

Is Biogas Technology right for Australian Dairy Farms?





Biogas for my dairy farm

Despite dairy farm waste being a good resource for biogas production, there are currently few working examples of biogas technology in Australia's dairy sector. Biogas technology not only supplies renewable energy, but in addition the technology can provide the following co-benefits for dairy farms:

- simplified waste management
- reduced odour and Greenhouse Gas (GHG) emissions
- improved fertiliser value of manure and other by-products.

Biogas technology does not have to be complex or difficult to operate, but it does need to be tailored to the specific needs of the farm in terms of farm management, waste characteristics and biogas use.

Biogas formation

Biogas is produced by anaerobic digestion (AD) of organic materials and consists of 50–70% methane (CH₄) and 30–50% carbon dioxide (CO₂) as well as minor gas components, such as water vapour, nitrogen and hydrogen sulphide. AD is a multi-step process that involves a range of micro-organisms that all have specific requirements (e.g., pH, temperature, nutrients). However, given sufficient time, a productive and stable micro-organism community can be established for a wide range of organic materials and operating conditions.

Anaerobic Digestion technology

The most common technologies for on-farm AD are either engineered, heated and completely stirred tank digesters (CSTD), or ambient temperature, unmixed Covered Anaerobic Ponds (CAP) (see table below). On an annual basis the quantity and quality of biogas produced by both technologies is similar.

	CSTD	CAP
Construction	Concrete or steel tank with insulation, heating, mixing and plastic membrane roof.	Earthen pond with plastic cover (and plastic liner where required).
Substrate dry matter (DM) concentration	>4%	<5%
Operating temperature	Heated: 35–39°C or 55°C.	Varies with ambient temperature (5–25°C).
Advantages	Applicable to a wide range of materials, shorter treatment time, small size, standard designs, applicable for use in all climates.	Lower cost construction using local resources, lower operation and maintenance requirement, no heat demand, tolerant of shock loads, cover also provides biogas storage.
Disadvantages	Higher construction and operation costs including heat demand, requires skilled operation.	Large size, suitable only for liquid organic materials and temperate to warm climates.

Biogas substrates

Milking shed effluent and the more concentrated manure scrapings/slurries from dairy cow housing systems or feed pads are the main organic materials available for anaerobic digestion on dairy farms. The amount and quality of dairy farm waste available for anaerobic digestion is difficult to estimate, since small management differences can lead to up to $\pm 50\%$ variation in the amount of waste available between otherwise identical farms. Differences can include the time taken to milk the herd (small shed vs large shed, running the herd as several mobs, etc.) whether milking is once or twice daily, the feed type and quality (i.e., age/condition of pasture), average animal live weight as well as several other factors.

The waste volume depends on the amount of manure collected (milking shed, feed pad) and the amount of washdown water used. High water use results in dilute effluents with low dry matter concentration, which are more suited for digestion in CAPs. Little or no water use results in higher dry matter concentration slurries that are more suitable for CSTDs. Use of bedding material can complicate anaerobic digestion. CSTDs can cope with moderate amounts of straw bedding, but wood-based bedding material, such as shavings or sawdust (which cannot be broken down anaerobically) can cause problems. Sand bedding material needs to be removed before the manure can be digested. Since both, the amount of organic material (kgVS) available as well as the waste volume, determine the digester size and configuration, an accurate assessment of average daily waste volume and quality is needed before embarking on any biogas project.

The biogas methane yield of cow manure ranges from 0.18 to 0.25 m³CH₄/kg volatile solids (VS – a common measure for organic matter). This moderate yield is mainly due to the relatively high content of indigestible lignin found in most manures.

For illustration purposes only, rule of thumb values of dairy manure production and biogas yield for hypothetical dairy farms of increasing size and intensity are given in the table below:

No. of cows	Farm intensity	Organic load per cow (kgVS/cow/d)	Total daily organic load (kgVS/d)	Waste concentration (%VS)	Daily methane yield (m ³ CH ₄ /d)	GHG emission/abatement (tCO ₂ equiv./d)
400	All pasture fed (milking shed only)	0.25	100	0.7–1.0	20	0.35
600	With feed pad (milking shed and feed pad)	0.6	360	1.0–1.5	70	1.3
1000	Fully housed (milking shed and housing)	5.0	5000	3.0–7.0	1000	18.0

A great range of organic wastes and by-products can be co-digested with dairy farm manure like food processing wastes (e.g., stillage, whey), vegetable processing wastes, green waste, non-woody crop residues, slaughterhouse wastes and municipal organic wastes. However, many of these materials require elaborate and costly quality assurance, monitoring and specific handling procedures (removal of foreign objects, pasteurisation, biosecurity, etc.).

In general, most off-farm substrates have a higher theoretical biogas methane yield (0.3–0.5 m³CH₄/kgVS) than manure. However, the actual methane yields need to be determined experimentally, and the specific handling requirements determined in detail, for every potential co-digestion material substrate prior to embarking on any co-digestion project.

Greenhouse Gas benefit

Methane is a powerful GHG when emitted to the atmosphere each – 56 m³ of biogas methane emitted is equivalent to 1 tonne CO₂. Collection and combustion of methane from manure management is, therefore, one of the most straightforward pathways for reducing GHG emissions from the agricultural sector. The GHG abatement potential for the capture and combustion of the daily biogas methane yields from the hypothetical 400, 600 and 1000 cow dairy farm are shown in the table below.

The Emissions Reduction Fund (ERF) offers an opportunity for farmers to earn Australian Carbon Credit Units (ACCUs) for avoidance or sequestration of greenhouse gas emissions. One ACCU is earned for each tonne of carbon dioxide equivalent (tCO₂-e) emission avoided. Anaerobic Digestion technologies that capture an existing methane emission are eligible for earning ACCUs regardless of whether they involve combusting methane in a flare, boiler or electricity generator. However, at the current value of 1 ACCU any potential income from the ERF is unlikely to be high enough to justify installation of AD technology by itself. Earnings from GHG emission abatement should, therefore, only be regarded as a bonus.



Biogas use

Appropriately treated biogas could theoretically be used for all the applications that natural gas is currently used for, but three options are most relevant for dairy farms:

1. Flaring – for AD schemes that primarily focus on reducing odour and methane GHG emissions.
2. Hot water provision using gas boilers – particularly for small AD schemes.
3. Biogas as generator fuel – for the provision of electricity (and hot water).

Hot water

Biogas can be combusted in slightly modified standard gas hot water boilers without the need for substantial biogas quality improvements. The equipment costs for this hot water use are AU\$4–8k and little operation and maintenance is required. A hypothetical 400 cow all pasture fed dairy farm (see table above) may be able to produce ~1400 L of hot water (90°C) per day with the biogas recovered from the cow shed effluent.

Electricity Generation

The use of biogas as electricity generator fuel is the most common use of biogas worldwide, but does require a moderate level of biogas quality improvement (i.e., condensate removal, reduction of H₂S to <200 ppm, etc.). A biogas fuelled generator not only substitutes grid electricity but will also provide a back-up source of electricity for the farm during power outages. The capital cost of an electricity generator large enough to power a milking shed (~50 kW) ranges from AU\$30k for entry level equipment to AU\$80–120k for more advanced equipment. A hypothetical 600 and 1000 cow dairy farm (see table above) could generate 220 and 1000 kWh of electricity per day, respectively. Additionally, several thousand litres of hot water (90°C) per day could be recovered from the biogas generator engine coolant and exhaust gases.

For large biogas schemes incorporating co-digestion of off-farm materials, export of generated electricity to the grid could be a substantial source of revenue. However, the value of exported electricity is often much lower than the value of imported electricity and the size of the scheme may be limited by a lack

of spare capacity in rural electricity networks. Moreover, some states (e.g., WA) require very sophisticated safety equipment and procedures for grid connected electricity generation schemes, making their establishment cumbersome and costly. Large biogas electricity generation export schemes, therefore, require thorough and long term planning.

Benefits of AD

While renewable biogas energy is the most obvious benefit of AD technology, it provides several other important benefits that should be taken into account. In many cases, these non-energy benefits may turn out to be the more important drivers for the application of AD technology.

Solids Removal

Anaerobic Digestion is very effective in reducing the (coarse) solids content of farm wastes (typically by 50–80%), which simplifies and reduces the cost of handling the digestate, particularly when it can be utilised for irrigation with existing irrigation infrastructure. Anaerobically digested effluent can also be easily recycled as wash-down water for non-critical areas around the milking shed.

Odour Reduction

Efficient AD removes most odorous volatile organic compounds (VOCs), from the waste since they are easily broken down to biogas. Other odorous compounds, such as hydrogen sulphide (H₂S) are released from the waste during AD but these are captured with the biogas and destroyed by combustion. Consequently, odour emissions from both the handling/storage of farm manure, and the land application of digestate are substantially reduced. Reduction of farm odour emissions can be a prime driver for the adoption of AD technology as occurred with the pork industry in Australia and New Zealand.

Fertiliser Nutrient Availability

Anaerobic digestion does not alter the fertiliser nutrient content of organic wastes. However, it does convert most of the organic nutrients into simple, more plant-available forms (ammonium-N and soluble phosphate). Application of digestate nutrients can, therefore, be more targeted and better planned than with undigested waste, providing cost savings and environmental benefits.

Field examples:

A) 75 kW all manure CSTD biogas plants slow to gain prominence in Germany

With over 8000 biogas plants in operation, Germany is the global leader in the farm-scale biogas sector. However, in states with smaller than average farm size (e.g., Baden-Wuerttemberg) less than 1/5 of all available animal manure was used for AD. A generous incentive scheme (with a 20 year fixed electricity export rate of 0.25 Euro/kWh) began in 2012 to promote the installation of biogas plants with 75 kW or less power output that use at least 80% manure (by volume) as input material.

As a result of the scheme, 200 CSTD biogas plants with 75 kW power output have been built since 2012. However, monitoring of 60 of these new small biogas plants showed that each plant required the manure from ~500 fully housed dairy cows, meaning that even for these small plants the manure from several farms was necessary to establish a CSTD scheme. The digesters used 6–10% of the electricity production onsite for operation, and some used all of the generator waste heat to maintain the CSTD temperature in the mesophilic range during the coldest days of winter. These small CSTD plants are also rather labour intensive, requiring 300–500 h per year (average 400 h/y) labour for operation, supervision and maintenance. The investment costs for the 75 kW plants ranged from 350,000 to 900,000 Euro with a median of 570,000 Euro. Consequently, despite the very attractive electricity export rate, many of the higher costing 75 kW plants failed to generate a profit. Many small technical improvements and substantial cost reductions are needed to increase the financial attractiveness and promote more widespread uptake of these small CSTD biogas plants.

B) CAP Biogas System at Lepper Piggery, New Zealand

The Lepper Trust piggery in New Zealand built a covered anaerobic pond biogas system in 2009 to primarily address odour emission problems from the farms effluent management system. A custom designed 7000 m³ anaerobic pond was built to digest ~70 m³/day of flush manure effluent with a VS concentration of 0.9–1.3%. The pond was fitted with an earth sealed, 1.5 mm LLDPE cover, complete with rain water removal system and biogas collection ring pipeline. From day 1 the CAP fulfilled its main task of markedly reducing effluent odour emissions. The daily biogas methane production (of 200 m³/d) is used to drive a 48kW spark ignition electricity generator that operates alongside the grid, but can also be used to provide back-up power to the farm during grid outages. With >8000 generator operating hours recorded, the generator and biogas system has proven to work reliably and only requires ~150 h/y labour for operation (almost all of this time is spent on maintaining the electricity generator rather than the CAP). As a result, the NZ\$120,000 capital cost was recouped half way through the 4th year of operation.

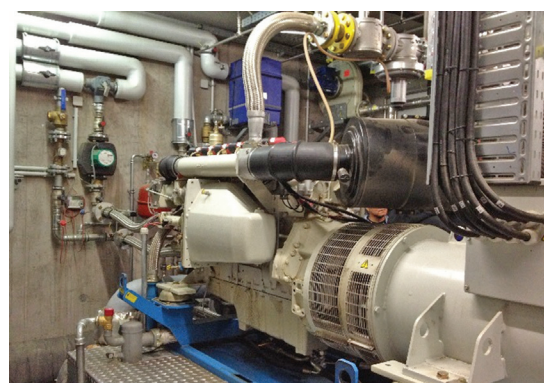


Biogas for an Australian dairy farm

Anaerobic digestion schemes could be established on Australian dairy farms for any of the benefits that they provide. However, when considered individually, these benefits may not be sufficient to justify installation of AD technology on a farm. But, when multiple benefits are accounted for, the rationale for installing AD technology often becomes much more compelling. In the near-term, the primary drivers may be to overcome manure management issues such as improved/simplified land irrigation of digestate, or to assist with regulatory problems, such as odour emissions and water use reduction (digestate reuse). Biogas electricity generation will be of most benefit when substituting imported grid electricity and would be particularly beneficial for total energy self-sufficiency or off-grid farms and cow sheds which are currently supplied by diesel generators.

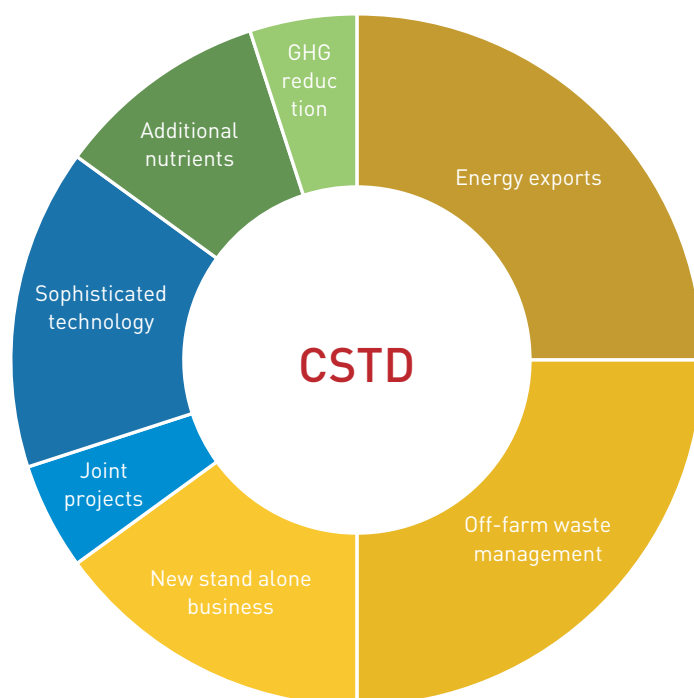
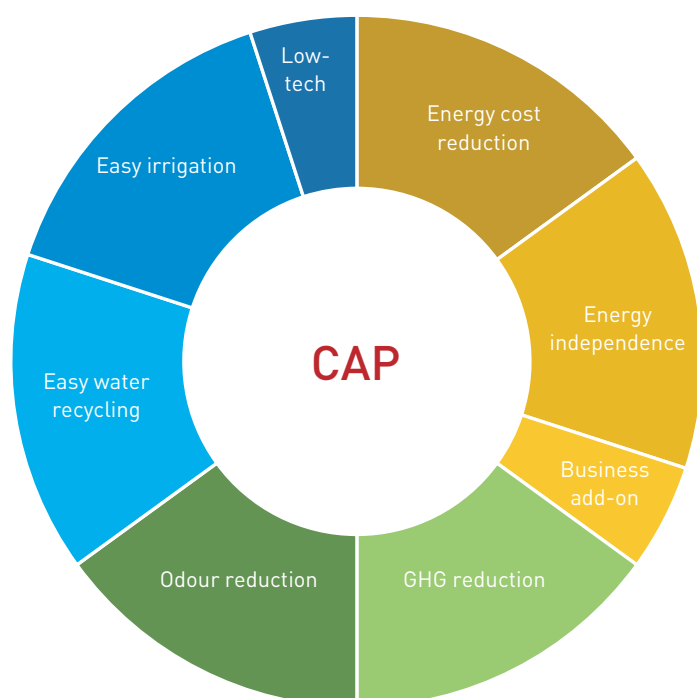
Which AD technology is most appropriate will depend on site-specific factors at each farm. In general CAP systems can be applied at smaller scale, require less operation and maintenance, and can be constructed much more cost-effectively than CSTDs. The opportunities for CSTD systems are with larger systems that are often developed as stand-alone businesses and address regional organic waste problems, generate electricity for export and recover nutrients from off-farm waste for agricultural use. Importing designs from Europe or North America is not always appropriate as regulatory support and drivers for AD adoption differ greatly. In Australia, little government support is available and technical knowledge among potential service providers is so far limited.

The decision support compass below is intended as a first scoping tool to help farmers assess if, and why, one of the two most common biogas technologies may be appropriate for their farm, by giving a relative weighting to key drivers for the technology. The decision support compass includes non-monetary drivers that can be more important for selection than the often limited financial benefit.



Biogas decision support compass

Blue colour represents 'Farms Management drivers', Yellow colour represents 'Monetary Drivers' and Green colour represents 'Environmental Drivers'.





Dairy Australia is the national services body for dairy farmers and the industry. Our role is to help farmers adapt to a changing operating environment, and achieve a profitable, sustainable dairy industry.

For more info visit:

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