producers with known existing biogas systems.

Funds available to assist producers with biogas system monitoring

The Pork CRC is funding grants to pork producers to assist with installing instrumentation for remotely monitoring the operation of existing on-farm biogas systems. This new initiative is being administered by the Department of Agriculture and Fisheries (DAF), Queensland. A total grant amount of $30,000 is available to share equally between a maximum of three pork producers. These grants must be used to purchase and install instrumentation for monitoring the volume, moisture content, temperature and composition of biogas used in existing on-farm biogas systems. The instrumentation will log the composition of the biogas (methane, carbon dioxide, oxygen and hydrogen sulphide concentrations) at regular intervals, both upstream and downstream from the biogas treatment system. The instrumentation must also include a data logger and communications system to allow remote monitoring of the system operation. The total cost of purchasing and installing the entire biogas monitoring and communication instrumentation is estimated at $50,000 per farm; however, this cost may vary substantially, depending on the existing system components, costs associated with complying with the relevant state gas safety legislation and the amount of labour provided by the producer to assist with system installation.

The comprehensive monitoring data which will become available following installation of this instrumentation is expected to greatly assist producers in the daily operation of their on-farm biogas systems, particularly in relation to:

- early diagnosis of operational irregularities or system faults,
- evaluating operating strategies and biogas treatment methods,
- managing changes in biogas composition,
- validating the energy and economic value of the biogas,
- assessing short- and long-term seasonal variations in biogas production and quality, and
- managing biogas use options to maximise economic benefit.

All expressions of interest submitted by producers will be assessed by Pork CRC representatives and a maximum of three producers will be selected to receive the subsidies. If fewer than 3 expressions of interest are received, the available funds ($30,000) will be shared equally between eligible producers. Agreements will then be negotiated between the successful producers and DAF. Under these agreements, each producer will be responsible for the purchase, installation and commissioning of the instrumentation, in accordance with all relevant regulatory standards and legislation. This will require a substantial investment by the

participating producer(s) to fund the shortfall between the grant amount and the total cost of the installation. Pork CRC Bioenergy Support Program (BSP) researchers will be available to provide technical support with the installation of the monitoring equipment. The agreements will also require participating producers to grant Pork CRC BSP researchers with full access to the data collected by the biogas monitoring instrumentation for a minimum period of 2 years (subject to reasonable privacy provisions).
For further information on how to participate in this initiative, please contact Mr Alan Skerman (07 4529 4247, alan.skerman@daf.qld.gov.au). The deadline for receiving expressions of interest is Friday, 22 September, 2017.

Appendix 4 - APN article

It's a gas article published in the September 2017 edition of Australian Pork Newspaper.

Taking biogas system monitoring for granted

Pork CRC

by ALAN SKERMAN
Leader, Pork CRC Bioenergy Support Program

PORK CRC is funding grants to a limited number of Australian pork producers with existing biogas systems to help them install remote monitoring instrumentation on their Australian biogas systems.

This initiative is being administered by the Queensland Department of Agriculture and Fisheries.

A total of $30,000 is available to share equally between a maximum of three pork producers.

Grants must be used to buy and install instrumentation for monitoring flow volume, moisture, temperature and composition of biogas used in existing Australian on-farm biogas systems.

The instrumentation, which will regularly log the composition of the biogas (methane, carbon dioxide, oxygen and hydrogen sulphide concentrations), upstream and downstream of biogas treatment, must also include a data logger and communications system to allow remote monitoring of the system operation.

The total cost of buying and installing the entire biogas monitoring and communication instrumentation is estimated at $50,000 per farm, however this may vary depending on existing system components, costs associated with complying with the relevant state gas safety legislation and labour to assist with system installation.

The purpose of the monitoring is to provide full data collected to the Pork CRC Bioenergy Support Program for a minimum of two years (subject to reasonable privacy provisions).

This monitoring data is to be used for the following purposes:

- Early diagnosis of operational irregularities or system faults;
- Evaluating operating strategies and biogas treatment methods;
- Managing changes in biogas composition;
- Validating the energy and economic value of biogas;
- Assessing short and long-term seasonal variations in biogas production and quality;
- Managing biogas use options to maximise economic benefit; and
- Quantifying biogas production in the pork industry.

Expressions of interest are to be submitted to the email address below and will be assessed to select a maximum of three for receipt of the grants.

If fewer than three eligible expressions are received, the available funds ($30,000) will be shared equally between eligible expressions received.

Agreements will be negotiated between the successful producers and DAF Queensland.

Under these agreements, each producer will be responsible for the purchase, installation and commissioning of the instrumentation, in accordance with all relevant regulatory standards and legislation.

This will require a substantial investment by the participating producer(s) to fund the shortfall between the grant amount and the total cost of the installation.

Pork CRC Bioenergy Support Program researchers will be available to provide technical support with the installation of the monitoring equipment.

For further information on how to participate or make a submission, contact me on 07 4529 4247 or email submissions to alan.skerman@daf.qld.gov.au

Please note, expressions of interest close Friday, September 22, 2017.

www.porkcrc.com.au