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# Methane recovery and use at Grantham piggery

## *Addendum to final report*

DECEMBER 2013

RIRDC Publication No. 13/107

Australian Government

Rural Industries Research and
Development Corporation

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## Addendum to final report

by Alan Skerman

December 2013

RIRDC Publication No. 13/107
RIRDC Project No. PRJ-005672

ISBN 978-1-74254-600-1
ISSN 1440-6845

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*Publication No. 13/107*
*Project No. PRJ-005672*



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Electronically published by RIRDC in December
Print-on-demand by Union Offset Printing, Canberra at www.rirdc.gov.au
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# Foreword

Methane is the dominant greenhouse gas emission from Australian agriculture and has been identified as a priority area for emission reductions within the livestock sector. The potential for capture and use of methane is greatest in the intensive livestock industries, where manure management is estimated to contribute three percent of the emissions from Australian agriculture.

This project was part of the Australian Methane to Markets in Agriculture (AM2MA) program, which was managed by the Rural Industries Research and Development Corporation. The project was supported by funding from the Australian Government's Climate Change Research Program along with funding and support from industry partners: the Rural Industries Research and Development Corporation, Dairy Australia, Australian Pork Limited, Meat and Livestock Australia, the Australian Lot Feeders' Association, and the Australian Chicken Meat Federation.

This project involved upgrading the biogas extraction system installed in conjunction with a partial floating cover previously retro-fitted to the primary anaerobic pond at the Queensland Natural Pork Holdings (QNPH) Grantham piggery under an earlier AM2MA project (Project No. PRJ-003003). Following the system upgrade, the project also included the installation of a biogas reticulation pipeline to supply a water heating system used to heat the farrowing sheds at the piggery. The biogas water heating system is expected to significantly reduce Liquid Petroleum Gas (LPG) consumption, resulting in significant energy savings.

The outcomes of this project will benefit intensive livestock producers by reducing the risk involved in establishing biogas collection and use systems. This may encourage producers to implement similar systems for the purpose of reducing their energy consumption and greenhouse gas (GHG) emissions. The technologies developed in this project may also assist pig producers with the adoption of the recently launched Carbon Farming Initiative (CFI) methodology.

The objectives of the AM2MA program were:

- development and adaptation of methane capture and use technology for application in the Australian intensive livestock industries
- reduction of the uncertainty, risk and cost of installing methane capture and use systems
- effective communication of project outcomes
- facilitation of commercialisation of on-farm systems for methane capture and use technology.

This report is an addition to the Rural Industries Research and Development Corporation's (RIRDC's) diverse range of over 2000 research publications and it forms part of our former AM2MA R&D program, which aimed to develop/adapt methane capture and use technology for application in Australian intensive animal industries.

Most of RIRDC's publications are available for viewing, free downloading or purchasing online at www.rirdc.gov.au. Purchases can also be made by phoning 1300 634 313.

**Craig Burns**
Managing Director
Rural Industries Research and Development Corporation

# Acknowledgments

Messrs John McAlpine, Jim McAuley and Brendan Marquardt of DAFF (Qld) for assistance in carrying out this project

QNPH Grantham piggery owners, Messrs Jeremy Whitby and Graham Bourke
Piggery manager, Mr Darren Keep and piggery employees

Australian Methane to Markets in Agriculture (AM2MA) program manager, Mr Griff Rose

# Abbreviations

| | |
|---|---|
| AGA | Australian Gas Association |
| AM2MA | Australian Methane to Markets in Agriculture program |
| APL | Australian Pork Limited |
| ASQ | Agri-Science Queensland |
| CFI | Carbon Farming Initiative |
| CHP | Combined heat and power (biogas use system) |
| $CH_4$ | Methane |
| $CO_2$ | Carbon dioxide |
| $CO_2$-e | Equivalent carbon dioxide global warming impact |
| DAFF | Australian Department of Agriculture, Fisheries and Forestry |
| DAFF (Qld) | Department of Agriculture, Fisheries and Forestry (Queensland) |
| DCCEE | Department of Climate Change and Energy Efficiency |
| GHG | Greenhouse gas |
| $H_2S$ | Hydrogen sulphide |
| HDPE | High density polyethylene |
| HWS | Hot water system |
| LPG | Liquid petroleum gas |
| PE | Polyethylene |
| Pork CRC | Pork Cooperative Research Centre |
| QNPH | Queensland Natural Pork Holdings |
| RIRDC | Rural Industries Research and Development Corporation |
| SPU | Standard pig unit |

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# Executive Summary

## What the report is about

This report is an addendum to the final report prepared for the Australian Methane to Markets in Agriculture (AM2MA) research project PRJ-005672 ‘Methane recovery and use at a piggery – Grantham’ (Skerman and Collman, 2012). It provides additional monitoring data relating to the performance of the biogas-fired water heating system and scrubber installed at the QNPH Grantham piggery, for the period extending from June 2012 to May 2013, following the submission of the Final Report.

## Who is the report targeted at?

The information provided in this report will assist producers, industry bodies, researchers, industry service providers, contractors, government policy makers and regulators who have an interest in the planning, design, installation and operation of biogas capture and reuse systems at Australian intensive livestock production facilities.

## Where are the relevant industries located in Australia?

The outcomes of this research are directly applicable to the Australian pork industry and could be adapted to other intensive livestock industries, particularly the dairy industry. The pork and dairy industries operate in all Australian states. There has been considerable interest in adopting biogas collection and use systems within the Australian pork industry during recent years. At the present time, several major Australian pig producers are in the process of investigating, planning or constructing on-farm biogas systems. The recent introduction of the Carbon Farming Initiative (CFI) ‘Methodology for the destruction of methane generated from manure in piggeries’ (DCCEE, 2011) has resulted in increased producer and industry interest in adopting on-farm biogas technology.

## Background

This project followed on from two previous AM2MA projects carried out at the Queensland Natural Pork Holdings (QNPH) Grantham piggery, viz. Project No. PRJ-003003: ‘Biogas production by covered lagoons – QNPH piggery, Grantham Qld’; and PRJ-004547: ‘Options for biogas cleaning and use on-farm’. The final reports for these projects (Skerman *et al.*, 2011 and 2012, respectively) provide detailed background information regarding the piggery operation, design and installation of the partial floating pond cover, operational monitoring data and details of the design and installation of the biogas scrubber.

Due to delays in upgrading the original biogas system and installing the new pipeline and heating system at the Grantham piggery, limited water heating system monitoring data was available prior to June 2012 deadline for submission of the Final Report for Project No PRJ-005672 (Skerman and Collman, 2012). To maximise the benefits resulting from the significant investment already made in establishing the facilities at the piggery, this project was formally extended to 31 May 2013, to enable the collection of additional monitoring data. This report is an addendum to the Final Report. It provides additional monitoring data relating to the performance of the biogas water heating system and outlines several issues addressed in operating the system and commencing initial scrubber trials during the period from June 2012 to May 2013.

## Aims/objectives

The objectives of this project, as outlined in the research agreement, were:

- to drive the uptake of waste water methane recovery and beneficial use technologies in Australian agriculture by demonstrating such technologies at a piggery
- to communicate the benefits of methane recovery and use as a clean energy source through reports and field days at the demonstration site
- to adapt technologies, quantify risks and collect data to facilitate improvement of economic assessment and emissions estimation through activities at the demonstration site
- to increase understanding of the benefits of recovering waste methane as a resource
- to reduce the uncertainty, risk and cost of installing methane recovery and use systems.

## Methods used

The additional data collection was implemented as follows:

1. Ongoing monitoring of biogas and LPG consumption in the water heating system, biogas composition, and pond effluent, biogas and air temperatures. This monitoring data has been collated and analysed.
2. Maintaining the biogas system installed at the piggery.
3. Carrying out a preliminary trial employing a commercial scrubbing medium to remove hydrogen sulphide from the biogas in an iron-sponge type scrubbing vessel.
4. Carrying out a range of activities to communicate the benefits of methane recovery and use as a clean energy source. These activities included hosting site visits by various groups, and preparing and presenting formal papers and talks at public and industry conferences and meetings.

## Results/key findings

The temperature data collected during the extended monitoring period was generally consistent with data presented in the Final Report (Skerman and Collman, 2012). The relatively high thermal mass of the effluent stored in the pond resulted in more stable pond effluent temperatures in comparison with the ambient air temperatures recorded at the site. This buffering effect appeared to increase with depth in the pond.

Biogas composition analyses suggested average methane, carbon dioxide and hydrogen sulphide concentrations of 67%, 32% and 2198 ppm, respectively. These results are consistent with data presented in the Final Report (Skerman and Collman, 2012).

Following the installation of a new data logger in December 2012, the average biogas and LPG consumption rates in the water heating system were 83.97 and 15.13 $m^3$/day, respectively, with maximum values of 117.45 and 16.31 $m^3$/day, respectively, (excluding periods when the hot water systems were not operating). To date, the partially covered anaerobic pond appears to be able to sustain constant operation of the biogas water heating unit. The recent biogas usage rates exceed the previously measured flows reported by Skerman and Collman (2011) by 24%. This apparent increase in biogas production may be due to changes in piggery shed flushing practices.

## Implications for relevant stakeholders

The monitoring data collected during the extended monitoring period indicates that a saving in LPG costs of $31,776 per year should be possible provided the biogas HWS can be made to operate reliably, with minimum downtime. It is estimated that biogas could supply approximately 64% of the total farrowing shed heating energy requirement for the piggery, based on the LPG usage records presented by Skerman and Collman (2012) for the period from April 2009 to March 2010.

Based on using SULFA-BIND® for scrubbing the raw biogas collected under the partially-covered pond, and assuming that the SULFA-BIND® can be effectively regenerated 12 times, as suggested by the manufacturers, it is estimated that 221 kg of SULFA-BIND® would be required annually to effectively treat the biogas. Based on a unit cost of $28.60/kg, the annual SULFA-BIND® cost would be $6,312 per year.

The unit cost of SULFA-BIND® may be reduced if several biogas users could arrange a bulk purchase. As the number of Australian piggeries installing biogas systems increases, bulk purchases may become a more realistic option. Alternatively, there may be other less costly scrubbing media available on the market.

A recently commenced Pork CRC funded research project is currently investigating a range of biogas scrubbing technologies and alternative low-cost media for use in iron-sponge type scrubbers. This project may provide more cost-effective options for improving the quality of biogas so that it is more suitable for a range of productive uses.

Experience gained during this project suggests that the use of raw (unscrubbed) biogas in the water heating system may reduce the working life of some of the components. Regular inspections and maintenance of gas train components are recommended. The installation of an effective scrubbing device may significantly prolong the life of the biogas hot water system and other system components.

## Recommendations

Regular inspections and maintenance of the biogas system components is recommended to ensure ongoing safe operation of the system and to prolong the life of the various components. This is particularly important due to the corrosive and toxic nature of the untreated biogas.

It is recommended that pig producers who install biogas collection and use systems investigate cost effective options for removing hydrogen sulphide from the biogas, to improve the working life of system components and so that it is more suitable for a range of productive uses.

It is anticipated that a recently commenced Pork CRC funded research project will draw on the findings of this project in investigating a range of robust, cost-effective biogas scrubbing technologies, suitable for use at Australian piggeries.

# Introduction

Due to delays in upgrading the original biogas system and installing the new pipeline and heating system at the Grantham piggery, limited water heating system monitoring data was available prior to June 2012 deadline for submission of the Final Report for RIRDC Project No PRJ-005672 (Skerman and Collman, 2012). To maximise the benefits resulting from the significant investment already made in establishing the facilities at the piggery, this project was formally extended to 31 May 2013, to enable the collection of additional monitoring data, as specified in a variation to the project agreement signed on 14 June 2012.

This report is an addendum to the Final Report submitted for RIRDC Project No PRJ-005672 (Skerman and Collman, 2012). It provides additional monitoring data relating to the performance of the biogas water heating system and outlines several issues addressed in operating the system and commencing initial scrubber trials during the period from June 2012 to May 2013.

# Objectives

The following objectives were specified in the research agreement:

- drive the uptake of waste water methane recovery and beneficial use technologies in Australian agriculture by demonstrating such technologies at a piggery
- communicate the benefits of methane recovery and use as a clean energy source through reports and field days at the demonstration site
- adapt technologies, quantify risks and collect data to facilitate improvement of economic assessment and emissions estimation through activities at the demonstration site
- increase understanding of the benefits of recovering waste methane as a resource
- reduce the uncertainty, risk and cost of installing methane recovery and use systems.

# Methodology

## Monitoring data

Table 1 describes the parameters monitored, locations, monitoring methods and data collection periods, for the operational data collected during the course of the extended project. This monitoring followed on from the data collection carried out under PRJ-003003, as reported by Skerman *et al.* (2011).

**Table 1. Parameters monitored during the course of the project.**

| Parameter | Location | Monitoring method | Data collection period |
|---|---|---|---|
| Pond effluent temperature | Edge of the floating pond cover at depths of 0.3, 1.0 and 1.8 m | HOBO Pendant temperature data loggers suspended from the floating cover using a stainless steel cable | June 2011 – Feb 2013 |
| Ambient air temperature | Beside covered pond | Tinytalk temperature data logger and HOBO Pendant temperature data logger installed in solar radiation shield | June 2011 – April 2013 |
| Biogas volume consumed in biogas water heater | Adjacent to the water heater, between piggery sheds 2 and 3. | Landis+Gyr Model 750 gas meter fitted with an Elster IN-Z61 low-frequency pulse transmitter connected to a HOBO UX120-017 four channel pulse input data logger | May 2012 – May 2013 |
| LPG volume consumed in LPG water heater | Adjacent to the water heater, between piggery sheds 2 and 3. | Landis+Gyr Model 750 gas meter fitted with an Elster IN-Z61 low-frequency pulse transmitter connected to a HOBO UX120-017 four channel pulse input data logger | May 2012 – May 2013 |

## Biogas water heating system

As described by Skerman and Collman (2012), during April 2012, a new Rheem Model 631265NO heavy-duty gas hot water system (HWS), designed to run on natural gas, was installed between piggery sheds two and three, beside a similar, existing LPG-fired unit. The new HWS was converted to run on biogas by Williamson Brothers Plumbers. This involved adjusting the burner pressure at the inlet regulator, drilling out the main jet from 4.8 mm to 6.0 mm diameter and making minor adjustments to the mixture (interrupter) screw on the throat of the burner (Figure 1).

Following the installation of the electrical control system, the biogas water heating system was commissioned during April 2012. A gas system compliance certificate was issued for the conversion of the HWS to biogas operation, on 22 October 2012 (Figure 2).

Figure 3 shows the water heating system and iron-sponge scrubber developed to remove hydrogen sulphide from the biogas. The development of the scrubber is described in detail in the Final Report for PRJ-004547 (Skerman *et al.*, 2012).

The biogas water heating unit was initially connected to the underfloor heating system in one of the two farrowing sheds (shed 2). The underfloor heating system in the other farrowing shed (shed 4) at the piggery was connected to the biogas water heating system on 23 July 2012.

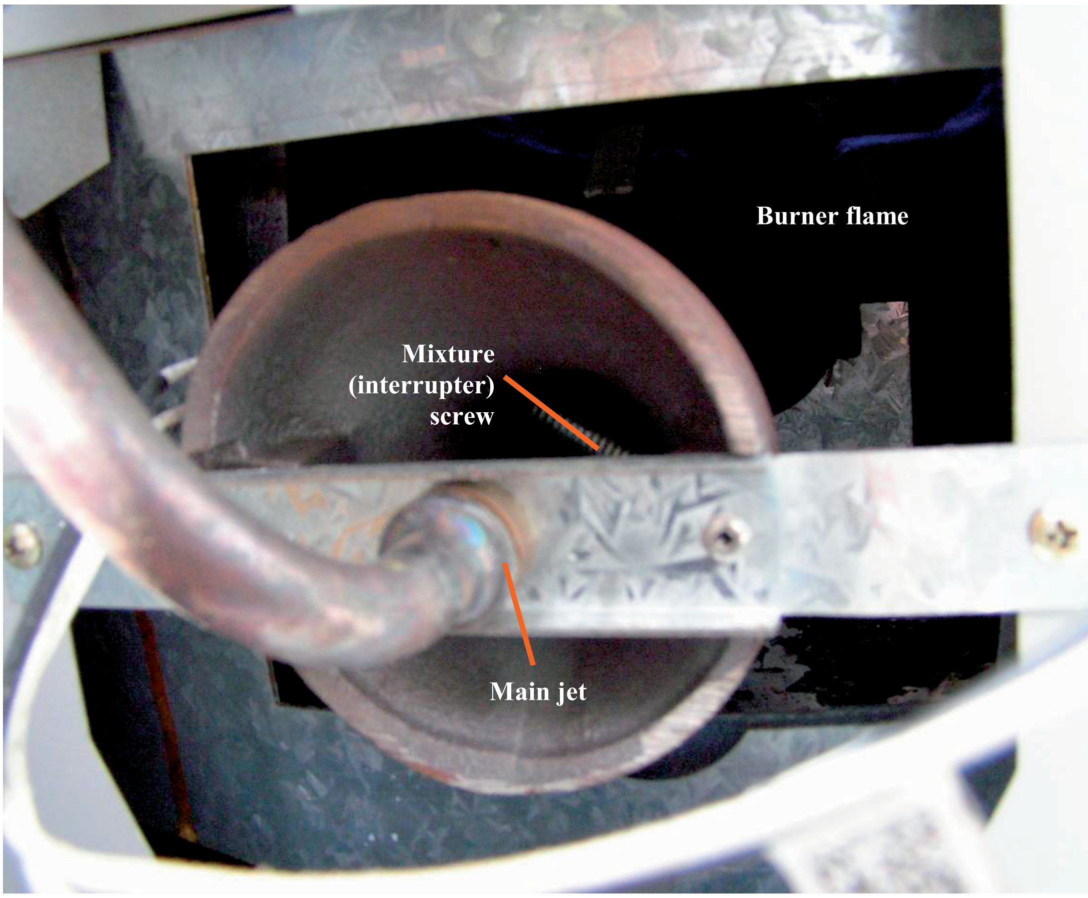


**Figure 1. Photograph showing the converted burner in the biogas hot water system.**

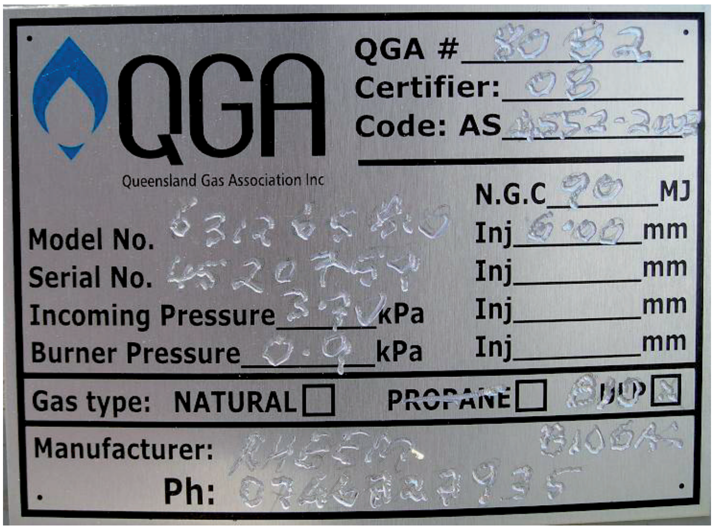


**Figure 2. Queensland Gas Association certification plate fixed to the side of the converted biogas hot water system.**


**Figure 3. Biogas and LPG water heating systems, biogas scrubber and elevated hot water header tank.**

The burner in the converted Rheem HWS was originally fitted with an electrically activated ceramic element to ignite the gas flow. After three attempts at lighting, the electrical control system in the HWS shuts down, requiring manual resetting before attempting re-ignition. During initial operation of the biogas HWS, it appeared that the biogas was not igniting reliably, resulting in the system shutting down on several occasions. To address this issue, an authorised Type-B gas fitter (Williamson Brothers Plumbers) installed an LPG pilot flame supplied from the nearby LPG gas line, on 5 October 2012. This appeared to improve the reliability of the biogas ignition. The ceramic element was retained as an alternative ignition option in the modified system.

Further problems were experienced with the operation of the biogas HWS and it was found that the gas control solenoid valve (White Rodgers 36C90H-408, Rheem part No 079500), as shown in Figure 4, was not allowing gas flow to the burner when the electrical control system was prompting start-up. The original valve was replaced on 17 October 2012.

To enable monitoring of the biogas and LPG water heater operation, a four channel pulse input data logger (HOBO UX120-017) was installed on 20 December 2012 to record the pulse output from the biogas and LPG gas meters (Landis+Gyr Model 750 fitted with Elster IN-Z61 low frequency pulse transmitters).

The biogas HWS once again ceased operating effectively during late December 2012. It was determined that the second gas control valve had failed after approximately 10 weeks of operation. This valve was replaced on 23 January 2013. The gas fitter believed that the gas control valve failures may have been caused by an excessive build-up of heat from the burner in the vicinity of the valve. It had been observed that the baffles in the HWS flue had been partially blocked by a build-up of a flaky sulphurous deposit, as shown in Figure 5. This may have prevented some of the hot exhaust gases from escaping up the flue, resulting in an excessive heat build-up near the gas control valve.

In an attempt to address the heat build-up issue, the gas fitter removed all of the radial steel baffles from the flue to improve exhaust gas flow. While this action undoubtedly improved the exhaust gas flow, the heat transfer performance of the water heater was noticeably reduced. After the removal of the baffles, the piggery manager observed that the biogas water heater operated continuously without reaching the target shut-off temperature of 65°C set on the thermostat.

The biogas HWS operated effectively for a period of approximately 7 weeks, until 11 March 2013, before the third gas control valve failed. Due to uncertainty over the availability of project funds and the availability of the gas fitter, a new gas control valve was not installed until 22 April 2013. To address the potential for further damage to the gas control valve due to excessive heat from the burner, the gas fitter installed a heat shield which was fabricated on-site from galvanised steel sheeting, as shown in Figure 6.

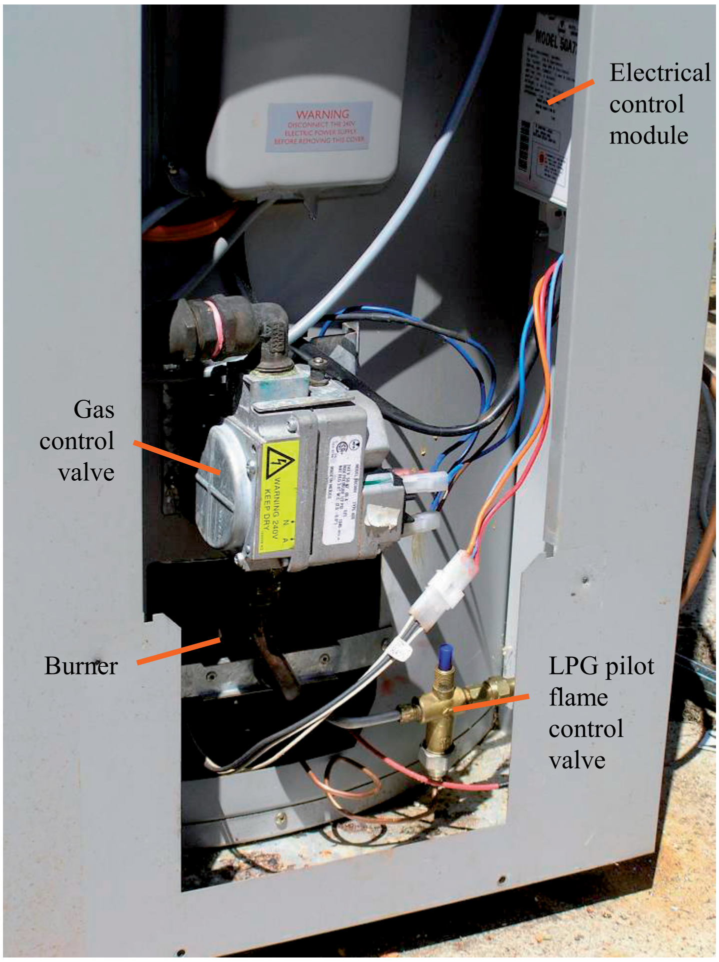


**Figure 4. Rheem Model 631265NO hot water system with cover plate removed showing the electrical control module, gas control valve, burner and LPG pilot flame control valve.**

**Figure 5. Flaky sulphurous deposit in the baffles of the biogas hot water system flue.**

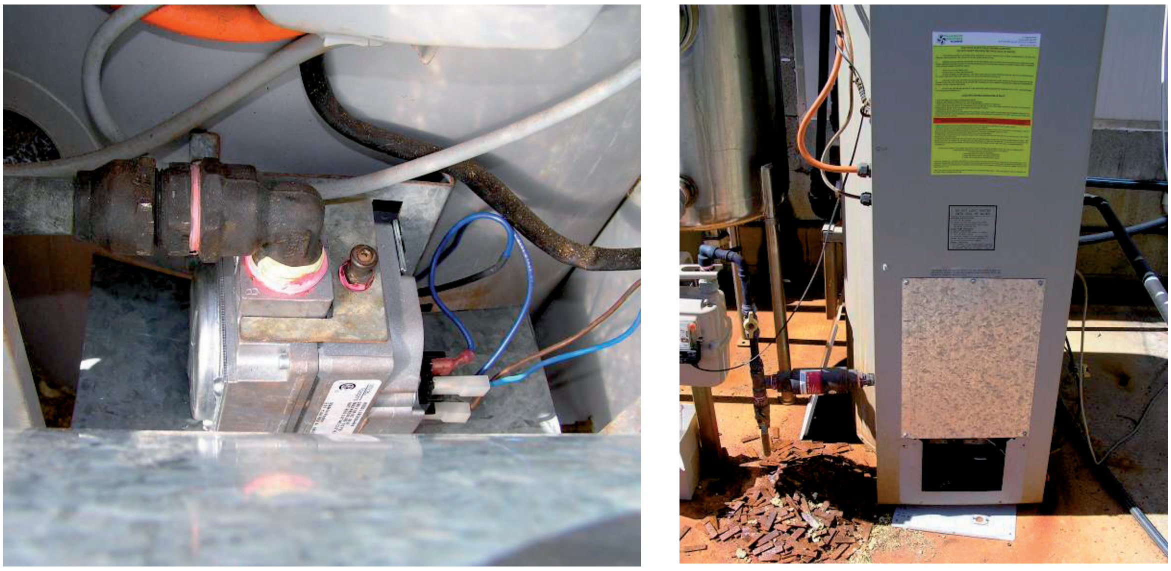

**Figure 6. Galvanised steel heat shield installed in biogas HWS to protect the gas control valve from excessive heat from the burner.**

An alternative trial baffle (Figure 7) was manufactured in the Agri-Science Queensland workshop and installed in the HWS flue on 1 May 2013. It is hoped that this baffle will improve heat transfer from the flue gas to the water tank, while being sufficiently free-flowing to minimise the risk of excessive heat build-up near the base of the HWS. This baffle can also be removed and cleaned relatively easily. While this trial baffle was made from galvanised steel sheeting which may have a limited life due to the corrosive nature of the raw biogas, if it proves to be successful, an improved version could be made from a corrosion-resistant material such as stainless steel.

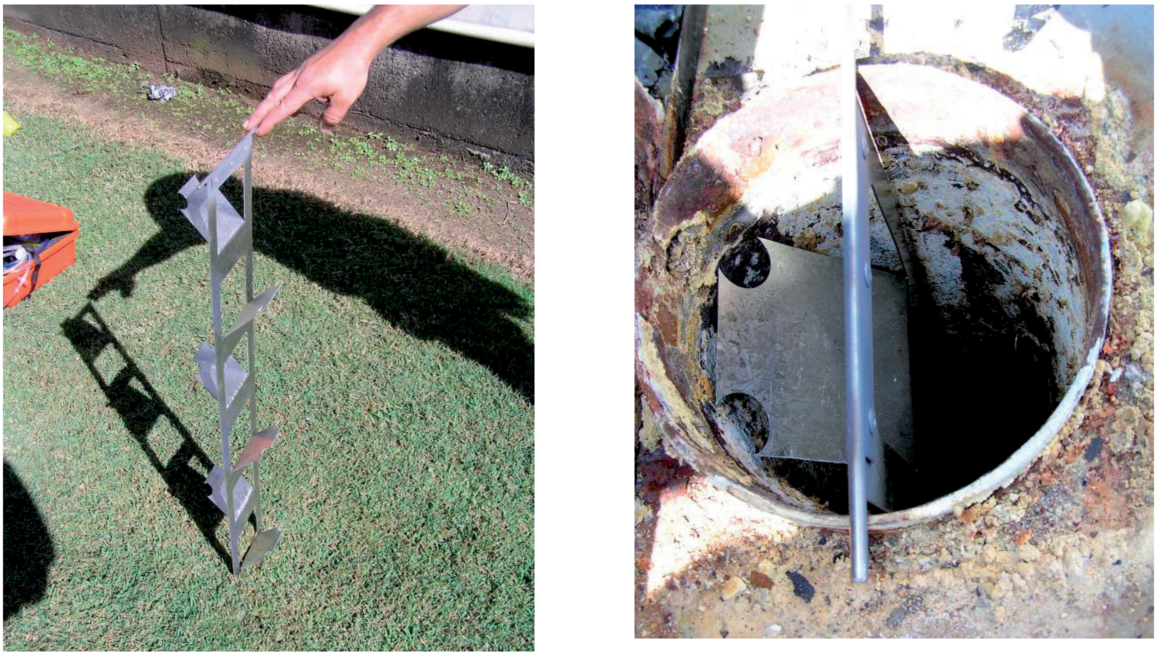

**Figure 7. Alternative baffle installed in biogas HWS flue.**

## Biogas composition

A Geotech Biogas Check portable gas analyser, as shown in Figure 8, was purchased in June 2011, to enable convenient, regular monitoring of the biogas quality. The portable analyser measures methane and carbon dioxide using infra-red absorption, oxygen using an electrochemical cell and hydrogen sulphide using an electrochemical cell installed in an external gas pod. This instrument was used to measure gaseous concentrations primarily just upstream from the hot water system. Calibration of the instrument was carried out at regular intervals using a cylinder of 60% methane – 40% carbon dioxide calibration gas and a cylinder of 2000 ppm hydrogen sulphide calibration gas purchased from a commercial company.


**Figure 8. Geotech Biogas Check portable gas analyser used to monitor biogas quality.**

## Scrubber trial

The commencement of the scrubber trial was delayed due to the ongoing reliability issues with the biogas water heating system and delays in the replacement of the gas control valve. Two drums (30 kg) of SULFA-BIND® commercial scrubbing medium was added to the iron-sponge type scrubber depicted schematically in Figure 9, prior to the replacement of the HWS gas control valve on 22 April 2013. The SULFA-BIND® medium was poured into a large funnel inserted into a 50 mm port on the top of the scrubber vessel. As the depth of the SULFA-BIND® bed progressively increased in the vessel, a manual spray bottle was used to dampen the medium. The biogas HWS has continued to operate virtually continuously since the valve replacement on 22 April 2013.

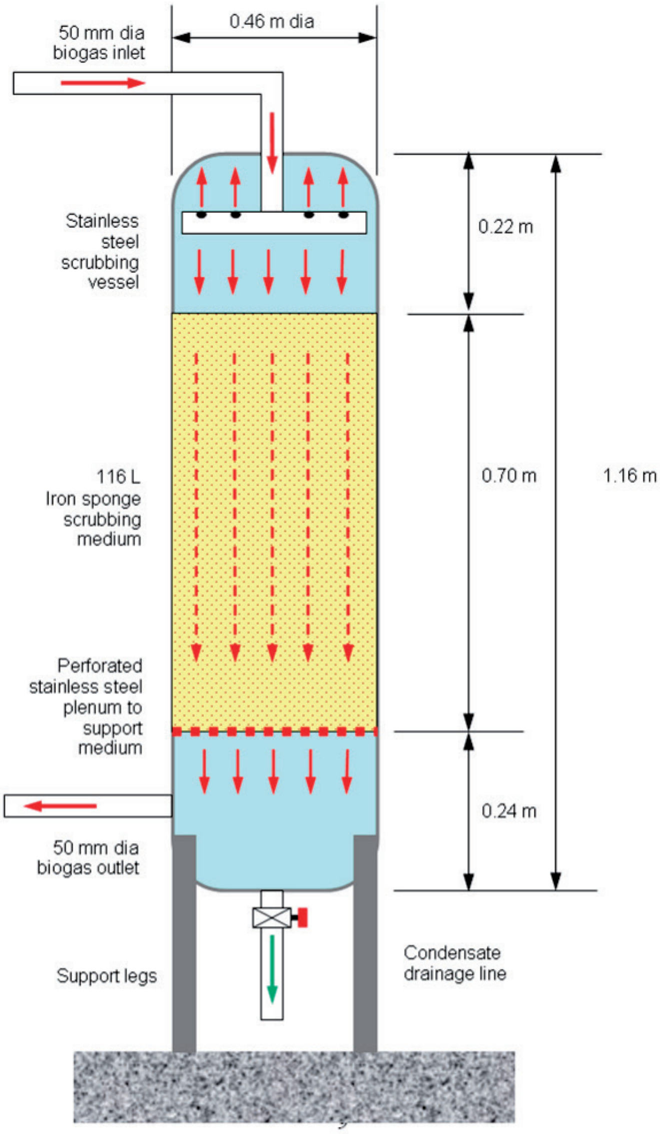


**Figure 9. Schematic drawing of the ironIron**

Following the addition of the scrubbing medium, the scrubbing vessel and short length of pipe between the scrubbing vessel and the HWS were purged with biogas prior to the HWS being restarted. Purging is carried out to avoid the possibility of an explosive air/gas mixture existing or forming in consumer piping, appliances or confined places (AS/NZS 5601.1:2010, Appendix D).

In this case, it was important to ensure that air which entered the scrubbing vessel during the placement of the scrubbing media was purged to prevent the possible ignition of a potentially explosive mixture of biogas and air (the lower and upper explosive limits of methane in air are 5% and 15%, respectively, while the average biogas methane concentration measured at the site was 67%). The purging process involved connecting a long length of tubing to the condensation release valve just upstream from the HWS. This tubing was connected to a purge bucket placed at a safe area beyond the end of the piggery sheds. The purge bucket was filled with water which acted as a flame arrester.

A third 15 kg drum of SULFA-BIND® was added to the scrubber on 1 May 2015. Following the addition of the third drum of SULFA-BIND®, the scrubbing media was thoroughly wet using a hose and the excess moisture was drained through the condensation release valve on the bottom of the scrubbing vessel. The Geotech Biogas Check portable gas analyser was used to measure the hydrogen sulphide concentration upstream and down stream from the scrubber.

## Flare maintenance

The biogas system at the Grantham piggery incorporates a normally-open, pneumatically actuated valve which directs the biogas collected under the pond cover to the flare when the hot water system is not operating. The flare operates under the relatively low passive pressure (approximately 30 Pa) which builds up under the pond cover (unassisted by the gas pressure booster which supplies the HWS). During periods when the biogas hot water system was not operating, it was observed that the flare (located adjacent to the biogas extraction system, near the partially covered pond) was not operating. After dismantling the flare, a blockage was found on the upper side of the ball valve fitted to the stem of the flare. This blockage appeared to consist of a hard plug of a carbon-rich deposit, as shown in Figure 10. Following the removal of this blockage, the flare has continued to operate effectively.

**Figure 10. Hard, carbon-rich deposit which had built up on the upper side of the ball valve installed on the stem of the flare, blocking biogas flow.**

# Results

## Temperature data

Table 2 provides a summary of the averages, maximums, minimums and ranges for the ambient air temperatures recorded at the site, and the pond effluent temperatures recorded at three depths (0.3 m, 1.0 m and 1.8 m) in the partially covered primary anaerobic pond. Figure 11 is a graphical representation of this temperature data recorded at 30 minute intervals. Unfortunately, the pond temperature loggers inexplicably disappeared between February and May 2013, effectively limiting the monitoring period.

**Table 2. Averages and ranges of ambient air, pond effluent and biogas temperatures.**

| Parameter | Ambient air | Pond effluent depth | | |
|---|---|---|---|---|
| | | 0.3 m | 1.0 m | 1.8 m |
| Monitoring period start | Jun 11 | Jun 11 | Jun 11 | Jun 11 |
| Monitoring period end | May 13 | Feb 13 | Feb 13 | Feb 13 |
| Logging interval (min) | 30 / 60 | 30 | 30 | 30 |
| Average temperature (˚C) | 19.0 | 21.8 | 21.9 | 21.9 |
| Maximum temperature (˚C) | 40.5 | 32.3 | 30.1 | 30.0 |
| Minimum temperature (˚C) | -0.7 | 11.6 | 13.0 | 13.2 |
| Temperature range (˚C) | 41.2 | 20.7 | 17.1 | 16.8 |

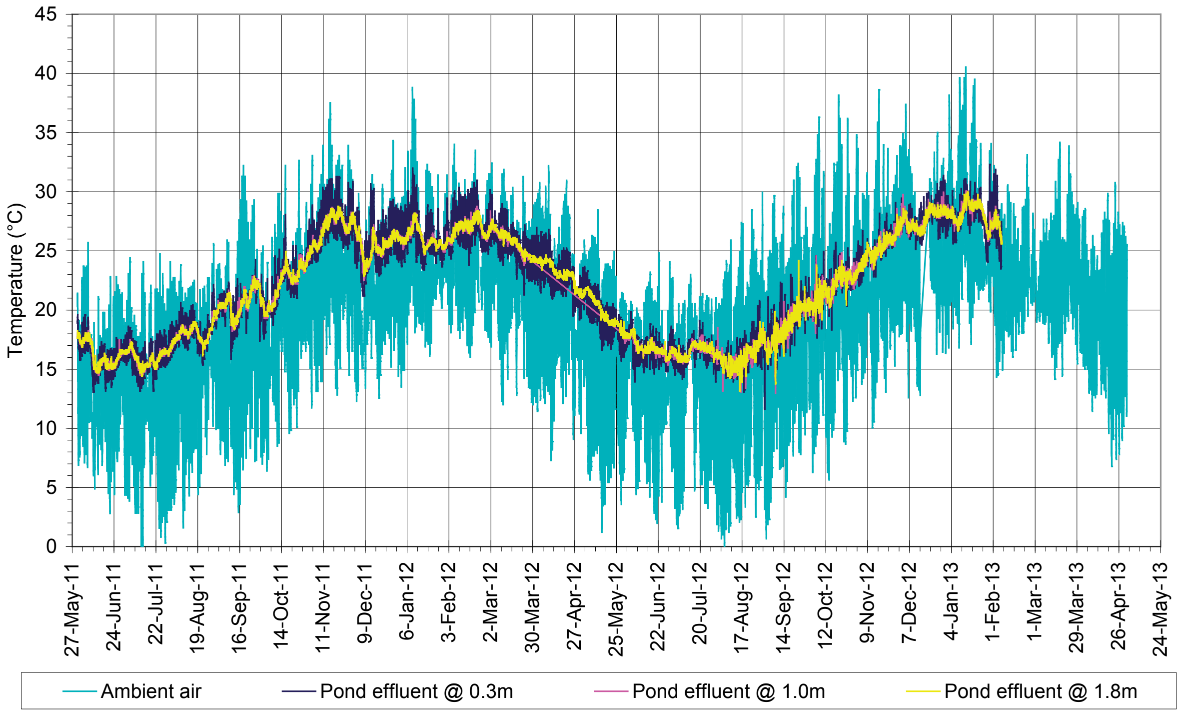


**Figure 11. Ambient air temperature and effluent temperature recorded at three depths (0.3 m. 1.0 m and 1.8 m) in the partially covered anaerobic pond**

In August 2012, some changes were made to the shed flushing practices at the piggery. Previously, the effluent stored in the static pits under the sheds was released approximately once weekly. However, in August 2012, a new pump was installed to more regularly flush recycled secondary pond effluent through the pits underlying the sheds. This change is reflected in the increased variability in the pond effluent temperature at a depth of 1.8 m, near the base of the pond (Figure 11). This change in practices may have also increased biogas production by minimising the potential for losses of volatile solids from effluent stored in the static pits for up to one week, and by improving the mixing of settled solids on the base of the primary pond.

The temperature data presented in Table 2 and Figure 11is very similar to the data previously presented by Skerman and Collman (2012). Figure 11 clearly shows less variation in pond effluent temperature than in the ambient air temperature, demonstrating that the effluent stored in the pond has a relatively high thermal mass which buffers fluctuations in the ambient air temperature. Furthermore, the variation in pond effluent temperature appears to decrease with depth.

## Biogas composition

The results of the biogas composition monitoring from March 2012 to May 2013 are plotted in Figure 12. These results were obtained using a Geotech Biogas Check portable gas analyser. The average methane, carbon dioxide and hydrogen sulphide concentrations were 67%, 32% and 2198 ppm, respectively.

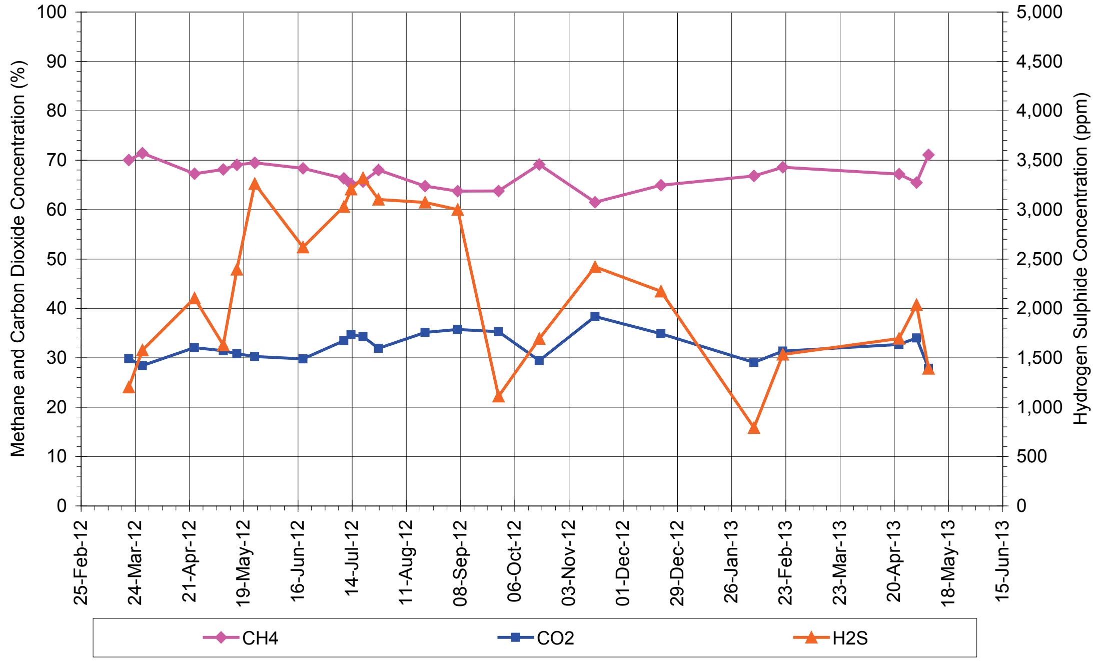


**Figure 12. Biogas composition determined using the Geotech Biogas Check portable analyser.**

## Water heating system gas consumption

The hourly and daily consumption of biogas and LPG used for farrowing shed heating are shown in Figure 13 and Figure 14, respectively. These records commence in December 2012, following the installation of the HOBO logger. Over this monitoring period, the average biogas and LPG consumption rates were 83.97 and 15.13 $m^3$/day, respectively, with maximum values of 117.45 and 16.31 $m^3$/day, respectively, (excluding periods when the hot water systems were not operating).

To date, the partially covered anaerobic pond appears to be able to sustain constant operation of the biogas water heating unit. For the period from April to December 2009, Skerman *et al.* (2011) recorded an average daily biogas flow through the flare of 68 $m^3$/day, with a corrected value of 65 $m^3$/day, based on standard temperature and pressure conditions (15˚C and 101.3 kPa). Consequently, the recent biogas usage rates exceed the previously measured flows by 24%. This apparent increase in biogas production may be due to the previously described changes in effluent management practices since the original measurements were taken in 2009.

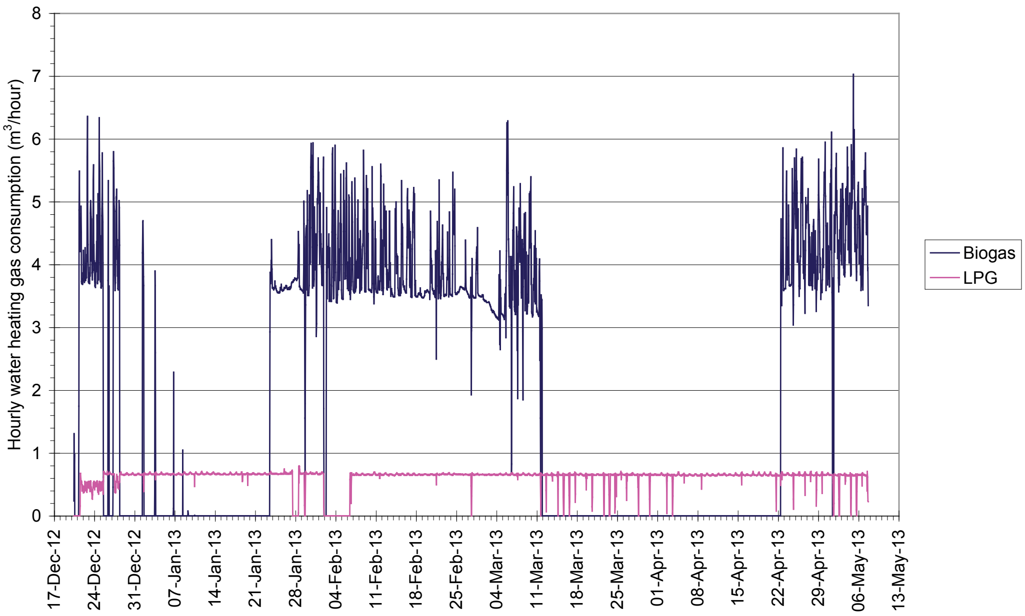


**Figure 13. Hourly biogas and LPG consumption for farrowing shed heating**

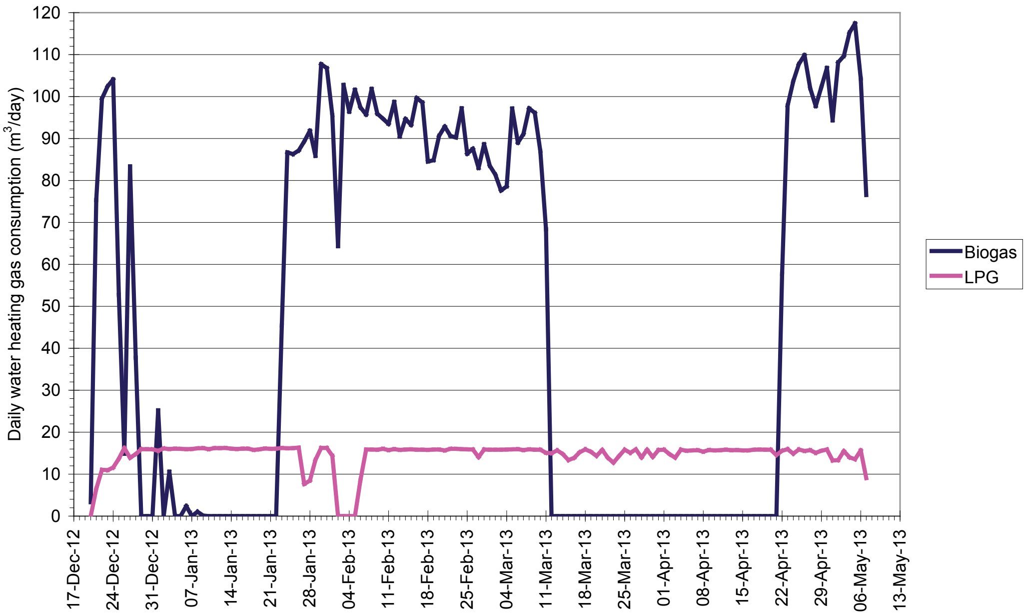


**Figure 14. Daily biogas and LPG consumption for farrowing shed heating**

The thermostats on the biogas and LPG fired water heaters were originally set to preferentially use biogas when it was available. To this end, the thermostats on the biogas and LPG units were initially set to cease heating when the water temperature reached 65°C and 55°C, respectively. This arrangement appeared to provide a water temperature that effectively achieved the target temperature of 32 - 34°C on the surface of the underfloor heating pads in the farrowing sheds, as previously described by Skerman and Collman (2012). Figure 15 is an infrared photograph showing the temperatures on the surface of one of the farrowing shed under-floor heating pads. The outline of the "S" shaped copper pipe which conveys the heated water through the concrete pad can easily be seen in this photograph.

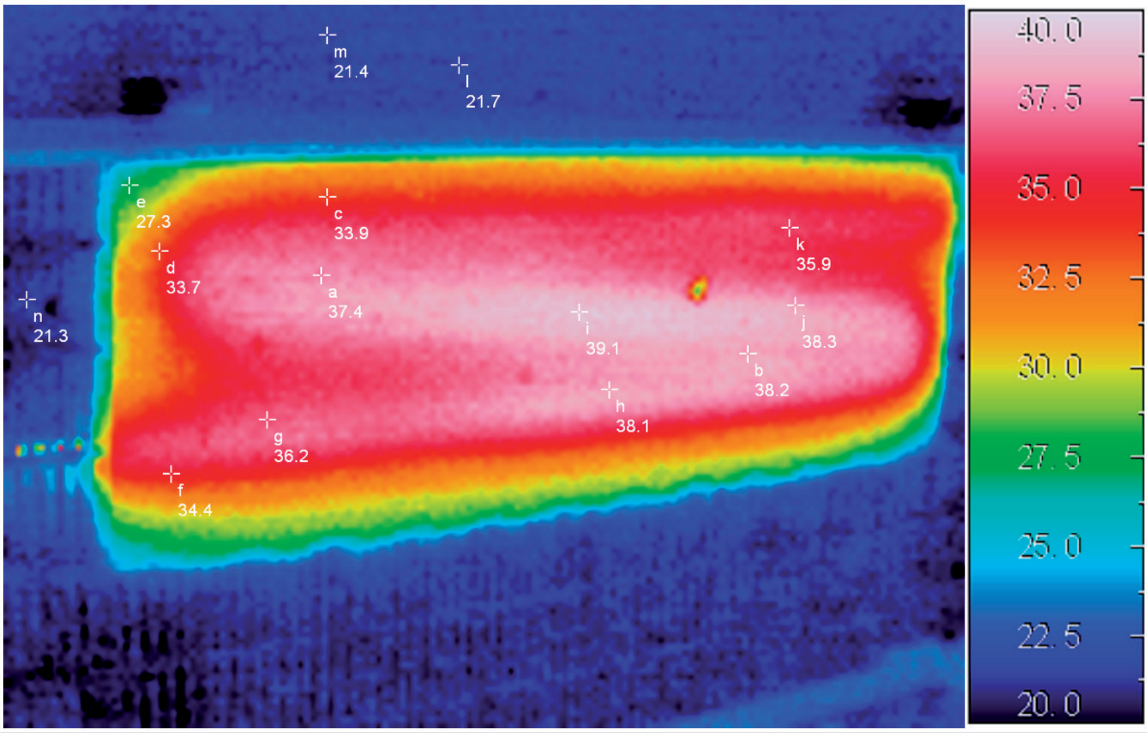


**Figure 15. Infrared camera photograph of one of the farrowing shed heating pads showing the surface temperature variation.**

Figure 16 shows the average daily farrowing shed heating energy consumption, presented on a monthly basis, for the period from July 2012 to April 2013. During November 2012, the LPG HWS was turned off by the piggery manager as it was considered that the biogas unit could provide sufficient heat energy over the warmer months. While the total required heating energy generally declines during the warmer summer months; the gas use during February 2013 was significantly higher than expected. It appears that the higher gas usage during this month followed the removal of the baffles from the biogas HWS on 23 January 2013, when the gas control valve was replaced. This reduced the heating efficiency of the biogas HWS resulting in increased operating times for both the biogas and LPG systems, as both systems struggled to heat water to the thermostat cut-off temperatures. As shown in Figure 14, the biogas system was not operating from 11 March to 22 April 2013, potentially resulting in lower overall gas consumption during these months, despite the fact that the LPG system was operating continuously over much of this period.

The operating efficiency of the LPG HWS was apparently declining due to a build-up of scale in the water heating tank, resulting from the use of relatively 'hard' (high mineral content) bore water for several years. With the impending onset of the cooler months, the piggery owners decided to replace the LPG unit in early May 2013. The thermostat settings on both the biogas and LPG units may now require adjustment to achieve the most efficient use of the available biogas following the replacement of the LPG unit and the installation of the new baffle in the biogas unit, effectively improving the heating efficiencies of both units.

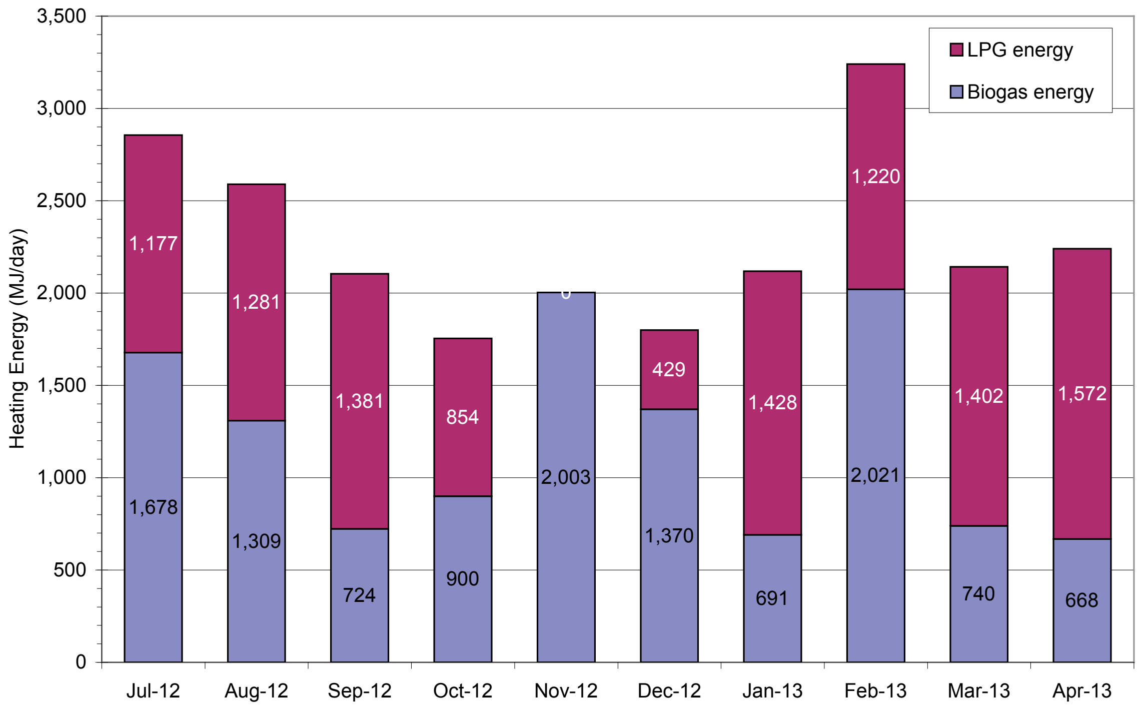


**Figure 16. Average daily farrowing shed heating energy consumption.**

## Initial scrubber trial

As previously noted, the commencement of the scrubber trial was delayed due to the ongoing reliability issues with the biogas water heating system and uncertainty regarding the availability of funding to carry out the required system repairs. Consequently, there was very little time available towards the end of the project period to carry out comprehensive or conclusive scrubber trials.

Following the addition of two drums (30 kg) of SULFA-BIND® to the iron-sponge type scrubber, there was an initial 28% reduction in the biogas hydrogen sulphide concentration from 1695 to 1227 ppm on 22 April 2013, based on measurements taken upstream and down stream of the scrubber using the Geotech Biogas Check portable gas analyser. However, the SULFA-BIND® medium may not have been sufficiently wet to achieve optimum performance at this time.

A third 15 kg drum of SULFA-BIND® was added to the scrubber on 1 May 2015. Figure 17 shows the interface between the old and new media observed through the porthole in the side of the scrubbing vessel. This photograph clearly shows the contrast between the exhausted, black SULFA-BIND® medium which had been added to the vessel on 22 April and the orange-coloured fresh medium. The manufacturers of SULFA-BIND® state that as the ferric hydroxide coating on the fresh medium reacts with the hydrogen sulphide in the biogas to produce ferrous sulphide, the colour of the medium changes from orange to black.

On this occasion, a hose was used to thoroughly wet the scrubbing medium while the excess moisture was allowed to drain from the bottom of the scrubbing vessel. When the biogas HWS was restarted, the biogas hydrogen sulphide concentration was reduced by 62%, from 2035 to 768 ppm.

By 13 May 2013, the scrubbing potential of the medium added to the vessel appeared to be practically exhausted, as indicated by its black colour, resulting in a 13% reduction in the biogas hydrogen sulphide concentration, from 1391 to 1214 ppm. Unfortunately, there was insufficient time available prior to the end of the project to regenerate the SULFA-BIND® medium and carry out further, more comprehensive trials.

**Figure 17. Viewing porthole in the biogas scrubber following the addition of the third drum of SULFA-BIND® showing the black colour of the exhausted medium in contrast to the orange coloured fresh medium.**

The recommended design criteria for iron-sponge type scrubbers are provided in Table 3. The predicted performance of the SULFA-BIND® scrubber based on using the existing vessel and also an improved vessel selected to give optimum performance, are outlined in Table 4.

**Table 3. Recommended design criteria for iron sponge type scrubbers (McKinsey Zicary, 2003).**

| Parameter | Units | Value / range |
|---|---|---|
| Residence time | sec | > 60 |
| Bed height | m | 1.2 - 3.0 |
| Gas velocity | m/min | 0.6 - 3.0 |
| Mass S loading | g S/min/$m^2$ bed | < 10 |

**Table 4. SULFA-BIND® scrubber performance predictions based on using the existing vessel and one selected to give optimum performance.**

| Scrubbing vessel | Units | Existing vessel / Initial trial | Existing vessel / recommended | Recommended vessel |
|---|---|---|---|---|
| Diameter | m | 0.46 | 0.46 | 0.393 |
| Total vessel height | m | 1.01 | 1.01 | 2.0 |
| Max media height | m | 0.70 | 0.70 | 1.5 |
| Cross-sectional area | $m^2$ | 0.166 | 0.166 | 0.122 |
| Total vessel vol | L | 168 | 168 | 244 |
| Max media volume | L | 116 | 116 | 182 |
| **Biogas** | | | | |
| Biogas consumption | $m^3$ biogas/day | 105 | 105 | 105 |
| Vessel flow velocity | m/min | 0.44 | 0.44 | 0.60 |
| Biogas $H_2S$ concentration | ppm | 1707 | 1707 | 1707 |
| Biogas $H_2S$ production | $m^3$ $H_2S$/day | 0.179 | 0.179 | 0.179 |
| | mole $H_2S$/day | 7.45 | 7.45 | 7.45 |
| | g $H_2S$/day | 254 | 254 | 254 |
| Biogas S production | g S/day | 239 | 239 | 239 |
| Biogas S loading | g S/min/$m^2$ bed | 0.998 | 0.998 | 1.365 |
| **SULFA-BIND®** | | | | |
| Mass media added | kg | 45 | 89 | 140 |
| Density | kg/L | 0.766 | 0.766 | 0.766 |
| Volume | L | 58.75 | 116.19 | 182.29 |
| Media height | m | 0.353 | 0.699 | 1.500 |
| Media residence time | sec | 55 | 101 | 150 |
| Adsorption rate | mg $H_2S$/g S-B | 35.00 | 35.00 | 35.00 |
| Mass consumed | g S-B /day | 7,256 | 7,256 | 7,256 |
| Volume consumed | L S-B /day | 9.47 | 9.47 | 5.58 |
| Lifespan | days | 6.2 | 12.3 | 19.3 |

From Table 4, it is evident that the configuration used in the initial scrubber trial did not meet the recommended design criteria outlined in Table 3. While the gas flow velocity and sulphur loading rate met the recommended design criteria, the media height (0.353 m) was significantly less than the recommended minimum value of 1.2 m, and the residence time (55 seconds) was just less than the recommended minimum value of 1 minute. It is therefore not surprising that the initial trial results showed relatively low rates of hydrogen sulphide removal compared to the manufacturer's claimed removal rate of up to 99.98%. The predicted 6-day lifespan prior to exhausting the SULFA-BIND® media is also consistent with the findings of this trial.

While it is not possible to achieve the recommended 1.2 m bed height with the existing scrubber vessel, improved performance could be expected by adding 89 kg of SULFA-BIND®, effectively increasing the residence time to 101 seconds. However, at the time when the SULFA-BIND® was purchased, there was only 60 kg of the product available in Australia. The increased mass of SULFA-BIND® should increase the lifespan of the medium to approximately 12 days, prior to requiring regeneration.

The right-hand column in Table 4 provides details of a taller scrubber configuration with a slightly smaller diameter which meets all of the design criteria, resulting in an estimated 19 day media lifespan, prior to regeneration.

## Extension of biogas technology

As outlined in the previous Final Report (Skerman and Collman, 2012) the Australian Methane to Markets in Agriculture (AM2MA) projects conducted at the Grantham piggery have created considerable media interest and have been used to publicise government initiatives such as the launch of the first Carbon Farming Initiative methodology. Since the submission of the Final Report to RIRDC in June 2012, the following additional activities have been undertaken by research project leader, Mr Alan Skerman:

| | |
|---|---|
| 20 September 2012 | Prepared and presented a talk at the CFI communications workshop in Goondiwindi. |
| 13 November 2012 | Prepared and presented a talk on biogas scrubbing to the Pork CRC Stakeholders' Meeting in Melbourne. |
| 26 November 2012 | Prepared and presented a talk entitled "Methane recovery and use at a piggery near Grantham Queensland" at the Bioenergy Australia Conference. |
| 30 November 2012 | The Final Report submitted to RIRDC in June 2012 was revised in November 2012 following a review by a federal DAFF officer. |
| 13 February 2013 | Prepared and presented a talk providing an update on this project (RIRDC Project No PRJ-005672) at the APL researchers' forum in Canberra. |
| 19 March 2013 | On-site meeting with Mr Erik van Driel, Senior Process Engineer with Aquatec Maxcon Pty Ltd, to discuss potential for biogas development in the intensive livestock industries. |
| 27 June 2013 | Requested to prepare and present a talk entitled "Update on biogas heating and scrubber trial at Grantham piggery" at the Bioenergy Australia Quarterly Meeting to be held at the University of Queensland. |

# Implications

Biogas and LPG consumption, since the two farrowing sheds were connected to the underfloor heating system on 23 July 2012, are summarised below, along with the economic value of the biogas as a substitute for LPG. Projected figures are also provided, based on eliminating biogas HWS downtime:

**Measured biogas and LPG consumption** (23 July 2012 – 7 May 2013)**:**

| | | |
|---|---|---|
| Total biogas use: | 13,123 $m^3$ | (340,000 MJ) |
| Average daily biogas use: | 46 $m^3$/day | (1,181 MJ/day) |
| Total LPG use: | 3,343 $m^3$ | (308,560 MJ) |
| Average daily LPG use: | 12 $m^3$/day | (1071 MJ/day) |
| Value of LPG saving: | $13,600 / 288 days (9.5 months)<br>(based on LPG price $1.00/L) | |

**Projected biogas and LPG consumption, eliminating biogas HWS downtime:**

| | | |
|---|---|---|
| Average daily biogas use: | 84 $m^3$/day | (2,135 MJ/day) |
| Potential value of LPG saving: | $25,073 / 288 days | |
| Projected annual LPG saving: | $31,776 / year | |

In summary, the above data indicates that a saving in LPG costs of $31,776 per year should be possible provided the biogas HWS can be made to operate reliably, with minimal downtime. It is estimated that biogas could supply approximately 64% of the total farrowing shed heating energy requirement, based on the LPG usage records presented by Skerman and Collman (2012) for the period from April 2009 to March 2010.

Based on using SULFA-BIND® for scrubbing the raw biogas collected under the partially covered pond, and assuming that the SULFA-BIND® can be effectively regenerated 12 times, as suggested by the manufacturers, it is estimated that 221 kg of SULFA-BIND® would be required annually to effectively treat the biogas. Based on a unit cost of $28.60/kg, the annual SULFA-BIND® cost would be $6,312 per year.

The unit cost of SULFA-BIND® may be reduced for the purchase of larger quantities or if a number of biogas users could make a bulk purchase. As the number of Australian piggeries installing biogas systems increase, bulk purchases may become a more realistic option. Alternatively, there may be other less costly scrubbing media available on the market.

A recently commenced Pork CRC funded research project is currently investigating a range of biogas scrubbing technologies and alternative low-cost media for use in iron-sponge type scrubbers. This project may provide more cost effective options for improving the quality of biogas so that it is more suitable for a range of productive uses.

Experience gained during this project suggests that the use of raw (unscrubbed) biogas in the water heating system may reduce the working life of some of the components. It is recommended that regular inspections and maintenance of gas train components be performed. The installation of an effective scrubbing device may significantly extend the life of the biogas hot water system and other components.

The Type-B gas fitter who carried out the certification of the converted biogas hot water system (Bizmatrix Pty Ltd) has recommended that the owners arrange for Type B safety services to be carried out twice annually, in accordance with AS 3814 standards and the gas regulations.

# Recommendations

Regular inspection and maintenance of the biogas system components is recommended to ensure the ongoing safe operation of the system and to prolong the life of the various components. This is particularly important due to the corrosive and toxic nature of the untreated biogas.

It is recommended that pig producers who install biogas collection and use systems investigate cost-effective options for removing hydrogen sulphide from the biogas, to extend the working life of system components and so that it is more suitable for a range of productive uses.

It is anticipated that a recently commenced Pork CRC funded research project will draw on the findings of this project in investigating a range of robust, cost-effective biogas scrubbing technologies, suitable for use at Australian piggeries.

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# Methane recovery and use at Grantham piggery

By Alan Skerman

Pub. No. 13/107

This report is an addendum to the final report 12/064 '*Methane recovery and use at a piggery – Grantham*' (Skerman and Collman, 2012). It provides additional monitoring data relating to the performance of the biogas-fired water heating system and scrubber installed at the QNPH Grantham piggery, for the period extending from June 2012 to May 2013.

The information provided in this report will assist producers, industry bodies, researchers, industry service providers, contractors, government policy makers and regulators who have an interest in the planning, design, installation and operation of biogas capture and reuse systems at Australian intensive livestock production facilities.

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