

# The Generation of biogas on-farm using animal and dairy waste



## Paul Wilson

AgriFood Skills International Fellowship

An International Specialised Skills Fellowship



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# i. Executive Summary

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Dairy farming in Australia currently consumes large amounts of energy and fertilisers.

With the depletion of fossil fuels and the subsequent increase in price of these inputs, alternative energy sources such as biogas generated on farm from animal waste may have application. In addition, the waste material from this process is a valuable fertiliser that could reduce the need for bought in chemical fertilisers.

This Fellowship aimed to determine if the biogas systems that are currently in use in China and Germany have application on Australian dairy farms. While feed in tariffs have been used in Germany to assist in the adoption of this technology, environmental concerns have been the major driver in China.

The Australian dairy industry is fully exposed to market forces so adoption of this technology will depend on the degree to which the local farming systems allow animal and other farm waste to be collected and how much of the biogas generated can be used on farm to offset bought in energy.

Waste management is increasingly a problem as dairies become larger, especially for 'green field' sites that must meet stringent Environmental Protection Agency guidelines. Biogas generation systems provide an option for helping to deal with this problem by treating the waste as a resource.

A 'light bulb' moment for the Fellow occurred during a visit to a 'state-of-the-art' dairy farm near Shanghai, China. This newly constructed 6,000 cow dairy represented the future of intensive, industrial farming in China, and possibly the world. Whatever concerns people may have about this type of farming, it surely represents a future for a large segment of the industry: the dairy was re-using all waste product to produce both energy for use on the farm and fertiliser for growing crops nearby for use as cattle fodder. While the Fellow gained no direct financial information, it is his considered opinion (based on anecdotal discussion and evidence) that the operating costs of this dairy would undoubtedly be lower than a comparable dairy that is still buying in its electricity and fertiliser, despite the initial increased capital expenditure costs.

It is the lower cost and highly productive enterprises that will become the successful future of the industry.

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## ii. Abbreviations/Acronyms

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BIOMA	Biogas Institute of Ministry of Agriculture
CHP	Combined Heat and power
Fe <sub>2</sub> SO <sub>3</sub>	Iron Sulphate
kW	kilowatt
mW	megawatt

# iii. Definitions

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**Biological scrubber**

A microbial based system for removing hydrogen sulphide from biogas

**Biomethane**

Methane that has been created from biogas

**Closed loop farming**

A system in which all wastes are recycled

**Co-generation**

Generation of electricity and heat

**Combined heat and power (CHP)**

Generation of electricity and heat

**Digestate**

Output from a digester

**Feed in tariff**

Payment from the government for electricity

**Feedstock**

Input for a digester (eg. animal waste)

**Gate fees**

Fees charged for dumping waste

**Genset**

Electricity generator

**Heat grid**

Piped hot water system for distributing heat

**Methanogenic bacteria**

Bacteria that produce methane

**Percolate**

Methanogenic rich solution

**Scrubber**

Device for removing hydrogen sulphide from biogas

# 1. Acknowledgements

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Paul Wilson would like to thank the following individuals and organisations who gave generously of their time and their expertise to assist, advise and guide him throughout the Fellowship program.

## **Awarding Body – International Specialised Skills Institute (ISS Institute)**

The International Specialised Skills Institute Inc is an independent, national organisation that for over two decades has worked with Australian governments, industry and education institutions to enable individuals to gain enhanced skills and experience in traditional trades, professions and leading-edge technologies.

At the heart of the ISS Institute are our Fellows. Under the **Overseas Applied Research Fellowship Program** the Fellows travel overseas. Upon their return, they are required to pass on what they have learnt by:

1. Preparing a detailed report for distribution to government departments, industry and educational institutions.
2. Recommending improvements to accredited educational courses.
3. Delivering training activities including workshops, conferences and forums.

Over 200 Australians have received Fellowships, across many industry sectors. In addition, recognised experts from overseas conduct training activities and events. To date, 22 leaders in their field have shared their expertise in Australia.

According to Skills Australia's 'Australian Workforce Futures: A National Workforce Development Strategy 2010':

Australia requires a highly skilled population to maintain and improve our economic position in the face of increasing global competition, and to have the skills to adapt to the introduction of new technology and rapid change.

International and Australian research indicates we need a deeper level of skills than currently exists in the Australian labour market to lift productivity. We need a workforce in which more people have skills, but also multiple and higher level skills and qualifications. Deepening skills across all occupations is crucial to achieving long-term productivity growth. It also reflects the recent trend for jobs to become more complex and the consequent increased demand for higher level skills. This trend is projected to continue regardless of whether we experience strong or weak economic growth in the future. Future environmental challenges will also create demand for more sustainability related skills across a range of industries and occupations.

In this context, the ISS Institute works with Fellows, industry and government to identify specific skills in Australia that require enhancing, where accredited courses are not available through Australian higher education institutions or other Registered Training Organisations. The Fellows' overseas experience sees them broadening and deepening their own professional practice, which they then share with their peers, industry and government upon their return. This is the focus of the ISS Institute's work.

For further information on our Fellows and our work see <http://www.issinstitute.org.au>.

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### Fellowship Sponsor

AgriFood Skills Australia is the Industry Skills Council for the agrifood industry: the rural and related industries, food processing (including beverages, wine and pharmaceuticals), meat, seafood and racing. The Fellow would like to thank them for providing funding support for this Fellowship.

### Supporters

- Dan Papacek, CEO, Bugs for Bugs, Mundubbera, QLD, Australia
- Heinz-Peter Manz, Lecturer and Consultant, Centre for Sustainable Environmental Sanitation at the University of Science and Technology, Beijing, China
- Griff Rose, Program Manager, AM2MA (RIRDC), Magma P/L, Canberra, ACT, Australia
- Shikun Cheng, Centre for Sustainable Environmental Sanitation at the University of Science and Technology Beijing, China
- Michael Köttner, CEO, International Biogas & Bioenergy Center of Expertise (IBBK), Austria
- Jeff Collingwood, Norco Cooperative Ltd, Lismore, Australia
- Ken Greenhill, Fellowship Adviser, ISS Institute
- Rebecca Stewart-Serger, Internal Communications Adviser, AMP, Australia

### Employer Support

The Fellow wishes to acknowledge the support, both financial and time, given to complete this Fellowship. Being involved in a small family run business means that when the Fellow stepped aside to fulfill the obligations of the Fellowship, other family members and staff had to stand in and fill the gap. Without their support this Fellowship would not have been possible.

### Organisations Impacted by the Fellowship

#### Government:

- Australian Dairy Farmers Limited (ADF)
- Dairy Australia
- NSW Industry and Investment
- Department of Primary Industries, Victoria
- Department of Primary Industries, Parks, Water and Environment, Tasmania
- Department of Primary Industries, Queensland
- Department of Primary Industries and Regions, South Australia
- Department of Agriculture and Food, Western Australia
- Department of Agriculture, Fisheries and Forestry
- Department of Climate Change and Energy Efficiency

## 1. Acknowledgements

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### Industry:

- AgriFood Skills Australia
- Australian Dairy Farmers
- Dairy Industry Association of Australia
- Biological Farmers of Australia
- NASSA – Certified Organic
- Norco Cooperative
- Parmalat
- Fonterra
- Lion Nathan National Foods
- Warrnambool Cheese and Butter
- Bega Cheese
- Murray Goulburn Cooperative

### Professional Associations

- Australian Dairy Farmers
- NSW Farmers Association
- Queensland Dairy Farmers Association
- United Dairy Farmers of Victoria
- South Australian Dairyfarmers' Association
- Tasmanian Farmers & Graziers Association – Dairy Council
- Western Australian Farmers' Federation – Dairy Council

### Education and Training

- National Centre for Dairy Education Australia
- Dairy Science and Technology – RMIT University
- Agricultural Science, Faculty of Science, Engineering and Technology, University of Tasmania
- Dairy Production and Technology, University of Sydney
- The Hawkesbury Diploma in Dairy Technology, University of Western Sydney

### Community

- Australian Biogas Group – Paul Harris

### Other

- Methane to Markets Partnership

# 2. About the Fellow

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**Name:**

Paul Michael Wilson

**Employment:**

Owner, Nimbin Valley Dairy

**Qualifications:**

BA in Rural Science, University of New England, 1988.

The Fellow grew up on a family-owned dairy farm near Lismore, in northern NSW. After graduating from university, he spent several years working in a consultancy role in the cotton industry in northern NSW and the citrus industry in central Queensland. While working at Bugs for Bugs in Mundubbera, he gained an appreciation for the complexities of melding modern industrial farming techniques and sustainable farming practices. Returning to the Lismore area he and his partner established Nimbin Valley Dairy, producing a range of goat and cow milk cheeses and other products from their own milk supply. The quest for a truly sustainable enterprise has led the business to investigate the possibility of using dairy waste to produce methane as an energy source for use on the farm.

# 3. Aims of the Fellowship Program

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The Fellowship provided the opportunity to investigate both low-cost and high-cost biogas generation systems that are currently in use on dairy and other farms in China and Germany. Germany represents world best practice in this field while China has many low-cost systems in place, that none the less fulfil a need in the community.

In particular the Fellowship provided the opportunity to evaluate:

- The design of a biogas plant
- The financial feasibility of a project
- Logistics of different feedstock
- Currently operating high and low cost systems
- Manufacturers of biogas plants and components
- Commercially operating biogas plants on dairy farms in both China and Germany.

# 4. The Australian Context

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Dairying is one of Australia's major rural industries providing farm-gate revenues of \$A3.4 billion in the 2009/10 financial year and employing approximately 40,000 people directly on farms and in manufacturing plants. According the latest ABARE statistics for the Australian Dairy Industry, as highlighted on the Australian Dairy website (February 2013 Update) (<http://www.dairyaustralia.com.au>) , it is estimated that the revenues from dairy farming have a multiplier effect of 2.5 in the regional economy.

The Fellow believes that as the industry enters a period of predicted sustained high energy prices, combined with a requirement to reduce carbon emissions, alternative clean energy sources and making use of animal waste streams has become increasingly important and potentially financially viable.

It is also currently widely reported in the media that the world is simultaneously entering a period of reduced food stockpiles at a time of increasing climate variability, a reduction in prime farming land, increasing population and the subsequent demand for food. This 'perfect storm' on the horizon makes the efficient and environmentally sustainable production of food even more critical. These forces reached a flashpoint in 2007 resulting in social unrest in many of the world's poorer countries. Since then, food supplies have increased and prices have decreased but at the time of writing world wheat, maize and sugar prices were again on the increase.

Interestingly, in Australia there is also an increasing demand for regionally produced and branded food from environmentally 'sustainable' farming systems, as evidenced by the increase in regionally located, small-scale manufacturers. The reasons for this are beyond the scope of this document; however a widespread disenchantment and anxiety surrounding large scale agro-industrial farming practices may be a significant factor. A farm-based value adding business that meets its own energy needs from an on-farm energy generation system will have a distinct marketing advantage if it can sell this message to these 'anxious' consumers.

## SWOT Analysis

### Strengths

The strengths of an on-farm biogas system include:

- Use of a current waste stream
- Reduced reliance on increasingly expensive electricity
- Odour control
- Reduced potential for nutrient runoff and pollution.

### Weaknesses

Weaknesses of an on-farm biogas system include:

- Potential for high capital requirement for feasibility study and construction
- High management skill level requirements
- Workplace health and safety risks
- No (or limited) local knowledge or support for such start-up systems
- Reduced availability of animal waste for on-farm composting systems that are increasingly being used on dairy farms pursuing a biological approach to farming.

## 4. The Australian Context

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### **Opportunities**

A few opportunities for on-farm biogas systems include:

- Alternative income stream to the business from energy sales
- Generation of local highly skilled employment as support industries grow to facilitate the growth of an on-farm biogas generation industry
- Waste product from the biogas system used as a highly useful fertiliser.

### **Threats**

The risks of an on-farm biogas system are not insignificant:

- Increased requirement for capital in an industry that is already capital intensive
- Increased workload and management ability, especially on family farms with little or no paid staff.

# 5. Identifying the Skills Deficiencies

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## 1. System design and construction:

- Investigate suitable location for biogas digester with respect to current animal buildings and existing farm infrastructure
- Evaluate type and quantity of animal waste and logistical issues associated with maintaining a constant supply to feed digester
- Scale the design of a suitable system to enable consumption animal waste supply and the generation of a useful amount of biogas to meet farm needs
- Determine engineering requirements of the digester
- Determine the possibility of using waste heat and gas for further energy generation, such as electricity

*It is vital that a thorough evaluation of feedstock availability and potential energy yield is undertaken first. Once this has been determined then a system can be designed to process this feedstock volume. The amount of energy produced can then be used to undertake the financial feasibility.*

## 2. Financial feasibility:

- Calculate construction and operational costs
- Calculate average biogas and/or electricity production on an annual basis
- Evaluate farm energy needs on an annual basis
- Undertake analysis of energy production costs and farm energy needs to determine net benefit to the farm business using standard financial analysis methods.

*To ensure the long term successful operation of a biogas system it must comply with standard accounting and financial management practices. If a marketing advantage can be obtained by promoting the use of renewable energy then a 'cash-neutral' position may be acceptable*

## 3. Operation and management:

- Determine daily, weekly, monthly and annual management routines
- Construct weekly, monthly and annual maintenance schedules
- Investigate the local and regional planning laws and other laws or regulations surrounding the operation of an on-farm biogas digester.

*To ensure the long term viability of the biogas system, appropriate work practices, routines and systems must be developed and then implemented.*

# 6. The International Experience

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## Destination One - University of Science and Technology Beijing (School of Civil & Environmental Engineering), China.

### Contact

- » Professor Ing Zifu Li, Professor, School of Civil & Environmental Engineering
- » Heinz-Peter Mang, Manager, School of Civil & Environmental Engineering
- » Shikun Cheng, PhD Student, PhD Student, School of Civil & Environmental Engineering, Centre for Sustainable Environmental Sanitation.

Mr Heinz-Peter Mang provided the Fellow's initial contact with the application of biogas technology in Chinese farming systems. The Beijing University of Science and Technology is a world-leading centre for the research and dissemination of research findings of practical biogas systems throughout the world. It is heavily involved in projects funded by the United Nations (UN) and The World Bank.

With the permission of Professor Li and with the cooperation of PhD student Mr. Cheng Shikun, the Fellow was fortunate to be able to visit several working biogas plants in Beijing, Chengdu, Hangzhou and surrounds. The Fellow was also introduced to several technology businesses that design, install and commission biogas plants throughout China and the world.

### Objectives

The main objective of the visit to the University of Science and Technology was to investigate both 'low tech' and 'high tech' system design and construction from a theoretical perspective. Many case studies of different designs from around the world were viewed.

During the afternoon visit to the University campus, the Fellow met departmental heads of staff. While there he was shown a video presentation of the main activities and projects currently being undertaken by the School of Civil and Environmental Engineering. The department is heavily involved in the construction and commissioning of small-scale biogas plants in East Africa, Pakistan, Vietnam and Central America. A project is currently being evaluated for construction in Chile. These projects tend to be initiated and funded by bodies such as The World Bank and The United Nations.

The departmental library is a significant resource for researching the fundamentals of biogas production and system design. Significant amounts of the literature detailed the application of 'low tech' biogas systems for domestic use or small holdings.

### Outcomes

The Fellow became aware of how widespread small scale 'low tech' systems have been adopted through out the world, especially in developing countries where mains power and other energy sources are limited. Many of the resources in the library are from the 1970s and 1980s, which in turn reference even older material.

### Concluding remarks

Clearly the generation of biogas in low-tech digesters from various types of farm waste is not new technology. The science behind it is well understood and if there is a clearly defined need for the gas produced and a source of substrate then engineering a low-cost solution has been proven over and

## 6. The International Experience

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again throughout the developing world. These types of systems may have application in very small scale dairy farms in Australia, however for most applications they would be too labour intensive. It was useful however for the Fellow to understand how widely adopted the technology is throughout the world.

### **Destination Two - Yingherui Engineering Company, Tianjin, Baodiqu district, Beijing, China.**

The Yingherui Engineering Company has constructed a number of biogas plants in the Beijing area. The first visited was a state-owned piggery which produces 100,000 pigs for slaughter every year.

#### **Contact**

» Mr Jackie Wang, Manager, Department of International Business.

#### **Objectives**

This site visit provided an opportunity to evaluate system design and construction. There was an opportunity to see a newly commissioned large-scale, state-of-the-art biogas plant which dealt with the waste for a large commercial piggery. The state provided a 10 per cent grant towards the total construction cost of RMB10million (AUD\$1.5 million). These included a 'bio-scrubber' to remove hydrogen sulphide from the biogas and back up pumping systems in case of mechanical failure.



*Biogas digesters showing outflow into storage ponds*

## 6. The International Experience

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*Underground pre-treatment storage tank showing piggery in the background*

### **Outcomes**

The Chinese government is keenly aware of the heavy environmental price China has paid for its rapid industrialisation and dealing with pollution is often paramount. Large scale industrial farming is necessary to feed China's growing mega-cities and animal waste must increasingly be dealt with on site. The main goal of this plant is treatment of the piggery waste. Currently the gas produced is used for heating the digester tanks but in the future it is planned to use this gas for heating piglet rearing facilities and hot water for use in the piggery.

Waste is removed from the piggery on a weekly basis and stored until pumped into the digester. Since pigs are monogastrics, they do not have any methanogens present in their manure so it is possible to store the waste before being pumped into a digester. Ruminants naturally have methanogenic bacteria present in their manure so storage for any longer than a few hours is not an option due to the production of methane which represents both a safety issue and a loss of energy.

Retention time in the digester is eight to ten days. This is significantly less than dairy waste due to the lower fibre content of the waste. At the end of the digestion process after the biogas has been produced and extracted, digestate or 'waste' is removed from the system and given away to local farmers for fertiliser. It was unclear how the liquid waste was dealt with after being stored in several large lagoons. It should be noted that there is very little reduction in volume between feedstock and digestate. If, for example, 100 kilograms of feedstock is pumped into a digester, then approximately 100 kilograms of digestate will be produced.

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### Concluding remarks

Observing a state-of-the-art system allowed the Fellow to understand the value of back up systems such as storage and additional pumps. Given that dairy waste cannot be stored for more than a few hours before it naturally starts producing methane, redundancy engineering is important. This is particularly important in the Australian dairy context where labour constrictions mean that breakdowns are very disruptive.

A biogas system that does not fully utilise the gas produced may initially appear to be wasteful; however, the environmental benefits from dealing with the waste stream must not be discounted. The digestate is a valuable fertiliser. However, it must also be understood that the digestate is a high-volume, low-dollar-value product so transporting it beyond the immediate area is seemingly not cost effective. This was reflected in the 'fertiliser' being given away to local farmers as opposed to being sold.

### Destination Three - Xia Village Dairy Cooperative, (dairy waste biogas plant), Xia Village, Beijing, China; and a privately-owned dairy farm, Xia Village, Beijing, China.

### Contact

» Mr. Jackie Wang, Yingherui Engineering Company, Beijing, China.

### Objectives

System design and construction, financial feasibility and operation and management were evaluated at this site. This cooperatively owned system illustrates how capital costs can be defrayed amongst many farmers and how the gas produced can be utilised beyond the farm gate.

The system was engineered to meet the needs of dairy waste that is very high in fibre and provided a useful comparison to the previous plant, Yingherui Engineering Company that dealt only with low-fibre piggery waste. Logistical issues surrounding the collection and treatment of waste from many sources was also observed.

### Outcomes

This biogas plant was owned and managed as a cooperative by the local village and dairy farmers. Slurry from individual farms is collected and transported to the facility in open trucks. It is pumped directly from the receiving tank to the digester, again because of the naturally occurring methanogenic bacteria present in the ruminant waste.

Ruminant waste has high fibre content and requires a longer retention time of 40 days to efficiently degrade it and produce methane. This system in use at this biogas plant had two tanks giving a residence time of 20 days in each tank. The digestate overflowed from the bottom of the first tank into the top of the second. With the piping designed this way, the smaller, more digested particles sink to the bottom of the tank and are pushed into the top of the second tank under hydraulic pressure.

The system used an iron sulphate scrubber to remove hydrogen sulphide from the biogas. If hydrogen sulphide is not removed prior to burning, sulphuric acid is produced which corrodes the burner. The iron sulphate canisters are replaced every six months and are an easier system than a biological scrubber to manage.

## 6. The International Experience

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Sufficient biogas is produced at this site to meet the daily heating and cooking needs of 300 families. It should be noted that a family's needs equates to one cooking ring, one or two gas lights and a gas heater for two to four adults and one child, which is significantly less energy than a typical Australian family consumes.



*300m<sup>3</sup> digester is considered a medium sized unit.*



*Dairy cow slurry being delivered to the cooperatively owned biogas plant.*

### Concluding remarks

Cooperative systems work similarly to the way Australian farmers use contract services for harvesting or 'machinery pools'. A sufficient density of farms in a limited area this may impact positively on application in Australia. The viability of a cooperative or 'contract' system depends on transport costs for both the waste to the facility and digestate away from the facility. It must be remembered that both cattle slurry and digestate are both low value products, so transport to and from the digester quickly becomes financially unviable as distance increases.

The food growing regions around Beijing have huge groundwater contamination issues so the effective management of these problems may be of greater importance than the cost-effective production of biogas. This may become an issue in Australia if the trend to larger feed lot style dairies increases.

**Destination Four - Biogas Institute of Ministry of Agriculture (BIOMA), Chengdu, Sichuan Province, China; and Chengdu Chuanyu Biogas Devices Company Ltd, Chengdu, Sichuan Province, China.**

### Contact

» Professor Wu Libin, Secretary of Foreign Affairs, BIOMA.

### Objective

The main objective of the visit to BIOMA was to meet Professor Wu Libin who would accompany us to various sites over the next few days. The Fellow was able to see first hand many of the domestic

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appliances powered by biogas that are currently available. Many of these appliances were developed at BIOMA.

### Outcomes

Sichuan province has the greatest number of working biogas plants in China. What began as a UN initiative to assist in the research and development of biogas generation systems in 1978, has since been taken over and expanded by the Chinese Ministry of Agriculture; such is the perceived value of the utilisation of farm and domestic waste for biogas generation.

BIOMA holds several biogas training workshops and a conference every year, mainly in the design and construction of small scale systems for use in poorer rural areas of the world.

### Concluding remarks

Many of the domestic appliances for sale at BIOMA have been modified for burning biogas directly rather than having to upgrade it to methane first. They are undoubtedly important in developing countries where other energy sources may be limited but they do show that it is possible to use biogas directly for heating instead of upgrading to methane. Generally this involves increasing the air intake on the gas nozzle to compensate for the high carbon dioxide content of the biogas.



*A gas light modified for burning pure biogas*

In an Australian dairy farm context this is important since the most cost effective method of extracting energy from biogas is to burn it directly. Upgrading to biomethane is an added cost so directly burning biogas is the cheapest option.

### Destination Five - Xaoa Village, Sichuan, China (UN dry fermentation and kitchen biogas demonstration site).

#### Contact

» Mr Fujin Hu, Manager

#### Objective

System design and management along with financial feasibility were evaluated at this site. The dry fermentation process allowed the Fellow to gain an understanding of another type of biogas system and

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how this affects system design. Logistical issues surrounding feedstock access were also explored. The production of gas for sale to the local village illustrated another distribution model.

### Outcomes

This biogas plant was funded by the UN as a demonstration site for the generation of biogas from feedstock other than animal waste.

Rice straw was purchased from local farmers for about RMB300 (AUD\$45) per tonne delivered to the site. Methanogenic bacteria can utilise straw if it is ground finely to increase the surface area available for degradation; however, it needs to be inoculated with the correct bacteria to start the process. In this case human sewage was added to the system to provide the necessary bacteria. Theoretically this only needs to be done at start-up, however in practice the bacteria colonies tend to become less efficient and die off after 12 months, so the system needs to be re-inoculated. The science underpinning this phenomenon is not well understood and is the subject of current research activities.

Once the system is running, it is self-sustaining and just needs to be 'topped up' with a similar volume of water and feedstock to the volume that was removed as digestate. The straw is pulverised in effectively what is a very fine hammer mill. The pulverised straw is then stored for later use.

The gas produced was sufficient for about 3000 local families and was distributed via an underground pipe network. Each household has a meter and a 'charge card' that is inserted into the meter to turn the gas flow on. When the credit is used up the card is taken back to the biogas facility and recharged.

Gas is forced through the network by a floating drum storage system similar to many older natural gas systems that were in use in Australia. Essentially an inverted tank sits snugly inside another tank with a volume of water in the bottom. As gas enters the unit the top tank is pushed up and maintains pressure. As gas is withdrawn from the tank, the floating drum sinks to compensate for the decreased volume and this way maintains pressure.



*Biogas digester to the left and a floating tank storage gas storage vessel to the right. This system enables the gas to be pressurised for distribution.*

## 6. The International Experience

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*Straw ready to be fed into the digester on the left. Stored digestate on the right ready for return to the fields.*

### **Concluding Remarks**

Substrates such as straw illustrate clearly that all farm waste of organic origin can be used as a feedstock. This is important since in the Australian context dairy farms produce waste streams apart from just manure. Waste hay, silage and scrapings from feed pads are all valuable feed stocks.

An understanding of which feed stocks are available prior to designing the plant will ensure that the correct pre-treatment can be applied before addition to the digester. While it is unlikely that Australian dairy farms will sell gas off the farm, this practice highlighted the importance of having a use for the gas to ensure the financial viability of the system. The floating drum storage system is a useful way to maintain gas pressure for use on-farm or at locations distant from the digester and may have application on Australian dairy farms.

### **Destination Six - Chengdu Hongqi Industry and Commerce Company Ltd., Chengdu, Sichuan Province, China.**

#### **Contact**

- » Mr Zhang Tiejiao, President, Chengdu Hongqi Industry and Commerce Company Ltd., Chengdu, Sichuan Province, China.

#### **Objectives**

System design and construction were evaluated at this site. Low-cost modular systems such as the ones manufactured at this facility may allow for a significantly reduced capital outlay up front. Observing the manufacturing of modular systems allowed the Fellow to evaluate their application in small dairy farms with smaller volumes of feed stock and energy requirements. The possibility of expanding the system using a 'daisy chain' model was also investigated.

## 6. The International Experience

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### Outcomes

China has an estimated 20 to 30 million biogas plants in operation. Most of these are small-scale systems utilising household waste and waste from chickens, ducks, pigs and possibly one or two cows.

These modular systems are constructed from fibreglass and are sold unassembled to reduce freight costs. They are buried underground which helps maintain the thermal stability and they are fed manually. Digested material flows out of the top and is also removed manually. Gas is drawn off from the top of the dome and piped away for use. The structure is rigid so gas is produced and forced out by the weight of liquid above.

There is no stirring of the digestate so the efficiency of the system is likely to be lower than other systems. Also, given that there are no baffles inside, it is possible that feed stock may 'short-cut' from the inflow to the outflow and be removed before being fully digested.

The largest module available is eight cubic meters but they can be connected as a daisy chain with digestate flowing out one and into the next. As well as giving greater flexibility, this would also significantly reduce the possibility of digestate short-cutting and exiting the system prior to being fully digested.



*Fibreglass modular system ready for installation. Inflow and outflow are located on the top of the unit.*



*Fibreglass modular system installed (looking from above) showing inflow to the left, outflow to the right and gas line in the middle.*

### Concluding remarks

The cost of these systems (less than \$A1000 plus shipping) means that this is a very cost-effective way of 'exploring' a biogas system.

While most of the market for this business is domestic, the potential to daisy chain these makes them applicable for smaller dairy farms. The general rule of thumb is that every dairy cow requires approximately one cubic meter of digester space so a one hundred cow dairy would need up to ten of these units connected together as one system. This would still cost only AUD\$10,000 as compared to in excess of AUD\$100,000 for custom designed systems. It is likely that larger modular systems specifically for dairy farm applications will be commercially available in the future.

## 6. The International Experience

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### Destination Seven - Piggery One and Piggery Two

#### Contact

» Ms.Tong Boitin, DeTong Environmental Engineering Co. Ltd., Chengdu, Sichuan Province, China.

#### Objective

System design and construction were evaluated at this site. Both of the systems visited were of a scale that Mr Heinz-Peter Mang believes have application on farms in developed countries. He felt this would be an ideal size unit for a 200 head dairy farm.

These systems enabled the Fellow to gain an understanding of how gas is used to produce electricity that is then used on the farm. Management of environmental issues such as odour and noise were also on display here.

#### Outcomes

Both of the biogas plants visited were 300 to 400 cubic meters in capacity and all of the electricity that was generated was used on-farm. Each farm had in the order of 800 sows each. All of the energy needed to power these piggeries was generated on-farm derived from biogas.

Each pig shed was enclosed with large electricity powered extractor fans which pulls air through a water-cooled radiator at the opposite end of the shed. All manure fell through the floor slats and then pumped to a holding tank from where it was pumped into the digesters. There was an almost complete absence of odour at both sites.

These digesters had flexible dome membranes on the top that collected and stored the biogas. The tanks themselves were insulated steel. The insulation helped maintain thermal stability that is necessary for microbial growth.

Since pig manure is low in fibre, it is periodically recirculated around the tank by a pump to ensure it remains mixed. Dairy effluent has a high fibre content which creates its own cycling within the tank so mixing is not required. Agitation can, however, increase the rate of gas production. Gas that is stored in the flexible membrane flows through a 'scrubber' to remove hydrogen sulphide and is then pumped into the electricity generator where it is burnt.

The Genset unit, a gas burning engine combined with an electricity generator, did not capture any heat produced. A significant proportion of the total energy produced is heat so this represents a loss from the system; however, it met the needs of the farm. Controllers on the Genset determined automatically when to increase power production to meet consumption needs.

## 6. The International Experience

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*400 cubic meter biogas digester with flexible storage membrane on top.*

### **Concluding remarks**

At 400 cubic meters, both of these digesters were considered to be mid-size and have application on various intensive animal farms in developed countries. As a ball park figure it was estimated that they would cost in the order of AUD\$200 to \$250 to build outside China using German technology, Chinese manufacturing and local labour for construction.

The Genset system was meeting the needs of both of these farms in terms of electricity production; however, these units only capture a small percentage of the total energy contained in the methane since most was lost as waste heat. A CHP (combined heat and power or co-generation) system would increase efficiency greatly by capturing the heat and using it to run a steam turbine that also produces electricity.

## 6. The International Experience

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### Destination Eight - Shanghai Dairy Company, Hangzhou, China.

#### Contact

» Mr Yifeng Shou, Hanzhou Energy and Environmental Engineering Company Ltd., China.

#### Objectives

System design and construction were evaluated at this site. Some management issues were also highlighted. Two large-scale dairy farms were visited and this allowed the Fellow to evaluate state of the art systems that use dairy waste to efficiently produce heat and power. The use of digestate directly as fertiliser and as a mix in a composting system was also observed.

#### Outcomes

The two dairy farms that were visited were both owned by the Shanghai Dairy Company, a state-owned business. They were developed as model farming systems to showcase world best practice technology in both dairy herd and waste management as part of a Shanghai environmental expo held several years earlier. They have significant expansion plans.

All gas produced was used on-farm since Chinese regulations prohibit the connection of such a large system to the national grid. Beyond meeting their own energy needs they were mainly interested in managing the environmental impacts of such a large intensive animal-based facility.

The first dairy farm used rice straw as the main feedstock and only used manure for inoculating the digester. Digestate is combined with raw manure and composted to produce a pelletised fertiliser for sale.

The second dairy farm used all of the animal waste as feedstock in two 1000 cubic meter digesters. Also at the second dairy farm, a very efficient CHP plant produced sufficient power for the heating and cooling needs of the farm and digestate was spread directly back on cropping fields as fertiliser.



*Cattle sheds on a 600 head dairy farm.*

## 6. The International Experience

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*Automated compost making system which processes digestate for application back to fields and sale.*

### Concluding Remarks

The Fellow, Heinz-Peter Mang and Mr Yifeng Shou all agreed that these systems represent the future of large corporate dairies. Effluent management is the major factor limiting the expansion of farms. Biogas generation provides a means for dealing with effluent on site and meeting farm energy needs at the same time. However, digestate is expensive to transport and will still need to be dealt with close to the plant. Composting and selling it as pelletised manure is a way of value adding to the product and thereby overcoming this restriction.

The large degree of automation on these farms is critical to ensuring the complex system runs smoothly. Labour is relatively cheap in China and providing employment is paramount; however, in Australia even on smaller family farms it would probably not be possible to manage a biogas plant without significant automation since labour management is already an issue on many farms.



*Aeration tynes on the compost making system for turning compost.*



*Biogas digester on a 6000 head dairy farm.*

## 6. The International Experience

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### Destination Nine - University of Hohenheim, Stuttgart, Germany.

#### Contact

» Michael Köttner, CEO, IBBK Fachgruppe Biogas

#### Objective

System design and construction, financial feasibility and system operation and management were evaluated during this leg of the Fellowship. The Fellow attended the International Biogas Operator's Course over four days conducted by IBBK Fachgruppe Biogas and the University of Hohenheim.

The training was designed to provide plant operators, decision makers and investors with specific knowledge regarding the operation and design of biogas plants. The course combined practical experience with theoretical and scientific knowledge delivered by senior experts within the German Biogas Industry.

There were three main areas of study:

1. System design and construction
2. Financial feasibility
3. Operation and management.

#### Outcomes

Key points from each of the four days have been outlined below. A complete copy of course notes will also be available for download from the ISS website. Supporting documentation may also be available from IBBK Fachgruppe Biogas and the University of Hohenheim, <http://www.biogas-zentrum.de/aktuell.html>

#### Day One - Components of a Biogas Plant

In practice a biogas plant is a 'mechanical' cow. The same microbial processes that occur within the rumen of a cow are replicated within the digester. However whereas in nature a cow is 70 per cent efficient, a biogas digester is only five per cent.

The following are the basic components of an on-farm biogas system:

**MIXING PIT** - this is an area for receiving and the pre-treatment of feedstock material. Coarse material may need to be chopped finely or food waste may need to be pasteurised to meet government health regulations. Chopping will increase the surface area available for microbial attack which will increase the rate of biogas production.

**DIGESTER** - this is the fermentation vessel in which digestion will occur. Digestion is a series of interdependent microbial processes that need a constant temperature and anaerobic environment for optimum activity. The digester may be a simple covered earthen lagoon or a custom-built insulated tank.

**CONDENSATE TRAP** - biogas is approximately 40 per cent water that needs to be removed prior to burning. This may be as simple as routing the pipe work underground so the temperature drop condenses the moisture from the gas. The moisture then collects in a sump that is periodically pumped out.

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**SCRUBBER** - hydrogen sulphide is a small component of biogas. During combustion it is converted to sulphuric acid that causes corrosion so it needs to be removed.

**BOILER** - if the gas can be used directly it is burnt in a boiler to produce steam or hot water.

**ENGINE** - if electricity is to be generated the gas will be burnt in a Genset unit to produce electricity, or in a CHP unit to produce both electricity and heat (as hot water or steam). This steam may then be used to generate more electricity using a turbine or for maintaining the heat of the digester.

### Financial Considerations

The two main drivers that affect financial viability of an on-farm biogas unit are having access to sufficient feedstock and having a use for the energy that is produced.

Mr Michael Kottner indicated that in Germany many biogas plants derive up to 80 per cent of their revenue by charging gate fees to drop waste material off for digestion since the cost of landfill is high. However, he also stated that with the increase in competition for feedstock as the biogas industry has grown, these gate fees have disappeared in some areas.

The transport of feedstock to the digester and the digestate from the digester can become prohibitively expensive due to the high water content of both. Having a substrate source on-farm and being able to use digestate on-farm are the best options.

A lot of heat is produced when electricity is generated and having a use for it on farm will significantly increase efficiency. A closed loop farming system is likely to be more financially viable, especially if there are no feed-in tariffs for electricity.

### Concluding remarks

There are many different engineering solutions for a biogas system but they all have the same fundamental components. The final biogas yield is the same regardless of the system used; however the rate of biogas production may vary. This may be of consequence in the Australian dairy context since dairy energy demand may be higher than what some 'low tech' systems can deliver.

In the European context dairy cattle are housed for significant periods throughout the year so the majority of the manure can be collected and used as substrate. This is not the case in Australia so the maximum daily amount of manure that can be collected from holding yards and the dairy sheds needs to be calculated carefully.

The feed in tariff system in Germany ensures that it is financially viable to burn biogas to produce electricity which is then sold into the national electricity grid. This business model does not exist in Australia so individual farms will need to ensure that they have a use for the biogas on farm either for heating or cooling. It should be noted that electricity generation by burning biogas is in practice not likely to be higher than 35 per cent. Burning biogas to directly heat water or for cooling is going to be the most efficient use.

### Day Two - Biogas Plants as Appropriate Investments

Financial feasibility was evaluated in this module of the course. The decision to invest in a biogas plant should be preceded by a feasibility study. The feasibility study is one step within the life-time of a biogas project as detailed below:

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1. Project idea
2. Pre-feasibility study
3. Feasibility study
4. Detailed planning of the biogas plant
5. Permission procedure
6. Construction of the biogas plant
7. Operation and maintenance
8. Re-investment, renewal and replacement of components
9. Demolition or refurbishment.

This report will deal with the first three steps of this path, highlighting areas that are of importance to Australian dairy farmers.

### 1. Project Idea

There are two crucial considerations at this stage: firstly, how will the biogas be used; and secondly, how will a suitable quality and quantity of feedstock be secured to produce gas from?

#### How will the gas be used?

In Germany the existence of generous feed-in tariffs ensure that biogas can be profitably converted into electricity that is then sold into the national electricity grid. Indeed this is the business model of many farm-based biogas plants in Germany. These farms produce crops, mainly maize silage and/or sugar beets, solely as a feedstock for the production of biogas that is then burned in a Combined Heat and Power (CHP) generator to produce electricity.

Electricity production is at best 35 per cent efficient which means that only 35 per cent of the 'energy' contained in the methane of the biogas is available as electrical power. Significant amounts of heat are also produced. Due to the efficiency losses as energy is transformed from gas to heat to electrical power, it is unlikely that this business model would be financially viable in Australia without similar feed in tariffs. As such, it is the production of energy for on-farm use that should be investigated.

The question that Australian farmers must ask is, "Can the biogas be used on farm?"

Efficiency losses that occur during electricity generation mean the first objective should be to use all of the biogas produced for heating and/or cooling. Once these needs have been met then remaining gas should be used for electricity generation and use on-farm. Lastly, electricity produced above the needs of the farm is available for export to the power grid.

If there is no capacity to generate electricity, excess gas should be burnt in a flare to avoid the release of methane into the atmosphere.

#### What type and how much waste do I have access to for use as feedstock?

The quantity and type of feedstock available will determine the scale and type of biogas plant that is designed. It is critical that the biogas plant be designed around the available feedstock and not the other way round. It was noted several times that project failure has often occurred many times in the past because this rule was not observed.

## 6. The International Experience

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Once the quantity and type of feedstock has been determined a biogas system can be chosen. Generally manure from ruminant such cattle, goat and sheep is the easiest to manage in a digester. Ruminants are nature's perfect 'biogas digesters' so the waste contains all of the microbiology necessary to digest the waste in the digester. However, gas yields are comparatively low since most of the energy has already been extracted by the animal.

Waste from mono-gastric animals such as pigs, chickens and turkeys (as well as humans) provides relatively high gas yields. Food waste can provide even higher gas yields. However, biogas digesters using these waste types are significantly more difficult to manage. The system must be closely monitored to ensure that the chemistry remains in balance and suitable for microbiological activity. In layman's terms these systems can get indigestion very easily.

Using a combination of ruminant waste along with a higher energy feedstock such as pig or food waste provides the stability of former systems with the higher energy yields of the second.

### **What will I do with the digestate?**

Very little volume reduction occurs during digestion of the waste. Only some of the carbon is removed and all nitrogen, phosphorous and potassium, along with the micronutrients remain.

The digestate produced is in a slurry form and may be as high as 90 per cent water. Most of the nitrogen is dissolved in the water and the nutrients are in their mineralised form. This form ensures they are readily available for plant use as a fertiliser.

Due to the high water content, transport of the waste quickly becomes unprofitable so disposal on farm is the most logical solution. If the feedstock is only animal waste then the digestate can be pumped directly onto fields. Other feedstocks such as green waste or animal bedding may require pre-treatment through a cutting pump to ensure it is of suitable size for pumping through irrigation nozzles.

In Europe where farming is concentrated and intensive the nitrogen loading rate of the soil must be considered when pumping onto the fields. This is even more so during winter when plant water use declines. This is unlikely to be the case under Australian conditions and is likely to be of considerable benefit since less purchased chemical fertiliser will be required.

If the digestate needs to be stored for a period of time then the solids may need to be separated from the liquid fraction by a screw pump or similar. Most of the nitrogen will be removed in the liquid fraction and since it is in a mineral form it will be readily lost to the atmosphere if it is not used quickly.

The solid fraction contains the other macro and micro nutrients in the mineral form and as such it should be composted along with a high carbon substrate such as woodchips or poor quality hay to ensure their stability for longer term storage.

### **Concluding remarks**

A site specific financial analysis needs to be undertaken by an engineer who can evaluate all of the above considerations. A system can then be designed that meets the needs of the specific farming system. Before this analysis can begin the following information needs to be collated:

- Volume and energy yield of feedstock to determine how much biogas can theoretically be generated
- Daily, weekly, monthly and total annual availability of feedstock will help determine the likely pattern of gas production and hence the peaks and troughs of electricity generation
- The method and volume of digestate to be disposed of must be known to determine costs that will be incurred to deal with it

## 6. The International Experience

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- Daily, weekly, monthly and total annual energy demand – both electricity and gas – will enable determination of how much energy substitution can be achieved using the energy generated.

It should be noted that:

- Small plants have relatively low investment costs but running costs are relatively high. Economies of scale are maximised at 250 to 300kW plants. Beyond this size the transport of substrate and removal of digestate becomes less financially viable. Food wastes can significantly increase the yield of biogas so they are a valuable feedstock if available closeby.
- CHP plants generate significant amounts of heat that must be used to maximise efficiencies. Under European conditions approximately 50 per cent of the heat generated is used to maintain the operating temperature of the digester but this will likely be less under Australian conditions.
- Technology used does not affect the total gas yield, just the rate of gas production. The amount of energy 'embedded' in the feedstock is fixed and different technologies will be able to produce methane at different rates.

### Days Three and Four

Operation and management were evaluated in this section of the course. These two days contained large amounts of technical information regarding the microbiological processes that occur in the digester and different tools for monitoring them. Much of this detail has been omitted from this report but is available online from the course manual.

### Operating Schedules

A feeding plan needs to be determined to ensure that conditions in the 'mechanical cow' are kept as stable as possible. Stability of the system is critical to its efficient operation. Once a feeding plan has been determined, manure collection programs can be put in place to ensure a steady supply of substrate.

The start-up of the system is the most critical. Rather than one microorganism being responsible for the production of biogas there are many interdependent microorganisms that have distinct roles in the chain of production. Each microorganism must actively play its role or else the digester will 'die'. To this end many key indicators of digester 'health' need to be monitored including: temperature, gas yield and composition, pH, agitation hours, power output and feeding rates need to be logged. Visual inspections and smell should be noted as well.

Changes made to the feeding regime may take up to two weeks to become evident so need feedstock to be introduced slowly.

### Pre-storage and Treatment of Feedstock

Microbial activity and biogas yield is increased when the substrate is fine and has a large surface area. The pre-treatment by chopping or grinding of coarse substrate such as waste hay or woody plant material may be necessary to ensure efficient digestion. This can be done using various cutting pumps that are commercially available.

The feed-in and pre-treatment systems suffer the greatest wear and tear and require significant maintenance. Agitators are the next item subject to most wear and tear. The CHP units require the least maintenance although oil consumption can be considerable and needs to be factored into the running costs.

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### Concluding remarks

A well designed system does not require significant labour inputs. The Fellow visited one large system where the plant required at most one hour per day of labour, however the owner had invested heavily in automation technology. In the Australian dairy farm context it is likely that significant automation would be required since these farms already face labour constraints.

The day to day monitoring of a biogas plant does require skill; however given that it is a 'mechanical cow' it is likely that most good dairy herd managers would have these skills already.

### Destination Ten - KBK Kussmaul Biokraft GmbH Co., Gaufelden, Germany.

#### Contact

» Mr. Jürgen Kußmaul, Developer/Owner

#### Objectives

System design, financial feasibility and operation and management were evaluated at this site. This biogas plant gave the Fellow an opportunity to see another digester construction method. The daily work schedule was also discussed along with other skills and knowledge that facilitated the decision to start a biogas generation business. Financial considerations were also discussed.

#### Outcomes

This farm was interesting since while initially a dairy farm, the owners made the decision to close the dairy business and concentrate fulltime on biogas. The owner had previously undertaken contract work on many nearby farms and businesses so he had a detailed knowledge of the type and quantities of substrates available for use.

This farm processes a large amount of bakery and food waste. It charges a gate fee to customers who need to dump organic material that represented about half of the income for this business. The fees have decreased over time and the rate varies depending on what the feedstock is. Any wrappings that need to be removed obviously results in higher fees being charged.

Biogas is burnt in a CHP unit and the electricity is sold into the national grid and it attracts a feed in tariff. This system was constructed from concrete in 2005. Currently the digester takes three hours per day to maintain. Sourcing feedstock and managing other aspects of the business takes the remainder of the working day. The farm owners work with a consultant who monitors the digester routinely for gas production efficiency and feeding strategies.

## 6. The International Experience

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*Bakery waste ready for pre-treatment and feeding into the digester*



*Maize silage being made for use as feedstock at a later date.*

## 6. The International Experience

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*Biogas digester with flexible membrane storage vessel on the left.*

### **Concluding Remarks**

Although the business is breaking even, the absence of gate fees has significantly reduced profitability. This has reinforced in the Fellow's mind the importance in the Australian context of having both a readily available source of feedstock as well as an on-farm use for the biogas and energy produced.

Without the feed in tariff this business model would not work. In Germany it has been so successful that the government regulation has been introduced to restrict the amount of agricultural land on any one farm that can be devoted to biogas generation. It now stands at 30 per cent. Before this regulation was in place the extra farm income generated by the feed in tariff was being capitalised into land values. There was a general concern that higher land prices would result in food production becoming unviable. With the absence of these tariffs in Australia it would be unlikely that land price inflation would occur.

The use of consultants is widely accepted in the Australian dairy industry so the adoption of this system would seem to be an effective way of reducing the management labour as well.

## 6. The International Experience

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**Destination Eleven - Kompostierung Wetterau GmbH (Integrated waste management facility), Friedberg, Germany; and Marburger Entsorgungs GmbH (Recycling of biological and commercial waste), Marburg, Germany.**

### Contact

» Mr Kurt Schaefer, Operations Manager

### Objectives

System design was evaluated at this site. Local and regional planning laws and regulations surrounding the business were also discussed. The Fellow was also able to see firsthand how different waste streams can be utilised as feedstock. Also on display was the biogas digester being utilised within a larger waste management business.

### Outcomes

Sending organic material to landfill in Germany was made illegal in 2005 after a ten year adjustment period. This has resulted in the creation of many start-up businesses that collect organic household waste and green waste for composting. With the advent of renewable energy feed-in tariffs, many of these businesses have 'added on' a biogas digester system to extract the energy before composting.

Due to the disease risk, EU regulations prohibit the use of restaurant waste as a feedstock, although household waste may be used. This was the first of many instances where plant operators expressed frustration at the maze of often contradictory laws and regulations surrounding the biogas industry. Construction and operation of biogas systems must comply with local planning laws, German laws and also EU regulations which are not always aligned with each other.

### Concluding Remarks

Clearly waste streams are being seen as a resource in Germany from which money can be made. Regulations and feed-in tariffs have been necessary over a period of time to enable such business models to work. The adoption of a feed in tariff may encourage Australian dairy farmers to adopt such technology also.

Biogas generation has a place alongside composting, which in the Australian context will enable animal waste to be still used as fertiliser. It should be remembered that all that is being removed from the digestion process is energy – all of the nutrients that are contained in the substrate are in the digestate, although the form of nutrients may be changed.

## 6. The International Experience

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### **Destination Twelve - Mr Johannes Korner, privately owned digester, Munster, Germany.**

#### **Contact**

» Mr Johannes Korner, owner.

#### **Objectives**

System design, financial feasibility and operation were evaluated at this site. The Fellow was able to see how access to feedstock and the proximity to markets affect decisions to locate a digester directly as a result of the feed in tariff. The use of automation to reduce labour was also evident at this site.

#### **Outcomes**

This plant is another example of an 'energy farming' business. The owners grow and buy in crops specifically to produce electricity to sell back to the grid to generate income from the feed in tariff. Heat was also sold and fed into the local heat grid.

The plant has been located on the owner's land, however he also has access to maize silage and sugar beets from nearby farmers. Sugar beets are an energy dense substrate that can be stored for extended periods (greater than 12 months). The engineers on the study tour were truly impressed with the design of this plant. This one mega watt system requires only one person to run it for several hours a week. Automation has been included to the degree that it can be managed on a mobile phone over the Internet.

#### **Concluding remarks**

Due to the cost, it is unlikely that this business model would work in the Australian dairy industry without significant government intervention in the form of a feed in tariff. However, given the labour restrictions in the Australian context, any systems that are built would likely need to have a very low labour input and hence the degree of automation at this plant may have application.

## 6. The International Experience

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### Destination Thirteen - Albert Huber's family farm (biogas plant and farm supermarket ), Düsseldorf, Germany.

#### Contact

» Albert Huber, owner.

#### Objectives

System design and financial feasibility were evaluated at this site. The Fellow was able to observe how the initial business model can be adversely affected by changes in the market. Subsequent changes of environmental regulations and its impact on the business were also observed.

#### Outcomes

The Huber family constructed a biogas plant on their farm in 2005 using grain as a feedstock. At this time grain was worth EUR100 per tonne. Since that time the price moved to EUR250 per tonne at the time of compiling this report. To ensure the system remained profitable they moved to the use of sugar beets as a feedstock; however, the beets require washing as a pre-treatment that added another layer of complexity to management. They then moved to adding a variety of feedstock to the digester including chicken litter, corn cobs, maize silage and green rye grass.

Environmental laws have also changed and now require that all silage bunkers be completely sealed and bunded to capture all leakage and run off. This has become a considerable added cost. Mr Huber expressed his frustration at the increasing level of regulation surrounding the operation of his plant. At the time of construction regulation was less and any extra capital expenditure that he is forced to undertake now is not reflected in the initial financial analysis.



*Genset built into a shipping container.*

## 6. The International Experience

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### Concluding remarks

It is obvious that the costs of feedstock may vary over time and a risk management approach needs to be taken here. In terms of changes to environmental laws it may be wise to use industry best practice from the beginning even if this goes above and beyond current requirements.

Australian dairy farms would likely use their own animal and plant waste as a substrate so should not be affected by changes in the price of grains. However, the point needs to be made that if any substrate is being purchased for use in a digester any price fluctuation can affect profitability. At times large amounts of waste silage or hay and grass surplus to needs may be available as substrate on Australian dairy farms.

### Destination Fourteen - Bioenergie Schneider GmbH & Co, Kusel, Germany.

#### Contact

» Mr. Schneider, Founder and CEO

#### Objectives

System design and operation were evaluated at this site. The Fellow was able to observe first hand a 'garage digester' system and to gain an understanding of some of inefficiencies that surround the feed-in tariff system.

#### Outcomes

Most of the systems seen to date were continuous flow models where substrate is pumped into a large usually round vessel and the digestate then flows or is pumped out. For every litre of substrate that enters the system, one litre of digestate must come out.

The garage system is a batch system. A sealed vessel in the form of a garage is filled with solid feedstock and then sealed. Liquid percolate is then pumped into the roof of the digester where it trickles down through the substrate encouraging biogas production. The percolate is collected on the floor, pumped out and recirculated.

This system is less efficient than continuous flow systems but it met the labour requirements of this farm and was suited to the type of feedstock available; in this case it was dry rough waste hay and animal bedding material along with locally sourced green waste. There was no liquid manure on this farm.

Mr Michael Kottner stated that three per cent of the energy produced in this garage system is used to maintain it as opposed to eight to ten per cent in conventional digesters. The garages were loaded and unloaded using a front-end loader. The feed in tariff was only payable if 60 per cent of the heat produced from the biogas system was utilised. In this case it was used to dry fire wood. However to meet this requirement it was noted that some farms pump the hot air continuously into the same batch of wood for many months to meet the legal requirement but never replaced the wood.

## 6. The International Experience

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Garage digester showing individual 'garage' chamber doors. These doors are hinged at the top.



Spreader used for putting digestate onto the fields.

## **6. The International Experience**

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### **Concluding remarks**

The garage system is better suited to drier feedstock but it is more labour intensive. Given the labour restrictions on Australian dairy farms, this system may not be suitable although most Australian farms would have the front-end loader necessary to load and unload the garages.

It is apparent that any Australian government intervention needs to be carefully planned since this farm was another example of waste heat being used to dry the same stockpile of wood for many months to meet the contractual obligations. In this case there were even some pipes venting hot air directly to the air for no purpose.

Garage digesters may have a place on Australian farms where there are large amounts of coarse straw or animal bedding. However most of the animal waste on dairy farms is too liquid for use in this type of system.

# 7. Knowledge Transfer: Applying the Outcomes

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It is clear that the generation of biogas on farms using animal waste is technically possible. There are many established engineering solutions in both China and Germany that can ensure an efficient gas yield with minimum labour inputs that would have application in the Australian dairy industry. It seems likely that in order to minimise costs and maximise international comparative advantages, a future model may be one of German technology, built in China and constructed locally.

Given the lack of a feed in tariff in the Australian context the decision to proceed to construction and the subsequent financial feasibility of any on-farm biogas generation system will depend on effectively answering the following two questions:

1. Is there sufficient substrate on the farm or close by that will meet the farm daily, monthly and annual energy needs?
2. Is there a use on farm for firstly the biogas directly and secondly any electricity that is produced?

The type of system that needs to be constructed for any particular farm will become apparent after these two questions have been answered. In the process of answering these questions a qualified professional, likely an engineer with experience in this field, should be engaged.

For smaller farms with lower energy needs and less available substrate, a simple passive modular system may suffice. Larger enterprises may well need larger more complex systems.

Large state of the art systems constructed in China on 6000 head dairy farms suggest that biogas digesters in tandem with composting systems may be an important part of managing effluent on very large dairy farms that may otherwise cause groundwater contamination.

Any plan to progress the utilisation of biogas on Australian dairy farms must also broadly answer the same two questions above. Given the difference in farming systems between Germany and Australia, in particular the absence of animal housing and resultant reduction in volume of animal waste for collection, a necessary first step would be an audit to calculate the likely maximum quantity and quality of substrate available for digestion. This would include manure from the dairy and surrounding yards, calf rearing sheds and other areas where stock is held on a regular basis. Waste silage or hay and other surplus grass that could be cut, or crops that could be utilised should also be determined.

Given the diversity of dairy farming systems this should be carried out for large, medium and small herd sizes in different regions within Australia. The same process should be undertaken to determine the energy needs for heating and cooling on the farm, both in terms of 'raw' heat and electricity to achieve it. Following this audit an engineer could be engaged to undertake a feasibility study based on the audit outcomes.

Government could play a major role in facilitation of this process by underwriting the costs of the audits and feasibility studies. If the feasibility studies indicated that biogas systems may have a long term financial role on some farms, government may even encourage the adoption of this technology by offering grants to assist in construction.

Dairy Australia and other industry players such as milk processors may already have much of this information already from different previous projects that have been undertaken. Dairy Australia could oversee the collation of this information if it already exists or its collection if it doesn't. If the audit process indicates the likely feasibility of biogas systems, as the peak industry body, Dairy Australia could lobby government for funds to conduct the feasibility studies.

The Fellow will forward copies of this report to Dairy Australia and major Australian milk processors to highlight these findings indicating the respective roles they could play. At a local level the Fellow will also undertake information days explaining the outcomes to interested dairy farmers. Most processors have 'farm walk' groups that will provide an opportunity to give a one hour presentation and question and answer session explaining the Fellowship and its findings. Given the current increases in energy costs these will be timely.

# 8. Recommendations

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There are many skills deficiencies within the three broad areas of biogas system design and construction, financial feasibility and operation and management that have been listed. Addressing each of these deficiencies at this early stage when it is possible that the technology may not have widespread application within the Australian dairy industry, will likely be a waste of resources.

Simply concentrating on the two key questions 'Is there sufficient substrate?' and 'Is there use for the biogas generated?' is likely to illuminate the path forward more effectively than a piecemeal approach of addressing each skill deficiency.

Several key bodies could play roles in facilitating this process. Recommendations to each body is outlined below:

## **Dairy Australia**

- Collate and/or collect data to determine the maximum potential substrate available on three different size dairy farms in temperate, subtropical and tropical Australia
- Determine the typical energy demand for each of the types of farms listed above
- Lobby federal government for funds to undertake data collection and evaluation and feasibility studies.

## **State Government**

- Relevant state bodies assist Dairy Australia to collect/collate above information.

## **Milk Processors**

- Assist relevant state bodies and Dairy Australia to collect/collate above information
- Lobby Dairy Australia to obtain funds for data collection/collation and feasibility studies from federal government.

## **ISS**

- Within the three broad areas of skills deficiencies many deficiencies exist. If the feasibility studies suggest that biogas systems have a role on specific dairy farms then ISS will need to have Fellowships made available to farmers and/or consultants to fill these skills deficiencies to develop a broad and deep understanding of the construction and operation of biogas systems.

# 9. References

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1. Australian Dairy website (February 2013 Update) (<http://www.dairyaustralia.com.au>)
2. IBBK Fachgruppe Biogas and the University of Hohenheim, <http://www.biogas-zentrum.de/aktuell.html>