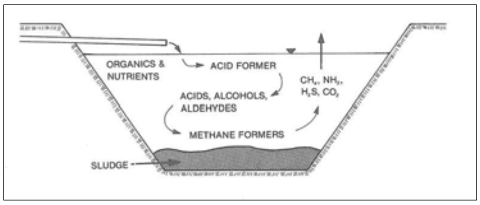
Methane from effluent ponds

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

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



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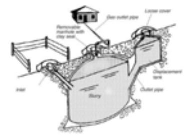
Energy from biogas

- 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.



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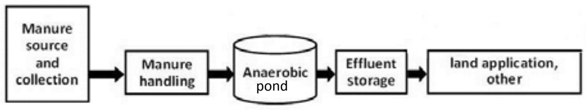
Digesters 101



Source: USEPA AgSTAR

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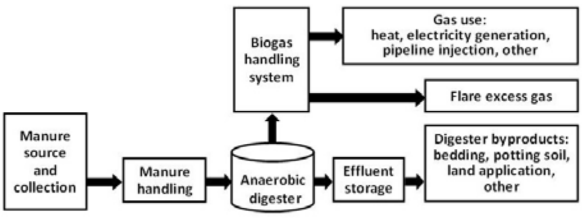
Digesters 101



Source: USEPA AgSTAR

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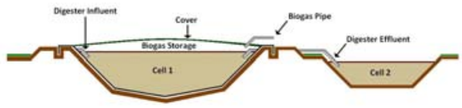
Covered anaerobic pond



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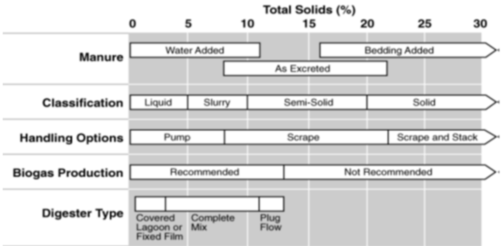
Which technology?

- 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).



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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.

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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

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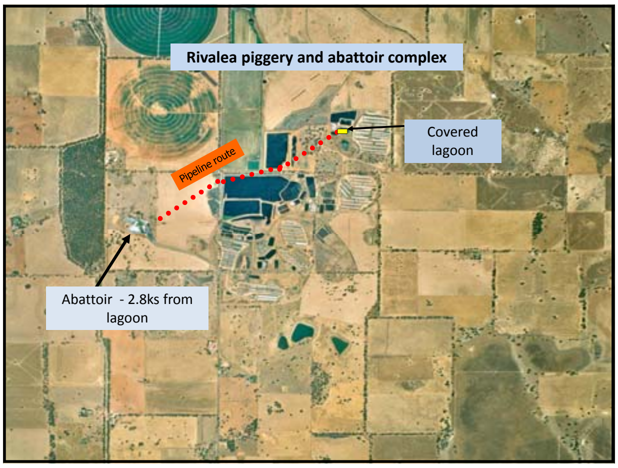

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Differences between pigs and dairy

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

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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.

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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

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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

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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

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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.

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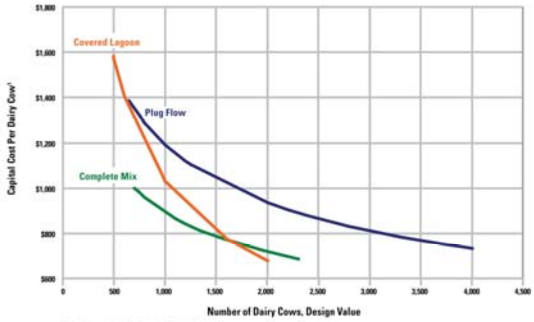
How much potential energy?

- 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 4°C, 20 L/d, COP 2.6) = 0.12 kWh/cow.d
  - Hot water (15 to 85°C, 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)



[1] *Costs are stated in September 2009 dollars.*

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