Covered Anaerobic Ponds for Anaerobic Digestion and Biogas Capture: Piggeries

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INTRODUCTION

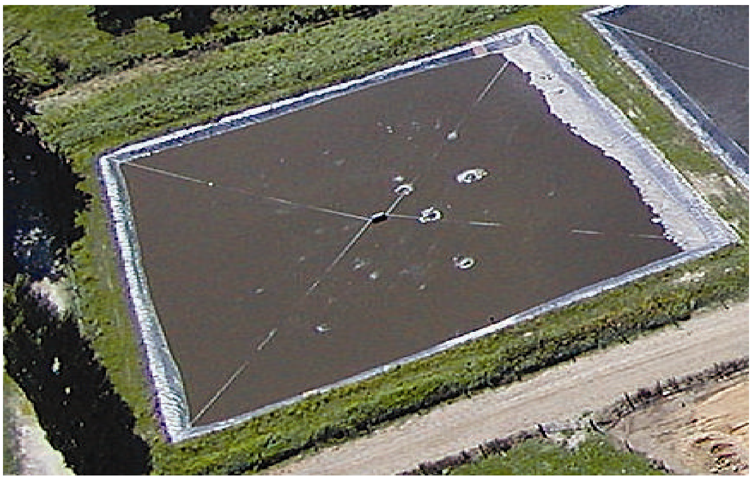
Anaerobic ponds have been traditionally used in New Zealand to treat piggery, dairy farm, meatworks and other agricultural wastewaters. They are cost-effective, require little maintenance, and have generally performed well in terms of BOD_5 and solids removal. However, they are not designed to optimise anaerobic digestion of wastewater solids to biogas and often have too large a surface area to economically cover the pond and capture this resource for energy use.

While several types of anaerobic digesters can be used to treat wastewater and recover energy as biogas methane, Covered Anaerobic Ponds are well suited to digestion of the relatively dilute wastes that are typical for New Zealand agriculture and industry.

Since New Zealand already has considerable investment in pond technology, it makes good economic sense to make use of this existing pond infrastructure by upgrading anaerobic ponds to Covered Anaerobic Ponds. Covered Anaerobic Ponds are also very cost-competitive as purpose built anaerobic digesters.

COVERED ANAEROBIC PONDS

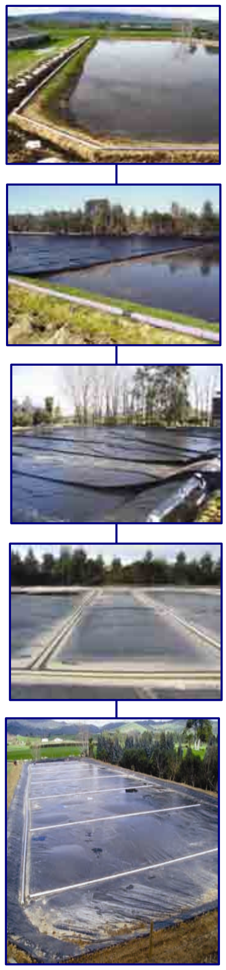
Covered Anaerobic Ponds (CAP) incorporate many improvements on traditional anaerobic ponds. They require much less land area than the anaerobic ponds that are currently used in New Zealand and are capable of ***consistently*** providing a higher degree of digestion and biogas production. Moreover, CAP are much easier to operate, and are more economical than other anaerobic digester technologies.



An uncovered dairy farm Anaerobic Pond in the Waikato

CAP have been developed by NIWA based on research over the past 10 years on the performance of traditional anaerobic ponds and enhancements in design and operation.

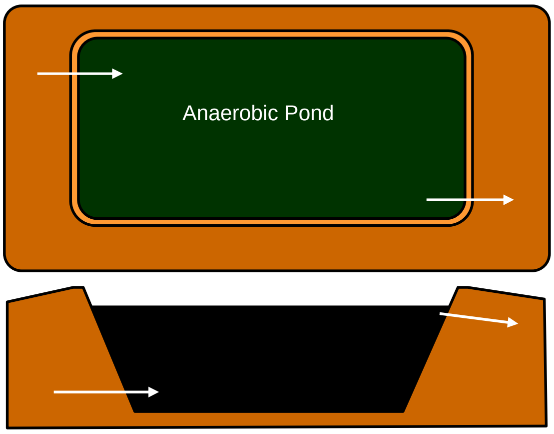
CAP are an “innovation” over traditional anaerobic ponds because they integrate appropriate pond design based on both organic and hydraulic loading, and our experience of how pond-based anaerobic digestion is influenced by environmental conditions. Moreover, CAP have sufficient operating volume to tolerate shock loads, which makes them much more resilient and robust than other anaerobic digestion technologies.



COVERED ANAEROBIC POND DESIGN

Pond Design

Covered anaerobic ponds are designed based on an organic loading rate to promote sedimentation of wastewater solids and efficient anaerobic digestion to biogas methane. They typically have a depth of 4-6 m depending upon ground water levels.



Schematic diagrams of a typical Covered Anaerobic Pond.

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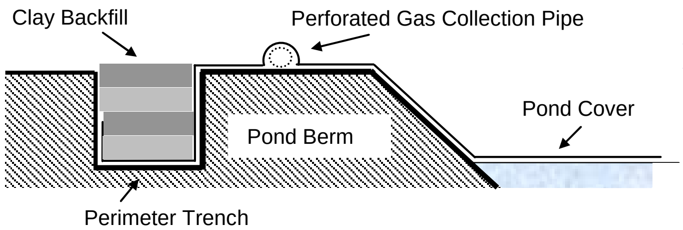
Biogas Capture

Biogas can be simply collected using cost-effective surface covers. These are secured around the pond perimeter either by burying in a trench or by anchoring to a concrete perimeter curb. Covers can be manufactured from high density polyethylene (HDPE) or preferably polypropylene (PP) or polyester scrim reinforced polypropylene (XR-5 or similar). These materials have a life-span of more than 20 years and are easily repaired.

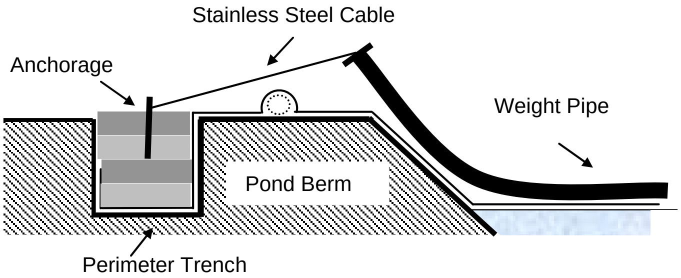


Schematic diagram of a perimeter trench bank attachment option:

Perimeter trench and biogas transfer pipe:

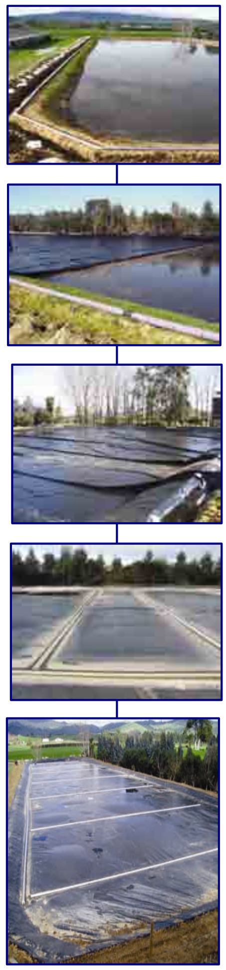
Rainwater Management

Rainfall is collected on the cover in depressions formed by lengths of water filled PVC or HDPE pipe placed at intervals across the width of the cover. These depressions channel the rainwater to a larger depression at one side along the length of the pond with a float switch operated pump to remove the water. The weighted pipes are held in place by attachment to the pond berm.



Schematic diagram of weight pipe and attachment:

Weight pipes in position on a pond cover:



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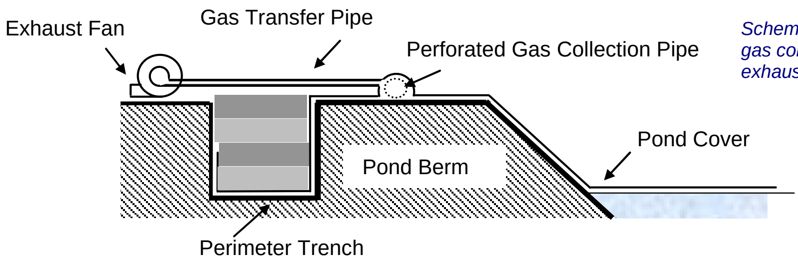
Biogas Collection

Biogas is removed from under the cover through a perforated pipe (100 mm slotted HDPE) placed around the pond perimeter. Biogas is drawn off by a slight vacuum (negative pressure) using a small centrifugal exhaust fan.

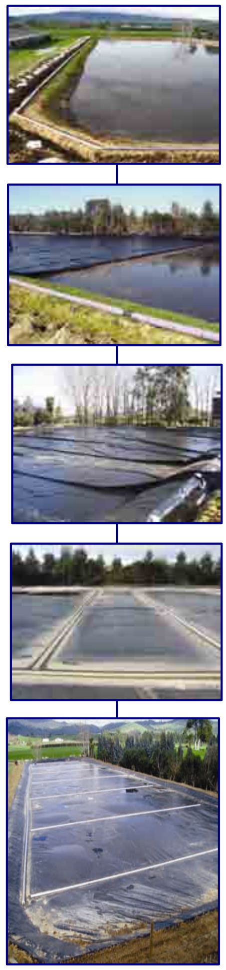


Schematic diagram of gas collection pipe and exhaust fan

Exhaust fan

Sludge Removal

Periodic sludge removal can be achieved either by temporary removal of all or part of the pond cover, or by providing gas tight openings around the cover perimeter to access the pond. Appropriate sludge removal intervals will depend on the loading of the CAP and the concentrations of inorganic solids and indigestible fibre in the wastewater.



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Retrofitting Traditional New Zealand Anaerobic Ponds

Existing anaerobic ponds can be retrofitted for biogas capture, however since they are usually oversized compared with CAP, the costs of the larger pond cover may be more than the cost of earthworks and cover for a new CAP. Other issues such as desludging the existing pond before installing the cover must also be taken into account.

COVERED ANAEROBIC POND PERFORMANCE

Over the last 10 years NIWA has developed and evaluated CAP under New Zealand conditions and has calibrated their design and operation. CAP consistently provide higher wastewater treatment and biogas methane production than traditional pond systems:

Wastewater Treatment

CAP achieve 60 - 70 % removal of wastewater solids measured as total volatile solids (VS) through sedimentation and anaerobic digestion.

Biogas Production

The typical median biogas and methane production rates of CAP are given below. The biogas methane production of CAP based on organic loading (m^3 CH_4 /kg VS / day) is comparable to that of more expensive heated and mixed anaerobic digesters. However since CAP operate at ambient temperature, biogas production varies with pond temperature both daily and seasonally. In the Waikato biogas production in the summer is double that of winter, although winter values are higher that would be expected given the pond water temperatures at this time of year. This seasonal variation in gas production is likely to be less in warmer regions (Northland, BOP) and larger in colder regions (Southland).

Parameter		CAP
Biogas production rate (m^3/kg VS_{added})		0.26 - 0.38
Biogas composition	CH_4 (%)	55 - 70
	CO_2 (%)	30 - 40
	O_2 (%)	0 - 0.3
	Other gases (%)	1 - 4
Methane production rate (m^3 CH_4/kg VS_{added})		0.20 - 0.28

VS - volatile solids

Biogas Disposal / Use

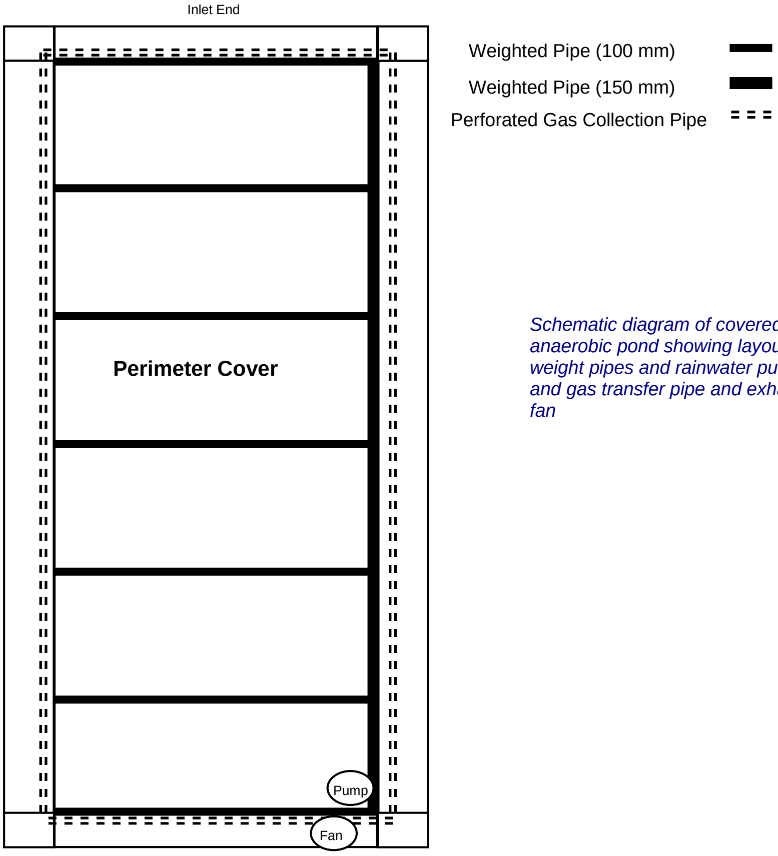
There are several options for disposal / use of the biogas:

<u>Disposal</u>

Release to air (some odour, but localized to vicinity of ponds)
Bubble into aerobic pond (less odour)
Flaring (elimination of odour and GHG emissions)

<u>Use</u>

Heat generation using a boiler substituting LPG
Combined heat and power (electricity) using motor generators
Compression and use as transport fuel in a CNG converted vehicle



Schematic diagram of covered anaerobic pond showing layout of weight pipes and rainwater pump, and gas transfer pipe and exhaust fan

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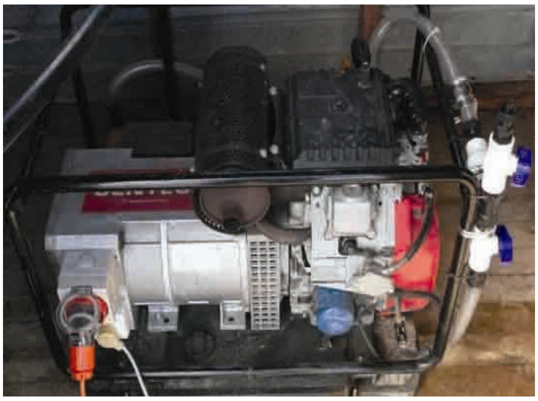
Covered Anaerobic Pond showing layout of weight pipes and rainwater pump



Petrol powered electricity generator converted to biogas

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Electricity Export
This is technically feasible; however the cooperation of local lines and/or power companies is required and the sizing and duty cycles of the motor generator will depend upon the degree of cooperation.

GHG Emissions
Covering an existing traditional anaerobic pond, or adding a CAP to an existing waste management system to capture biogas (methane) and then flaring or using the biogas could, in principal, earn greenhouse gas (GHG) credits. This may occur in two ways: (1) avoiding direct methane emissions; (2) use as renewable fuel substituting either direct fossil fuel use of fossil fuel derived electricity. The potential value of avoided GHG emission credits could be NZ\$25/tonne$CO_{2equivalent}$. However, New Zealand does not yet have a working carbon emission trading scheme, and the procedures for certifying these credits have not been established.

EEFLUENT IRRIGATION / DEFERRED IRRIGATION / REUSE

CAP effluent has a much lower solids content than raw effluent and can therefore be irrigated more easily (reducing operation and maintenance costs). CAP can be designed to have variable water depths so that irrigation may be deferred until soil conditions are suitable. CAP effluent may also be reused for washdown (reducing overall water use for waste management), although concentration of compounds that influence anaerobic digester performance (e.g. ammonia) or operation (e.g. struvite build-up in pipes) will need to be monitored. If further treatment is required (e.g. nutrient and pathogen removal), High Rate Algal Ponds may be used to combine treatment with production of algae biomass that may be harvested for use as a fertiliser, feed or biofuel.

COSTS

Typical unit costs of the components of CAP are given below.

Component	Lifespan (y)	Unit Cost
Anaerobic Pond (earth lined) (\$/m^3 excavated)	>20	8 - 10
Pond Liner (\$/m^2 installed)	20	15 - 20
Biogas Collection Cover (\$/m^2 installed)	20	20 - 25
Generator (CHP unit) (\$/kW)	5-10	1.0 – 1.5k

KEY FEATURES OF CAP

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- Low cost, advanced design
- Simple operation and maintenance
- Total elimination of odours, flies and insects from the pond
- Prevent rainwater intrusion and collect for beneficial use
- Enhanced treatment performance and biogas production
- Economically recover biogas energy
- Reuse treated effluent for washdown
- Storage for deferred irrigation
- Increased fertiliser value (~35% more ammonia in effluent)
- Reduction of odour from effluent irrigation (by as much as 70%)
- Reduced GHG emissions and potential for credits

Covered Anaerobic Ponds are an extremely cost-effective anaerobic digestion technology, eminently suitable for piggeries, dairy farms, meatworks and other agricultural processing plants needing to optimise anaerobic treatment and capture renewable energy while reducing GHG emissions.

EXAMPLE PIGGERY CAP DESIGNS: 400 AND 2,000 SOWS (FARROW TO FINISH)

The wastewater loads and flows, CAP designs, costs and potential revenues are given below:

Wastewater Loads and Flows

No. of sows	400	2,000
No. of pig fattening units (20 live piglets/sow/y; 2.8 rotations/y)	2,857	14,286
Average annual manure production sows (incl. piglets) (kg DM)	380	380
Average annual manure production fattening pigs (kg DM)	140	140
Waste production total farm (DM) (kg/day) (grain based diet)	1,512	7,562
% Volatile Solids (%VS)	85%	85%
Total daily VS load (kg/d)	1,285	6,427
Solids separator VS removal efficiency	15%	15%
Total daily VS load to pond (kg/d)	1,093	5,463
Total wastewater flow (m^3/d) (typical manure washdown)	71	355
% Volatile Solids of wastewater to pond (%VS)	1.5%	1.5%

CAP Designs

Pond volume (m^3)	3,642	18,211
Pond hydraulic retention time (d)	51	51
Pond depth (m)	6	6
Berm slope horizontal : vertical	1:2	1:2
Free board height (m)	0.5	0.5
Pond top berm width (m)	15.8	31
Pond top berm length (m)	53	114
Pond top berm area (m^2)	835	3529
Pond cover area (m^2)	1,109	4,108

Biogas Methane Production and Use

Annual average daily methane production (m^3/d)	240	1202
Daily gross thermal energy production (kWh/d)	2,258	11,288
Generator (CHP) electrical conversion efficiency	30%	30%
CHP usable heat (hot water) conversion efficiency	50%	50%
Annual electricity Generation (kWh/y)	246,797	1,217,079
Electricity price (export) ($/kWh)	0.10	0.10
Electricity price (import) ($/kWh)	0.21	0.21
Electricity Revenue (50% export / 50% import substitution) ($/y)	38,253	191,267
Annual heat generation (kWh/y)	411,328	2,028,465
Assumed on farm heat (hot water) use % of CHP production	20%	20%
Alternative heat cost (LPG hot water system) ($/GJ)	25	25
Heat revenue (20% use, 80% waste) ($/y)	7,404	36,512

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GHG Credits and Potential Value

Carbon credit value ($/tonne$CO_{2equivalent}$.)	25	25
Annually avoided methane emissions ($/tonne$CO_{2equivalent}$/y)	1,289	6,447
GHG value avoided methane emissions ($/y)	32,237	161,183
Annually generated electricity (kWh/y)	243,416	1,217,079
NZ electricity emission factor ($/tonne$CO_{2equivalent}$/kWh)	0.21	0.21
Avoided electricity generation emissions ($/tonne$CO_{2equivalent}$/y)	51	256
GHG value generated electricity ($/y)	1,278	6,390
Annual GHG revenue ($/y)	33,515	167,573

Capital and Operation Costs

Digester pond (earth lined) ($)	31,138	147,687
Gas collection cover ($)	24,708	59,400
Generator (CHP unit) ($)	56,286	221,430
Total investment cost ($)	112,132	428,518
Annual depreciated capital costs ($/y)	11,040	44,200
Interest rate (%)	11%	11%
Total annual capital interest costs ($/y)	5,891	23,292
Annual operation and maintenance costs ($/y)	8,887	8,887
Total annual cost ($/y)	25,818	76,379

Comparison of the capital and operation costs of a new CAP with the potential revenue from biogas use gives a payback period of less than 3 years. If the value of GHG credits is included the payback period reduces to less than 2 years. Further reductions in the payback period could be achieved if more waste heat is used.

CONTACT INFORMATION

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