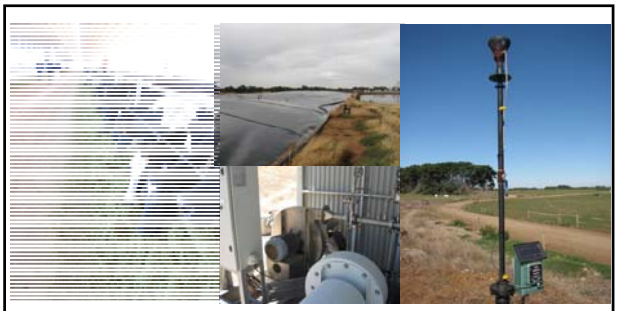
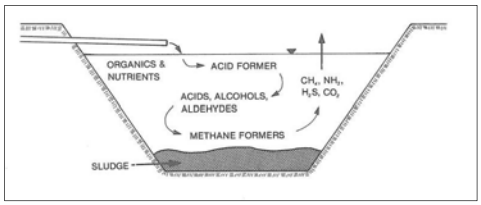


Methane from effluent ponds

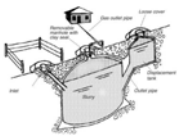
Anaerobic digestion 101

- Anaerobic digestion starts in the rumen (where the easy energy is extracted), continues in the pond.
- Methanogens are slow and sensitive – process can suffer upset
- Biogas is typically 60-65% CH_4 with most of the remainder CO_2

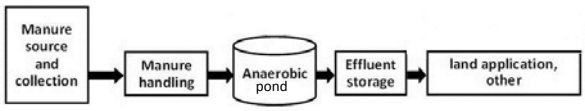


Energy from biogas

- Methane from anaerobic digestion has been utilised since the late 1800's.
- There are literally millions of small digesters in developing nations providing low cost energy for lighting and cooking.
- USA had 260 operating digesters on livestock farms (May 2015); 206 of those on dairies including 26 covered lagoons.

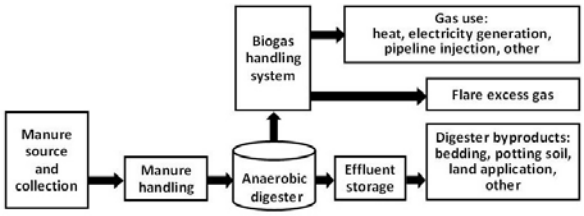


Digesters 101



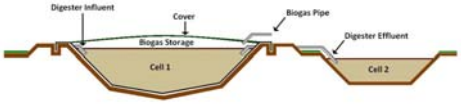
Source: USEPA AgSTAR

Digesters 101



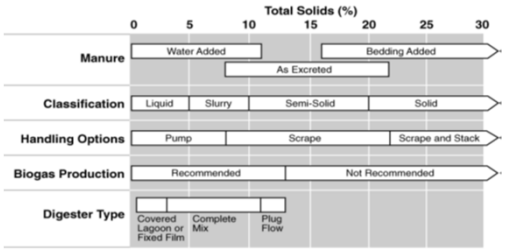
Source: USEPA AgSTAR

Covered anaerobic pond



Which technology?

- Covered anaerobic ponds "appear to represent the best option for commercial on-farm biogas capture and use" in Aust. (low tech, robust, suited to dilute effluent).



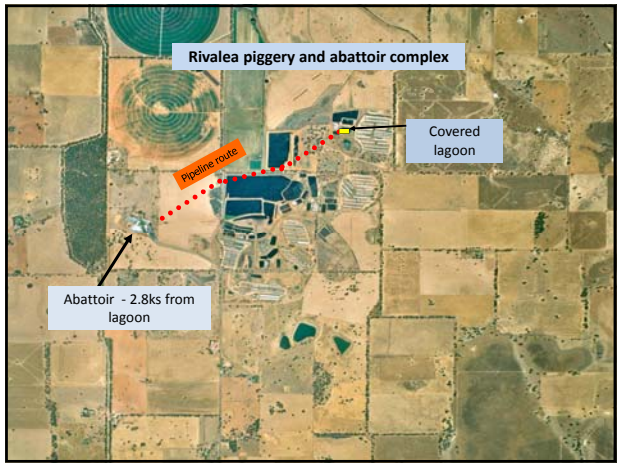
Uptake in Australia

- Pigs; 1 engineered (complete mix) digester and 6 covered pond projects (7% Aust pork production ~ 180,000 SPU's) *2014 data*
- Dairy; 0 covered anaerobic ponds.

Rivalea, Corowa NSW – 2 sites have biogas projects

A 14ML covered anaerobic lagoon at Bungowannah. A 6,000 sow 'breeder only' piggery 2012

A 42ML covered anaerobic lagoon at Corowa. A 5,000 sow 'farrow to finish' piggery' 2012
13,000 t/y CO_2-e mitigated – replace LPG hot water heating



Scott Birchall, Dairy Australia Consultant, Land, Water & Carbon – Murray region, March 2016

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Differences between pigs and dairy

1) Amount of Volatile Solids (VS) produced as the feedstock.

- 1 Standard Pig Unit (SPU) represents 90 kg VS/yr (an average size grower pig)
- 100 sow, farrow to finish = 1260 SPU and ~110,000 kg VS/yr.
- Typical dairy cow excretes 1200-1800 kg VS/lactation but only 10-15% collected (120-270 kg VS).

- 1 dairy cow (grazing) equivalent to 1.3 - 3 SPU.

Rivalea, Corowa NSW – 2 sites have biogas projects

A 14ML covered anaerobic lagoon at Bungowannah. A 6,000 sow 'breeder only' piggery 2012

= 4,000 to 9,000 cows (grazing herd)

A 42ML covered anaerobic lagoon at Corowa. A 5,000 sow 'farrow to finish' piggery' 2012

= 20,000 to 45,000 cows (grazing herd)

Differences between pigs and dairy (cont.)

- Intensive vs. extensive
  - Typical dairy 300 cows, majority of diet directly grazed with manure excreted in paddock, remaining ~10-15% collected. Equivalent to 400 – 900 SPU.
  - Intensive dairy, 1000 cows in freestall fed total mixed ration (TMR), ~80-90% collected. Equivalent to 10,000 – 18,000 SPU.

- 1 dairy cow (intensively housed) equivalent to 10 - 18 SPU

Rivalea, Corowa NSW – 2 sites have biogas projects

A 14ML covered anaerobic lagoon at Bungowannah. A 6,000 sow 'breeder only' piggery 2012

= 4,000 to 9,000 cows (grazing herd)

= 700 to 1,200 cows (freestall)

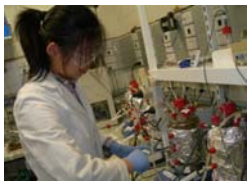
A 42ML covered anaerobic lagoon at Corowa. A 5,000 sow 'farrow to finish' piggery' 2012

= 20,000 to 45,000 cows (grazing herd)

= 3,500 to 6,000 cows (freestall)

Differences between pigs and dairy (cont.)

2) Degradability of excreted VS greater for pigs compared to dairy (monogastric vs. ruminant, differing diets)
   - B_o is maximum methane producing capacity. Default given by IPCC:
     - B_o pigs = 0.45 m^3/kg VS
     - B_o dairy = 0.24 m^3/kg VS



Relevant ERF methods

- Destruction of methane generated from dairy manure in covered anaerobic ponds
- Destruction of methane from piggeries using engineered biodigesters
- Destruction of methane generated from manure in piggeries
- Destruction of methane generated from manure in piggeries 1.1

Common elements:
- covering ponds to prevent the release of methane (or diversion to engineered digester)
- collecting the emitted methane, and
- combusting the methane to convert it to carbon dioxide and water.

Requirements of methods

- Ponds comply with industry guidelines; pond depth > 2m (pig) or VSLR > 50 g/m^3 (dairy)
- Only animal manure & normal waste feed & bedding may be digested
- Frequently sparking flare or monitoring of flaring system
- Record keeping; animal no's, time on yard, diet, etc

Baseline vs. measured emissions

- Estimate baseline if project did not occur (tonnes CO_2-e)
  - Tiered approach to calculating VS entering pond (DGAS, PigBal)
- Calculate net abatement; measured quantity of methane emissions avoided minus emissions from operating the project
- Cannot claim a quantity of methane destroyed higher than baseline

Data collection

- Measurement subject to quality controls. For example, measurement of quantity of methane emissions destroyed:
  - instrument operates with an accuracy of +/- 5%
  - field checked for accuracy within 2 months of end of reporting period
  - re-calibrated at lesser of manufacturer's recommended interval or every 5 years

Project costs & viability

- ERF reverse auction - min project size 2,000 t/y CO_2-e mitigated
- 400 sow farrow to finish piggery (4000 SPU) may mitigate 2,000 t/y CO_2-e

At present, projects are not economically feasible under about 4-5,000 t/y CO_2-e mitigated. However, this may reduce as smaller and cheaper equipment becomes available.

- 5,000 - 12,000 cow grazing herd may mitigate 4,000 t/y CO_2-e
- 800 - 1,500 cow fully intensive herd may mitigate 4,000 t/y CO_2-e

Under the ERF, projects are unlikely to be feasible for flaring methane only. Projects will have to generate electricity, CHP or tri-generation.

Energy cost rises will dictate project uptake in the future.

How much potential energy?

- 1 kg COD produces 0.25 kg CH_4 (or 0.35 m^3 at STP)
- 1 kg CH_4 contains 50 MJ energy (~14 kWh-e)
- 1 cow excreting 5.4 kg COD/d (NZ data), 15% collected, 50% destroyed
  - = 0.1 kg CH_4/cow.d
  - = 1.4 kWh-e/cow.d (NOTE only 25-30% of that is potential electrical output, or ~0.35 kWh/cow.d = 0.015 kW/cow)
- Could be 2.4 kWh/cow.d or 0.1 kW/cow under TMR/freestall scenario
- For comparison, approx. electrical energy required for:
  - Milk cooling (17 to 4ºC, 20 L/d, COP 2.6) = 0.12 kWh/cow.d
  - Hot water (15 to 85ºC, 2.3 L/d, COP 0.98) = 0.19 kWh/cow.d
- So energy budget looks positive, but need to consider system cost!

Capital costs (USA AgSTAR program)

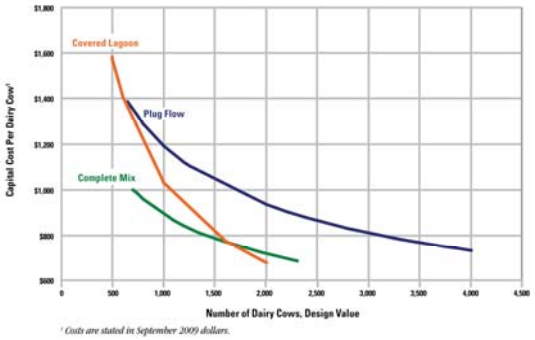


Figure 2. Capital cost per dairy cow for complete mix, plug flow, and covered lagoon AD systems

Cost energy of energy produced?

- Scarce Australian data; feasibility study for 2200 cow freestall dairy; approx. $800K (exc. pond earthworks and heat recovery) comprising:
  - $310K cover ($20/m^2)
  - $230K genset (typically allow >$1500/kW)
  - $100K engineering
  - ~$400/cow
- Using USEPA AgSTAR cost at $700/cow for 2000 freestall cows (2.4 kWh/cow.d), a 15 year lifespan and $0.02/kWh O&M
  - $0.05/kWh produced => *warrants investigation*

Scenario:		400 cow herd, grazing	700 cow herd, hybrid	1000 cow herd, TMR
Production	L/lactation	6310	6991	7671
	L/cow.d	20.7	22.9	25.2
Dry Matter Intake[1]	kg/cow.d	18.6	19.8	21.1
Volatile Solids excreted[1]	kg/cow.d	3.8	4.0	4.3
Proportion collected	%	10	25	85
Volatile Solids to pond[2]	kg/d	135	632	3259
Estimated methane yield[3]	$m^3 CH_4$/d	29	136	704
	t CO_2-e/yr	127	593	3059
Flare only:				
CFI incentive[4]	$/yr	1903	8891	45886
	$/cow.yr	4.76	12.70	45.89
Hot water, flare remainder:				
Hot water electricity offset[5]	$/cow.yr	7.34	7.02	6.82
Combined benefit	$/cow.yr	12.10	19.73	52.71
Combined heat & power:				
Potential electricity yield[6]	kWh/d	83	386	1990
	kW	3	16	83
Purchased electricity offset[7]	$/cow.yr	8.18	21.84	43.99
Electrical export revenue[8]	$/cow.yr	0.00	0.00	16.12
REC value[9]	$/cow.yr	2.20	5.88	21.24
Heat recovery benefit[10]	$/cow.yr	5.03	7.02	6.82
Combined benefit	$/cow.yr	20.18	47.45	134.06

Notes:
1. Calculated using DGAS
2. After allowing 10% VS removal by screen
3. Calculated using CFI methodology – 'baseline emissions'
4. Carbon price @ $15/t CO2-e, price will vary, benefit excludes energy used to capture and combust biogas
5. Electricity cost for water heating @ $0.10/kWh off-peak, offset limited to estimated hot water requirement
6. Electrical generation efficiency @ 30%
7. On-site consumption estimated @ 44 kWh/kL, electricity cost averages @ $0.15/kWh, $0.02/kWh O&M cost
8. Export @ $0.08/kWh under Victorian standard feed-in tariff (100 kW limit), $0.02/kWh O&M cost
9. Renewable Energy Certificates valued @ $35/MWh, price will vary
10. Engine jacket heat recovery only (0.8 kWh/kWh)

Resources

- Approved ERF methods http://www.cleanenergyregulator.gov.au/ERF/Forms-and-resources/methods/resources-for-agricultural-methods
- Dairy Shed Effluent and Biogas – Frequently Asked Questions http://www.dairyingfortomorrow.com/uploads/documents/Dairy%20Shed%20Effluent%20and%20Biogas_1.pdf
- Is biogas technology right for Australian dairy farms? http://frds.dairyaustralia.com.au/wp-content/uploads/2013/05/FINAL_Biogas-technology_A4-report-summary.pdf