Livestock Waste Technologies for Energy Production and Pollution Control

A Global Perspective

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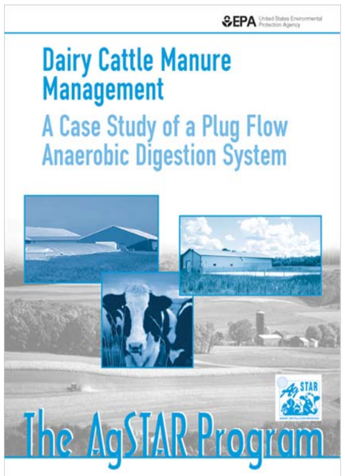
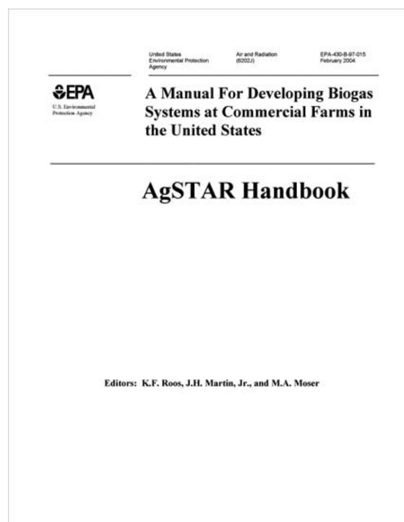
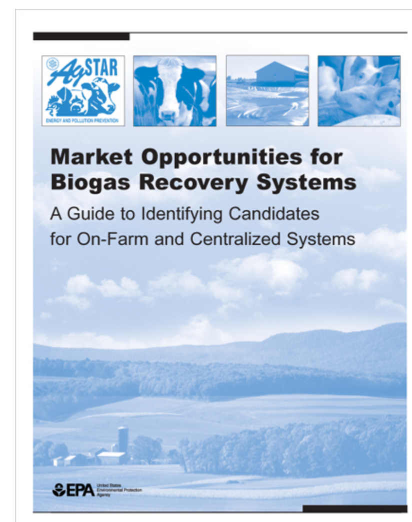
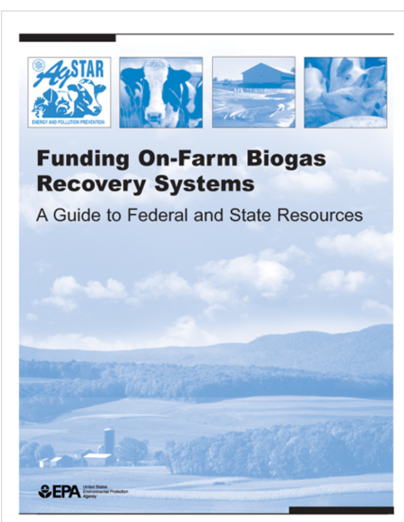
University of Florida – January 18, 2006



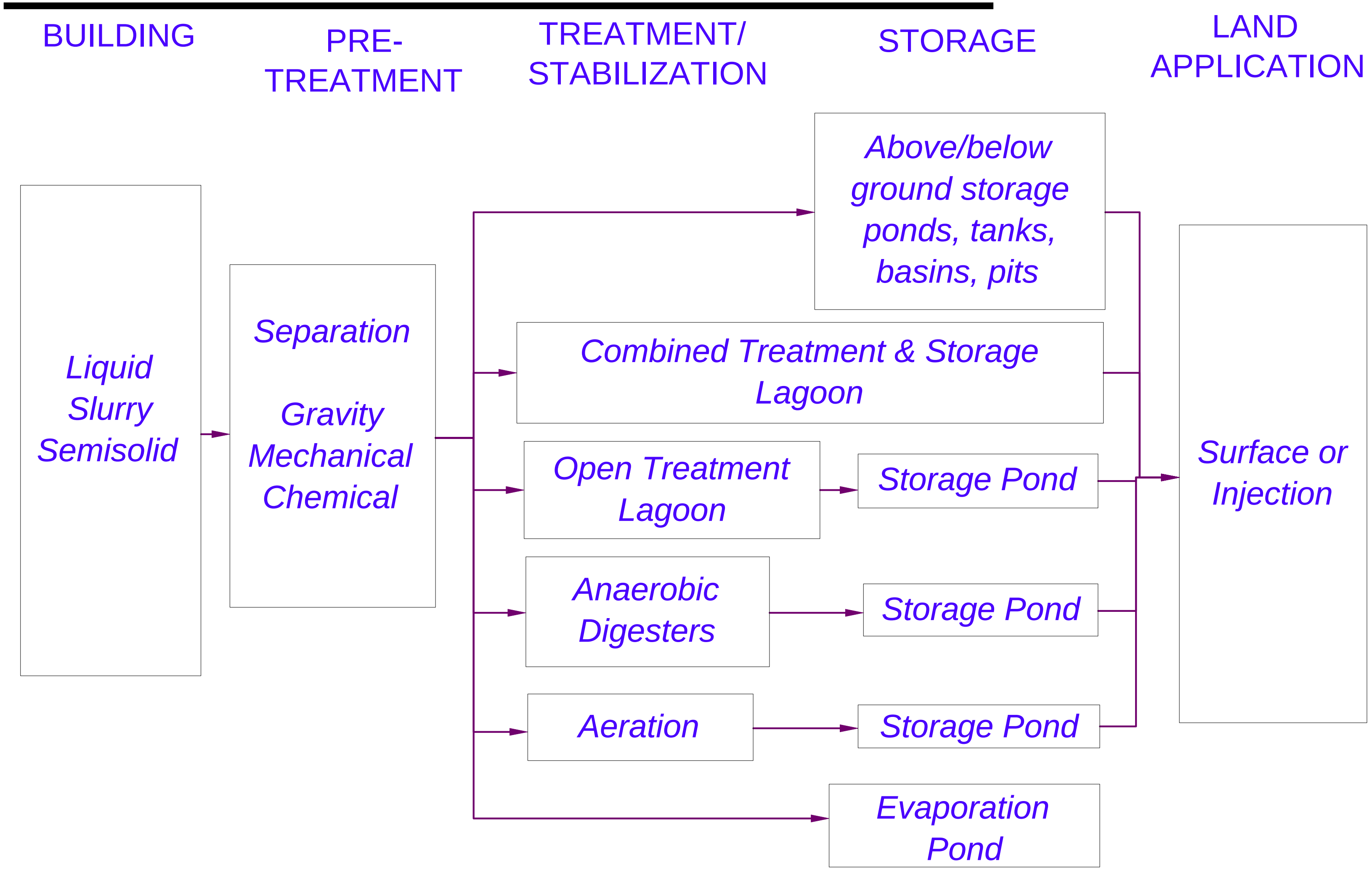
AgSTAR Program







Introduction: Farm Processes



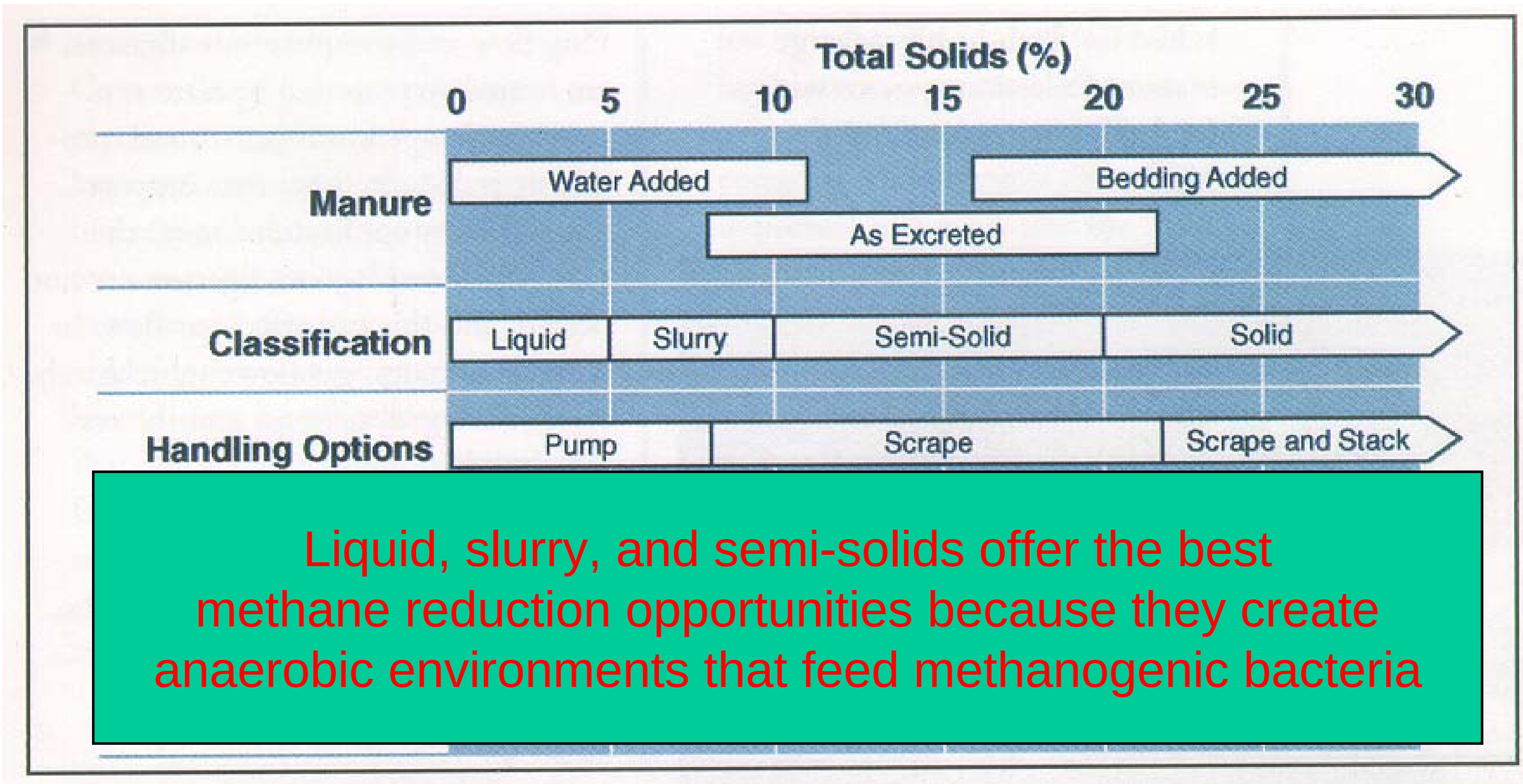
Waste System Considerations

- Livestock waste are high strength materials, comparatively 10-100 times stronger than sewage
- Wastes can pollute and cause disease when improperly disposed
- Main polluting elements:
  - High organic fraction (BOD and COD)
    - Fish kills – competes for dissolved oxygen
    - Odor attracts fly and other disease transmission vectors
    - Emits methane - greenhouse gas
  - Contain nutrients – nitrogen phosphorus and other
    - Causes eutrophication in surface waters
    - Can mutate plants when over applied or volatilized
  - Contain an array of bacteria, pathogens and other disease causing organisms
    - E. coli, Staph., Strep, Ascaris, etc.

- Livestock wastes are agricultural resources -

Challenge is to cost effectively manage wastes with consideration to human, water, air, and land impacts

Wastes are Handled in Different Ways



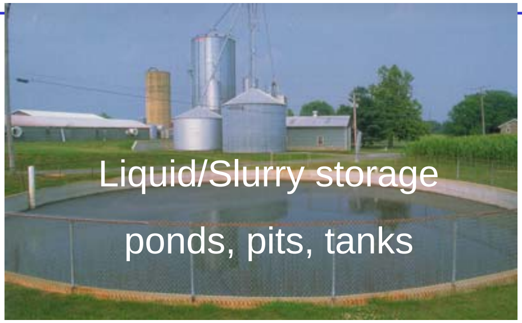
Liquid, slurry, and semi-solids offer the best methane reduction opportunities because they create anaerobic environments that feed methanogenic bacteria

Methane Emissions are Dependent on Waste System

Factors effecting methane emissions:

1) Manure type
2) Manure handling (liquid, slurry, semi-solid, solid)
3) Temperature and time

AMWS Systems and Methane Emission Factor by Climate Type									
	Manure Management System								
Climate	*Lagoon*	*Liquid and Slurry*	*Solid Storage*	*Dry lot*	*Pit <1 month*	*Pit >1 month*	*Daily Spread*	*Digester*	*Other*
Cool	90%	10%	1%	1%	5%	10%	0.10%	10%	1%
Temperate	90%	35%	1.50%	1.50%	18%	35%	0.50%	10%	1%
Warm	90%	65%	2%	5%	33%	65%	1%	10%	1%



Calculating Methane Reductions

Example: 500 cow dairy with varying baseline waste management systems in a warm climate

	Waste System Types		
	Daily Spread	Liquid/Slurry Storage	Lagoon
(A) Baseline Farm - MCF	1%	65%	90%
Baseline Methane Emission - MT/yr	1.9	120.3	166.6
(B) MT Combusted CH_4/Year[1]	185	185	185
(C) MT CO_2 Utility Emission Offset (as CH_4)	32	32	32
(D) Refractory Emission[2] @1% biodegradable VS	1.9	1.9	1.9
MT Methane Reduction/Year[3]	0.0	-118.5	-164.8
as CO_2	0	-2,488	-3,460
as C_{arbon} $E_{quivalent}$	0	-679	-944

<u>Notes:</u>

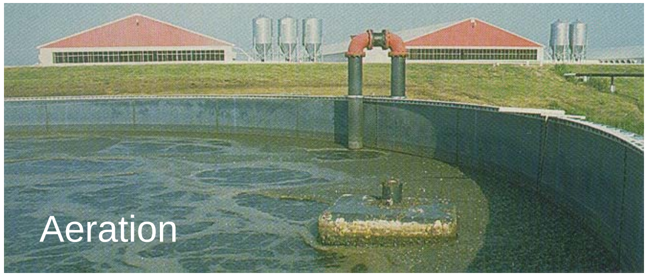
[1] For this farm energy capacity is about 80 kW. Energy output is about 69 kWh/hr.

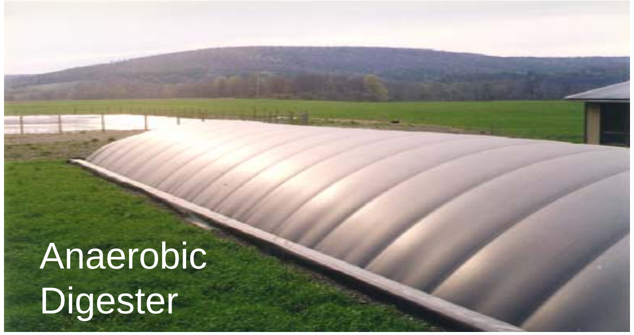
[2] Remaining biodegradale VS results in refractory emissions, assumed

[3] Positive value indicates increase in emission

Overview: Potential Methane Reducing Options

- Aeration – energy is used to provide oxygen to meet oxygen demand of waste (1 lbs. BOD requires 1 HP)
  - energy intensive and very expensive
  - used as tertiary treatment in sewage to meet discharge requirement
  - residual solids become problematic
  - Can produce nitrous oxide - much higher GWP
- Shifting liquid/slurry handling to solid manure handling
  - very limited because of scale
  - more economical to flush manure from confined production systems (pigs and dairy)
- Anaerobic digesters
  - consistent with farm waste handling objectives
  - oxygen demand satisfied anaerobically
  - produces biogas providing farm energy opportunities





What are Anaerobic Digesters?

Biological treatment/stabilization systems that collect and combust off-gases.

Offer Air Quality benefits

- -Control odors from storage <u>and</u> field application
- -Reduces Greenhouse gases (methane)
- -Controls other emissions (H_2S, ammonia)

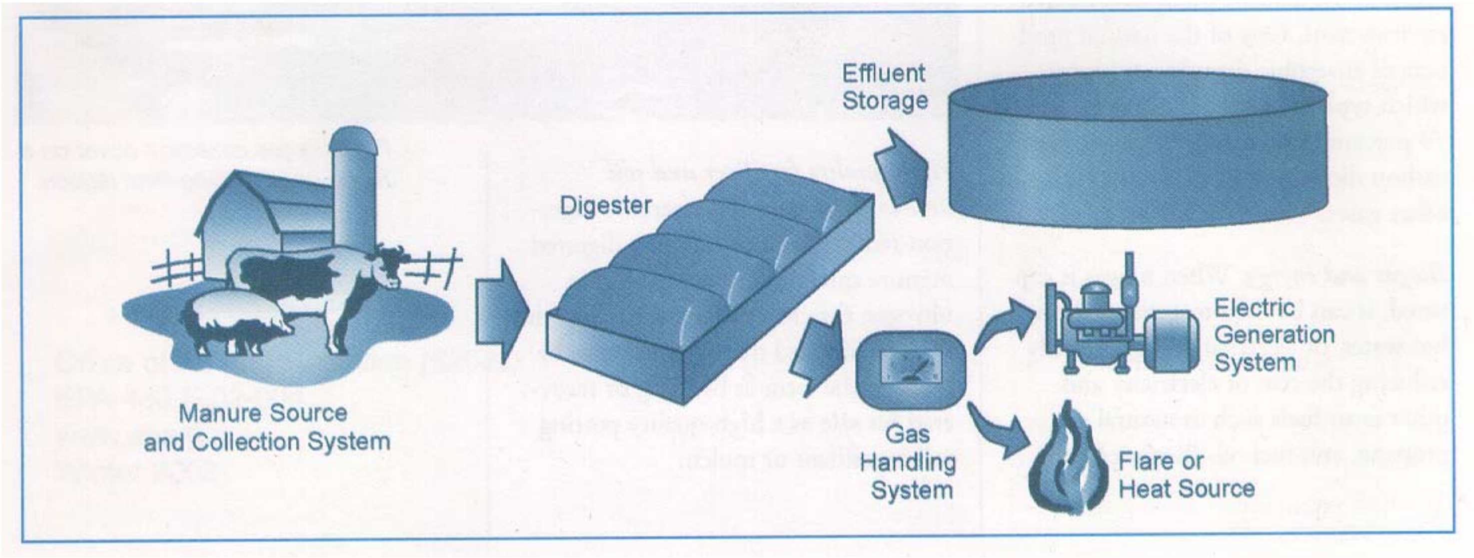
Offer Water Quality benefits

- -Stabilize manure organics (BOD)
- -Significantly reduce pathogens
- -Provide nutrient management predictability and flexibility

Offer return on Investment…….Energy revenues

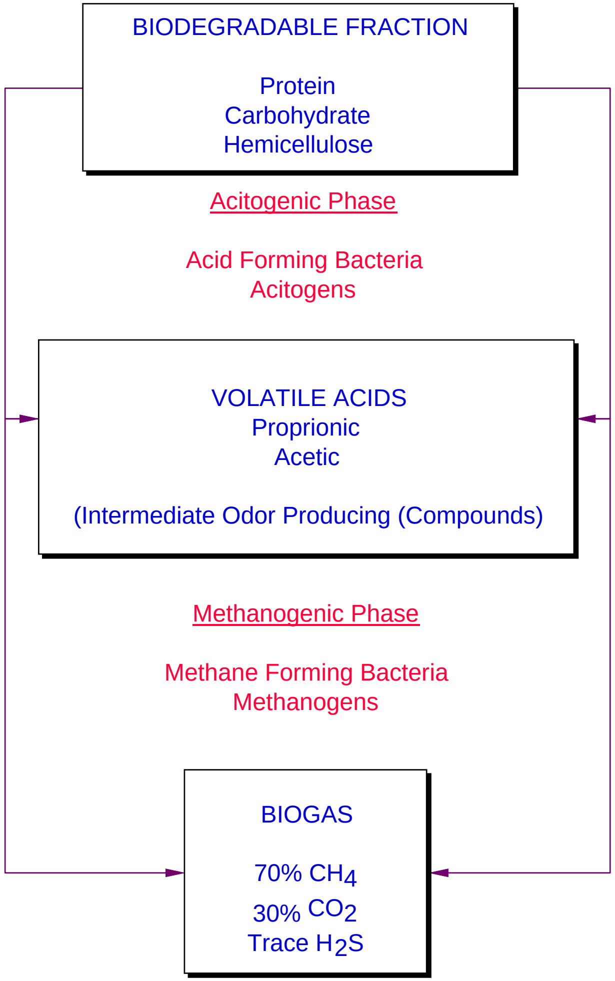
Anaerobic Digester Components

Digesters separate manure treatment from storage functions which can result in lower initial installation costs for new or expanding farms

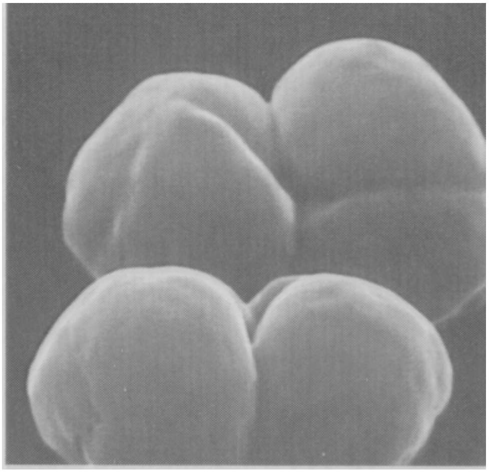


What Makes Digesters work?

Anaerobic digestion is a biological process. It occurs in an oxygen free environment.

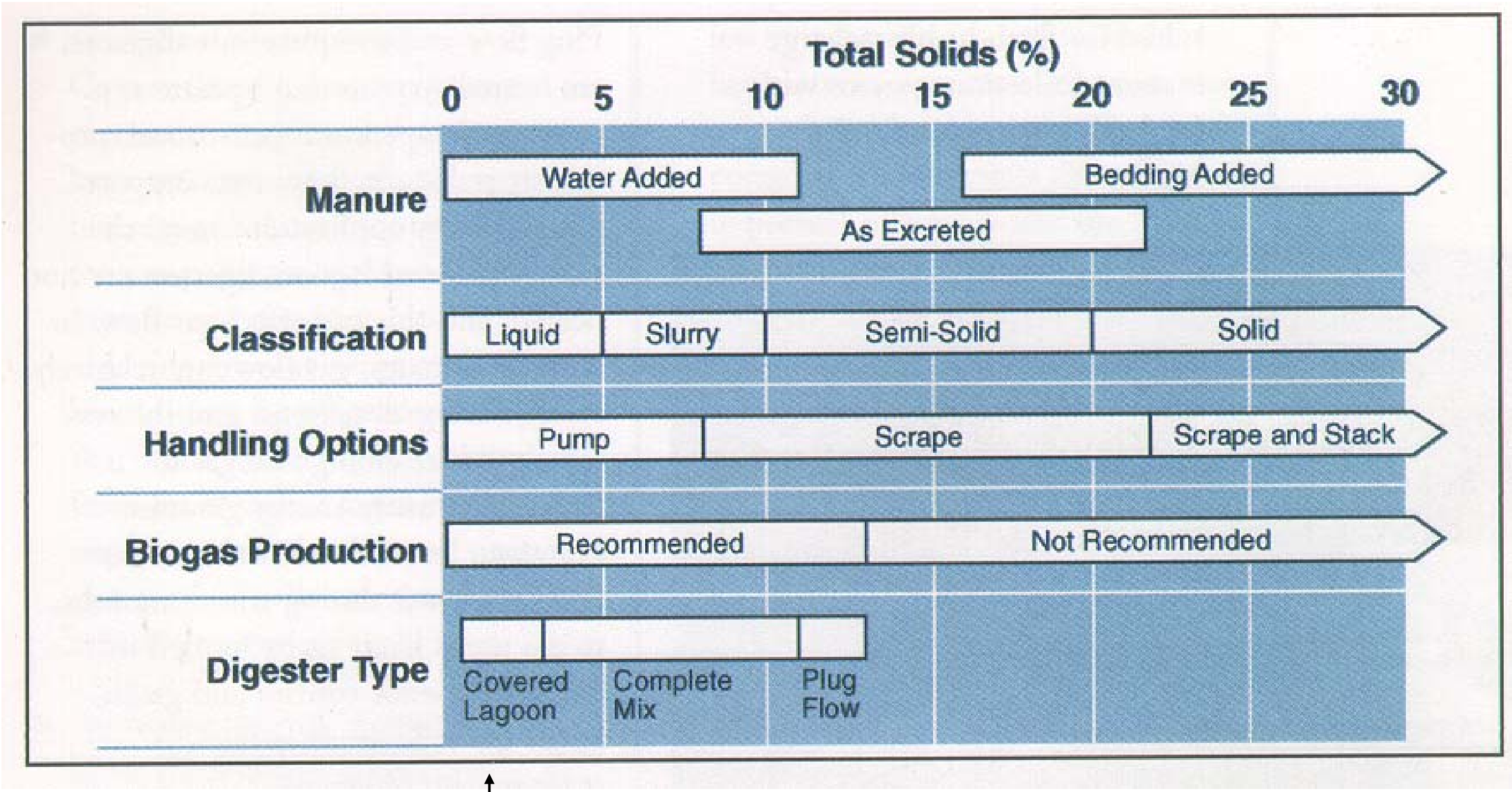


Methanogens



Appropriate Digester Selection?

- Hog and Dairy industry constitute >90% of market potential



Attached Film

Unheated Digesters

<u>Covered Lagoon Digester</u>

Bank-to-Bank Cover

Modular Cover

<u>Attached Media</u>

More Unheated Digesters

Small - Intermediate Scale Digesters

Heated (Mesophilic) Mixed Digesters

Heated (Mesophilic) Plug Flow Digesters

Used for Dairy only w/ Separation

Gas Use: *Electrical Generation*

Recip. Engines 40-150kW

C
O
M
P
O
N
E
N
T
S

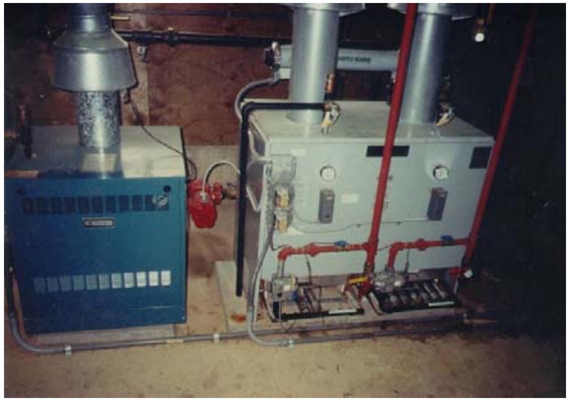
Gas Handling and Transmission

Engine Controller

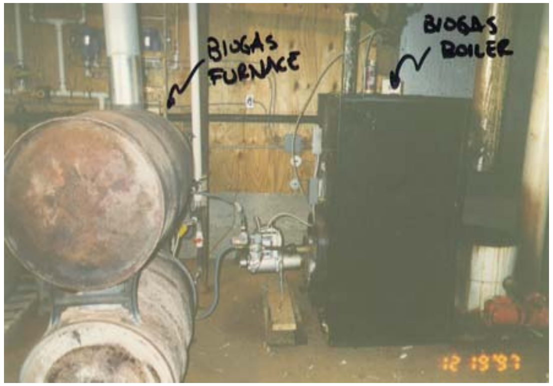
Electric Metering

Gas Use: *Heat*

Boilers



Forced Air



Hot Water Storage

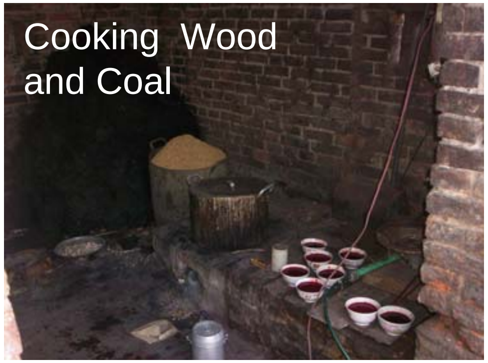
Hot Water Use

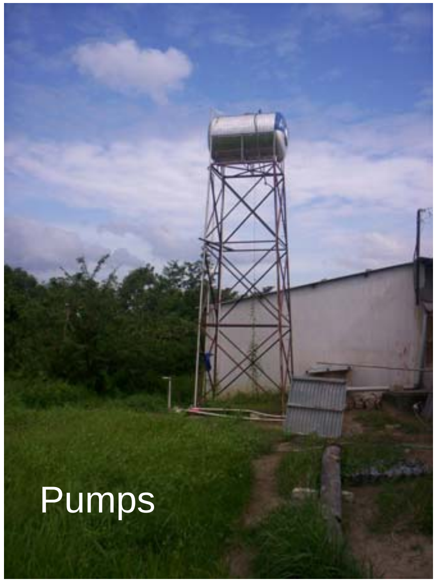
Gas Use: *Flares*

Odor Control and Greenhouse Gas Mitigation




Other Gas Use Options





Environmental Retrofit

Retrofit Plan

Before

After

Covered Lagoon

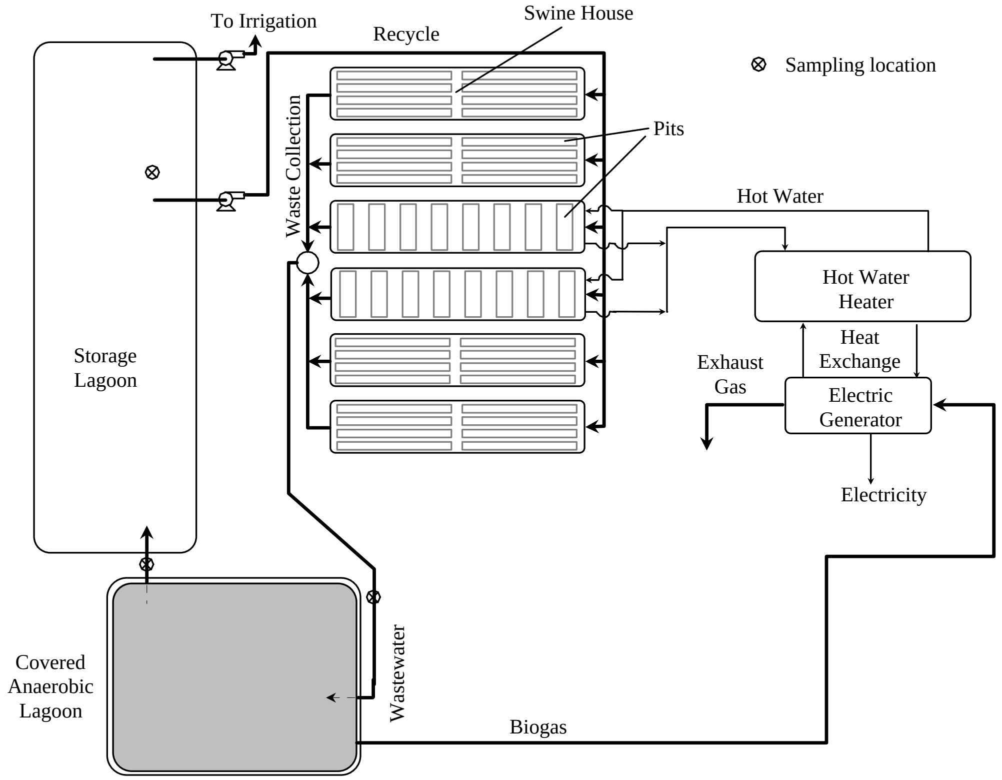
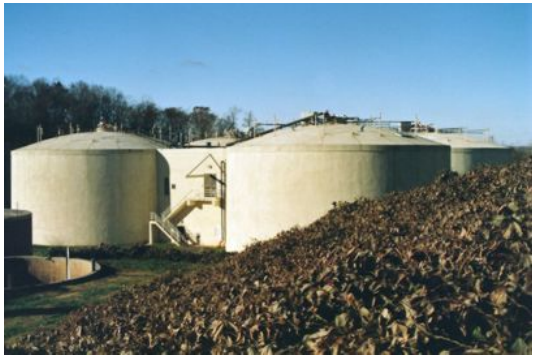


Fig. 1. A Schematic of Covered Anaerobic Lagoon System for Manure Management at Barham Farm.

Project Types

- <u>On-Farm or Farm Scale</u>: System is owned and operated by farm owner/manager
  - Currently the predominant project type in the U.S.
- <u>Regional or Centralized Digesters</u>: Off farm management and operation with a third party
  - Ideally located at a large energy (electric or heat) consuming source or interconnection point (feed mills or utility substation)



General Costs: *Livestock Basis*

Digester Type	Cost per Cow (1,400 lbs.)
Attached Media	$500-800
Complete Mix	$400-700
Covered Lagoon	$300-1,000
Plug Flow	$400-700

Swine equivalents: 4 sows = cow;10 feeder pigs = cow

Note: Cost assumes all manure is collected

Costs include engine gensets and separator (dairy systems)

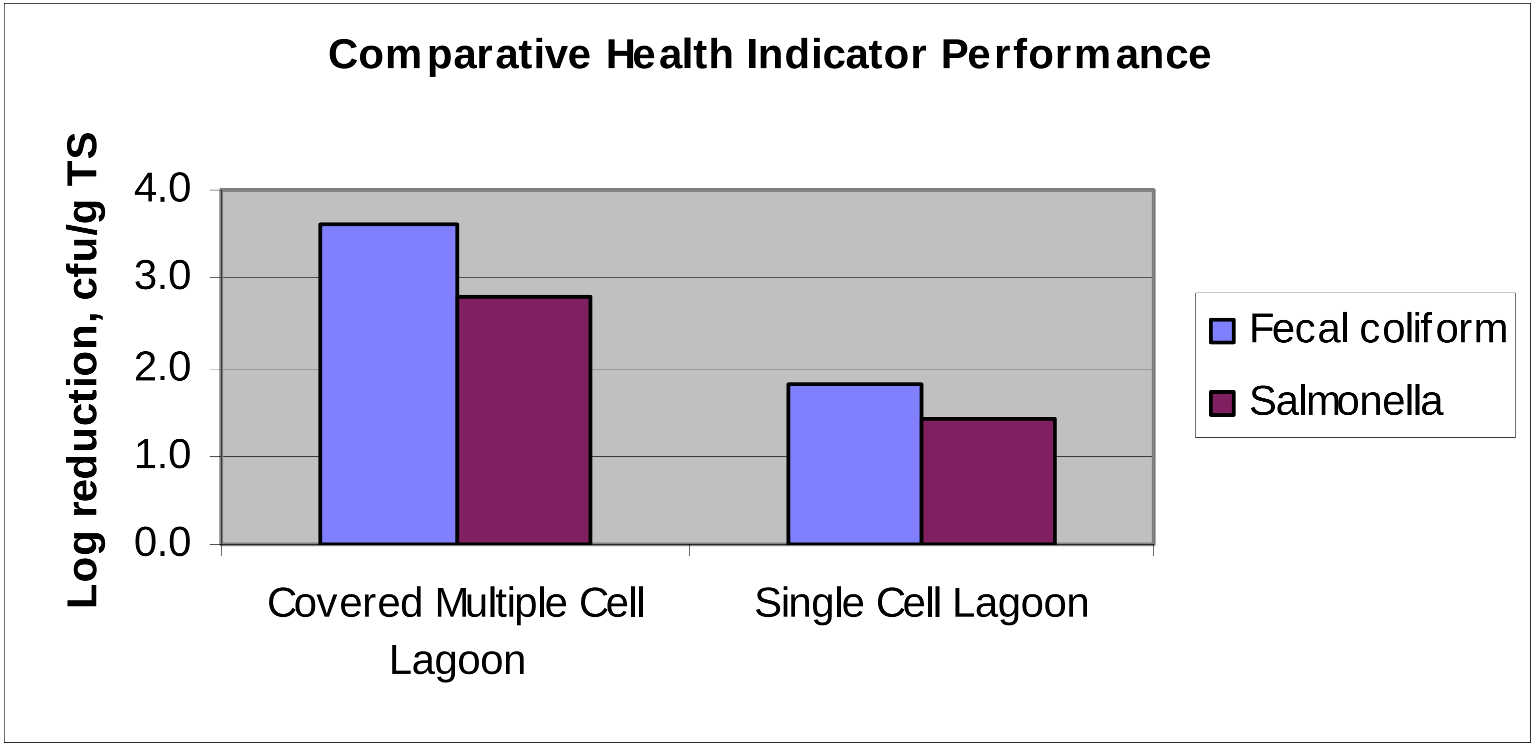
Caution - Digesters Can Fail!

Organic Stabilization and Odor

PARAMETER	Covered lagoon w/ separate storage Reductions, %			Combined treatment storage lagoon Reductions, %
	Covered lagoon	Storage pond	Total	Total
Total solids	90.1	7.7	97.8	95.6
Total volatile solids	95.4	3.7	99.1	98.9
Fixed solids	76.9	18	94.9	91.5
Chemical oxygen demand	97	2.8	99.8	99

Martin J.H. Jr., *A Comparison of the Performance of Three Swine Waste Stabilization Systems*, AgSTAR Program deliverable under contract #68-W7-0068, Draft March 2002

Pathogen Performance



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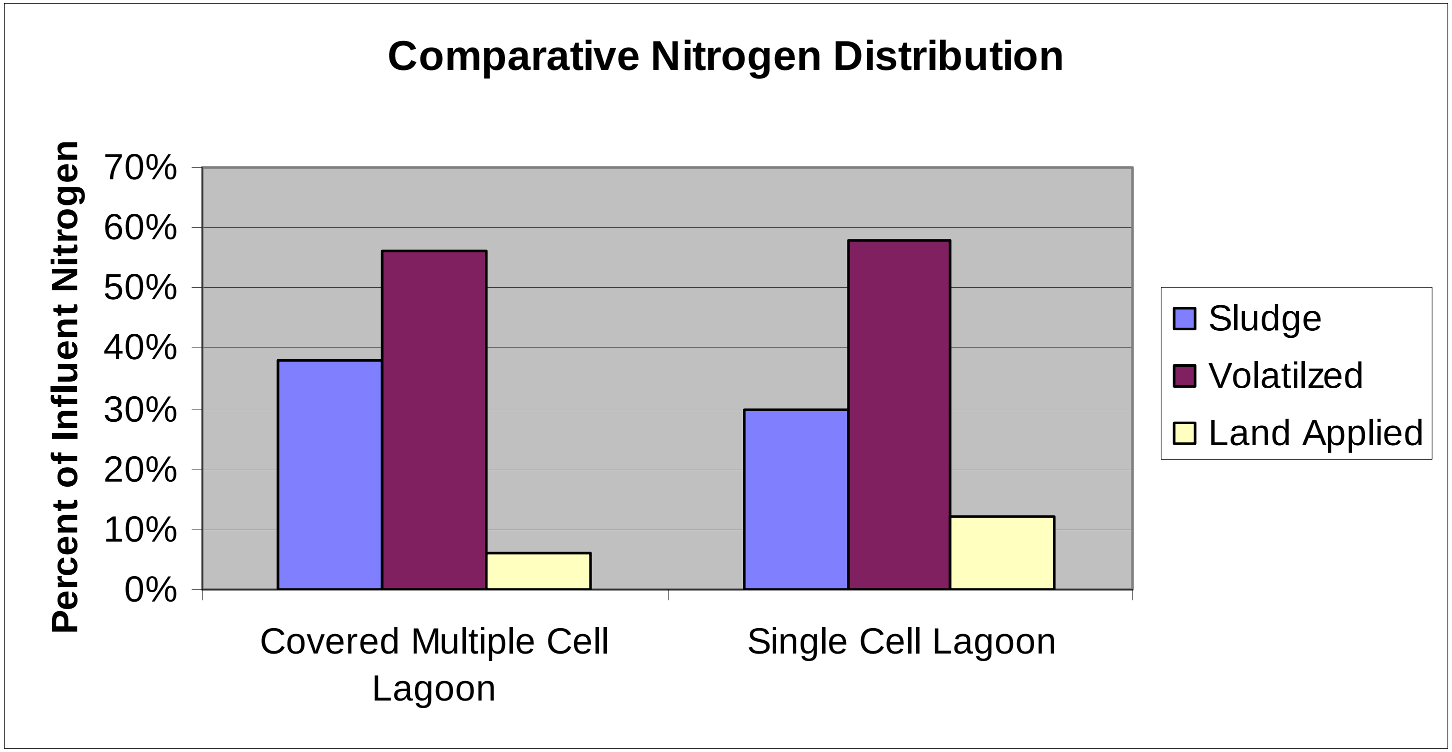
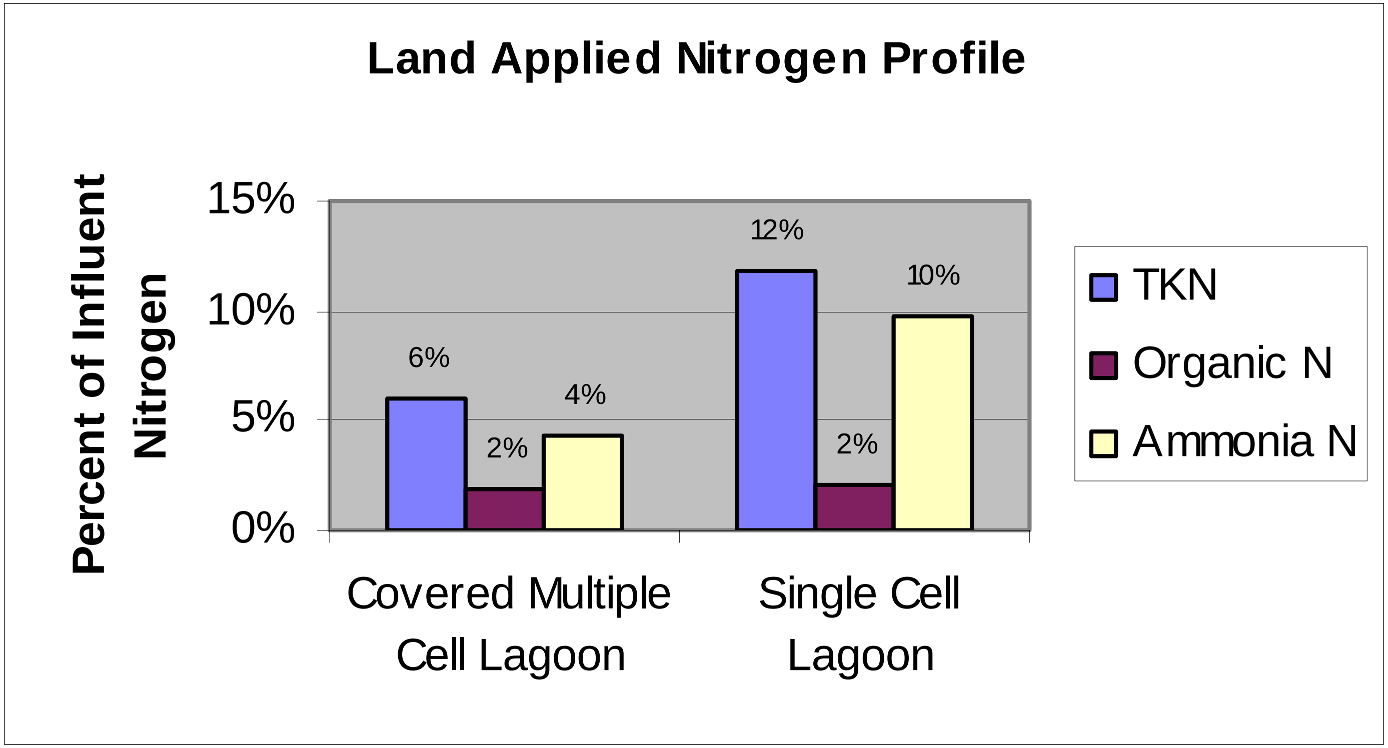
Nitrogen Performance



- Comparative reductions of Phosphorus (Total & Ortho) were @97% for each system

Martin J.H. Jr., *A Comparison of the Performance of Three Swine Waste Stabilization Systems*, AgSTAR Program deliverable under contract #68-W7-0068, Draft March 2002

Nitrogen Performance (cont)



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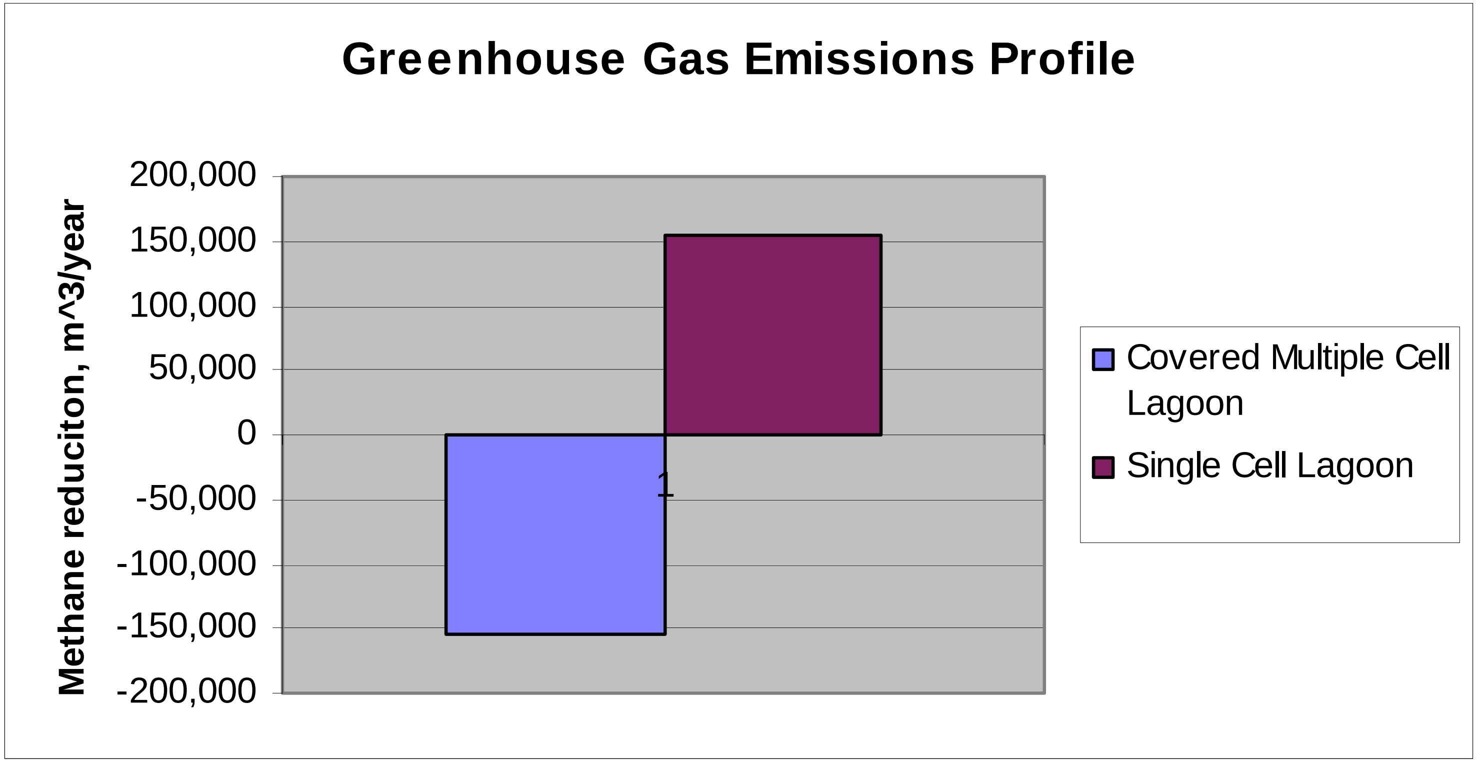
Swine Biogas Profile

Parameter	% by volume
Methane	67.9
Carbon Dioxide	32.1
Hydrogen Sulfide	.05

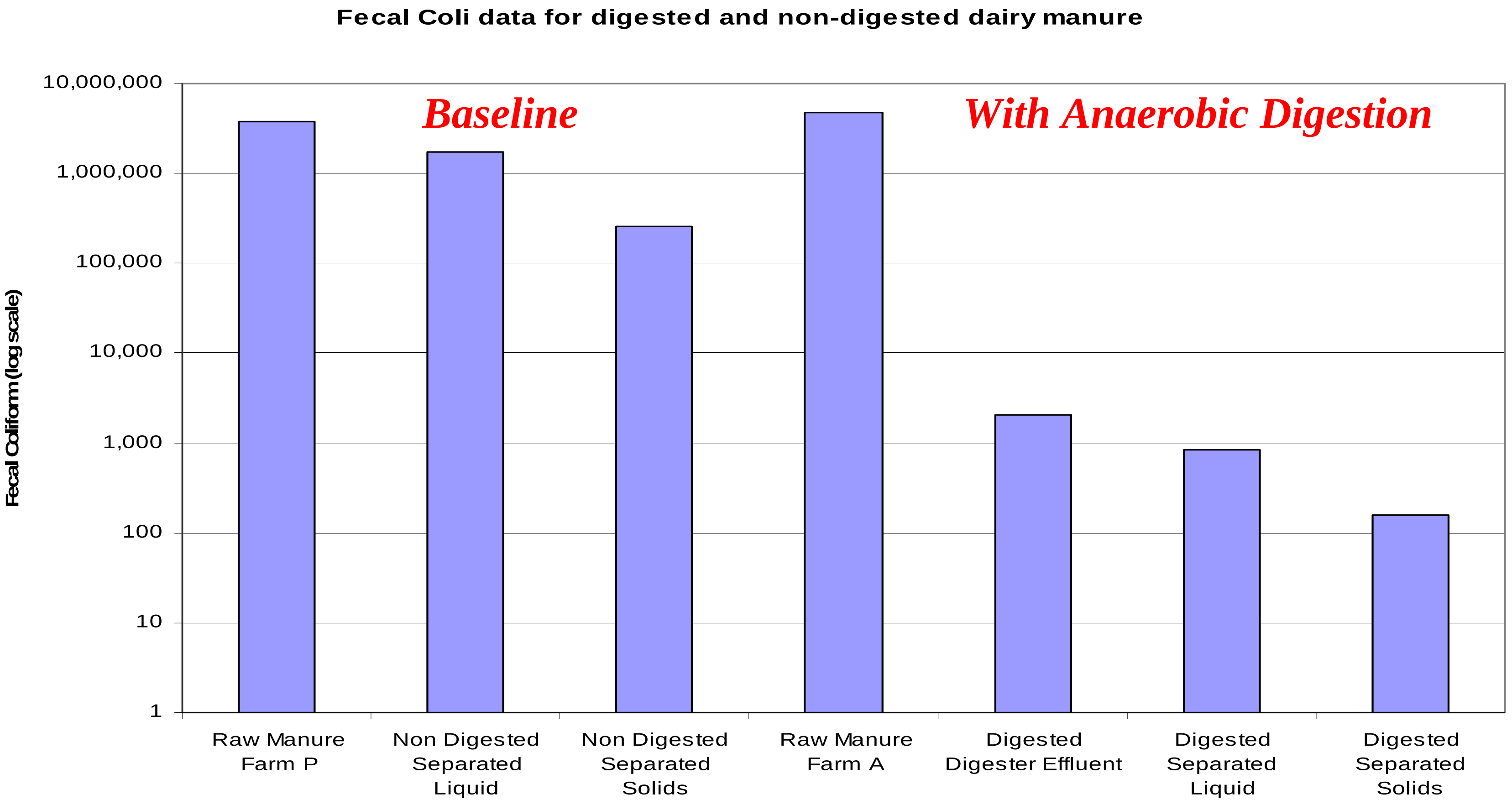
Martin J.H. Jr., *An Assessment of the Performance of the Colorado Pork, LLC. Anaerobic Digestion and Biogas Utilization System*, AgSTAR Program deliverable under contract #68-W7-0068, Draft March 2003

Greenhouse Gas Performance



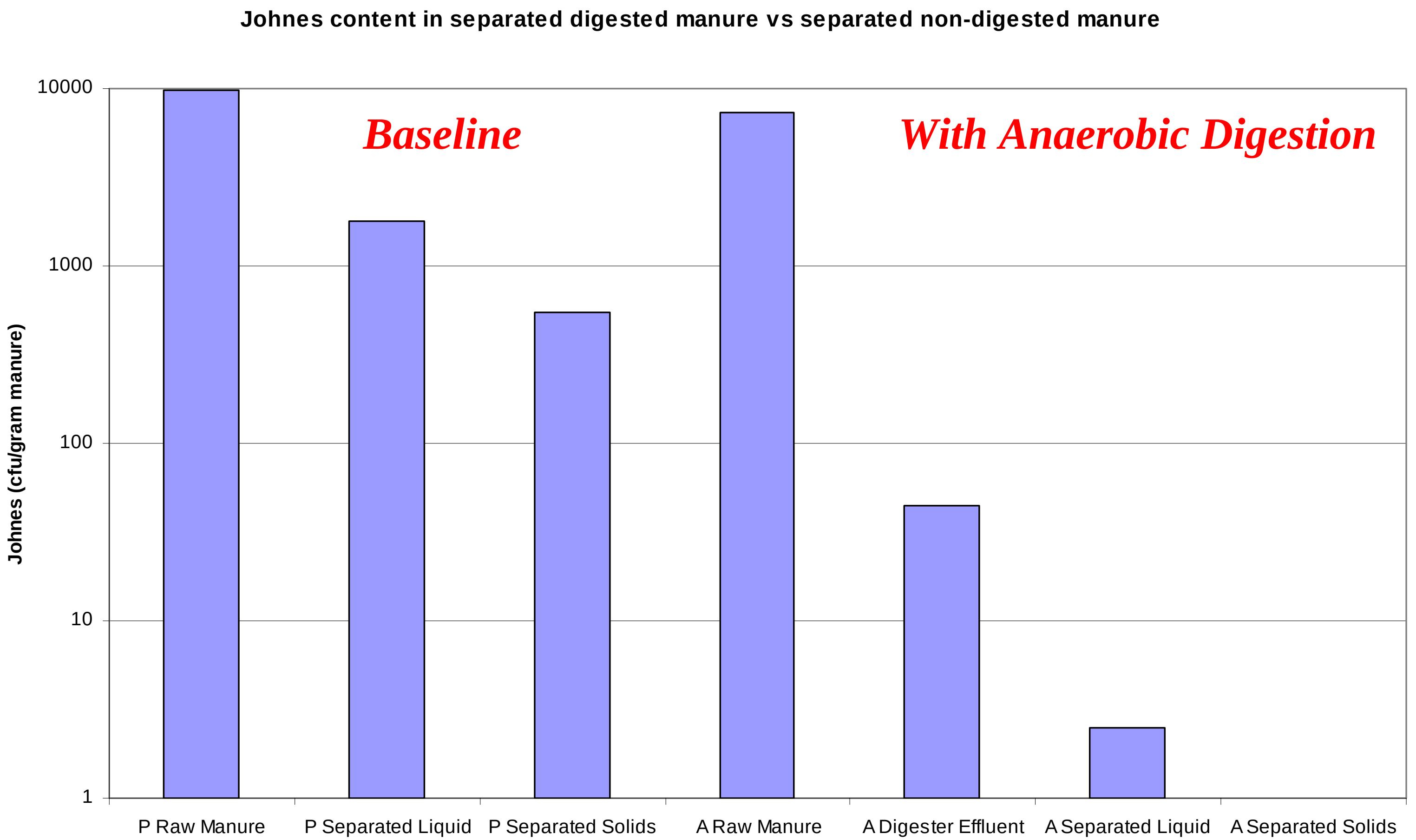
Martin J.H. Jr., *A Comparison of the Performance of Three Swine Waste Stabilization Systems*, AgSTAR Program deliverable under contract #68-W7-0068, Draft March 2002

Comparative: Fecal Coli



Martin J.H. Jr., *A Comparison of Dairy Cattle Manure with and without Anaerobic Digestion and Biogas Utilization*, AgSTAR Program deliverable under contract #68-W7-0068, March 2003

Comparative: Pathogens



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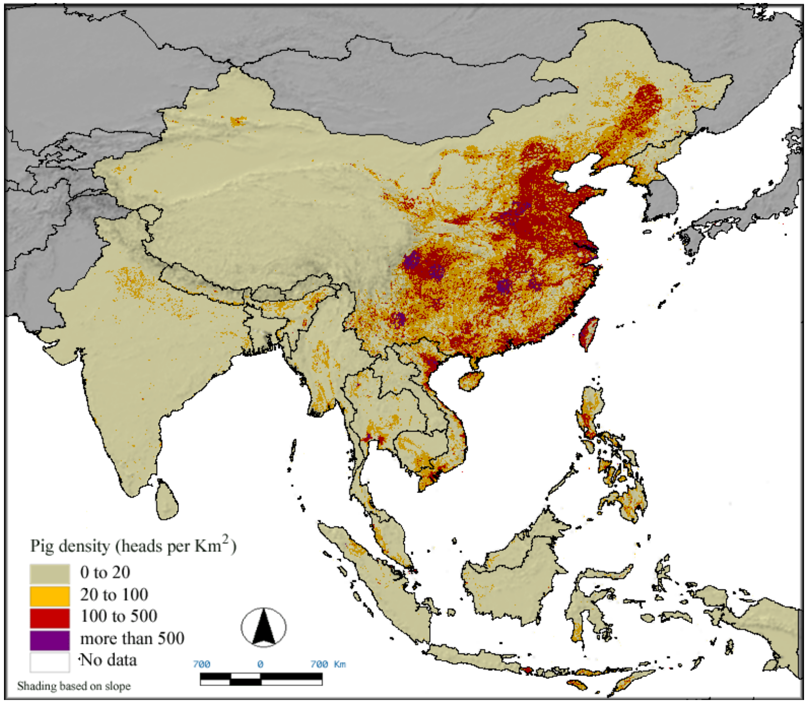
Livestock in East Asia Project
Pollution Control for Pig Waste

Kurt Roos
for

Weiguo Zhou – Team Lead
Rural Development & Natural Resources Sector Unit
East Asia and Pacific Region
The World Bank

Project Background

- Purpose: Reduce negative environmental and health impacts caused by confined livestock in region
  - Discharge to surface waters main issue
- Three country areas involved:
  - China, Guangdong Province
  - Thailand, Racthuburi and Chonburi province
  - Vietnam, Ho Chi Minh City and Hanoi
- Project implemented over a 5 year period
- Japan PHRD Grant Fund for Climate Change includes a Greenhouse Gas project component



Project Country Profiles

- Opportunities
  - Pig waste handled as liquids and slurries
  - Appropriate candidate for anaerobic treatment and gas recovery
  - All countries desire gas recovery technologies

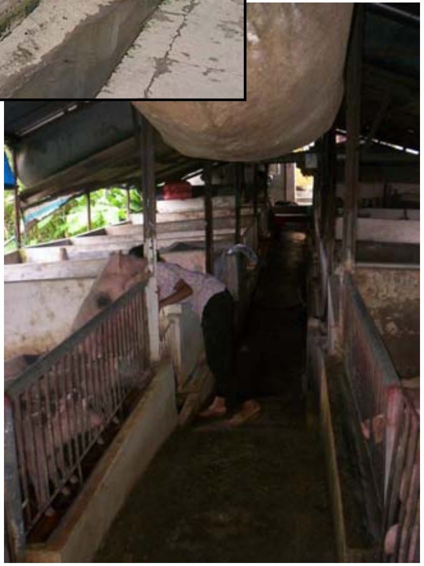
- Project Benefits:
  - Organic (BOD) stabilization
  - Pathogen reduction
  - Nutrient conversion
  - Odor control
  - Greenhouse Gas reduction
  - Energy - adds additional revenue stream to farm

	Standing Pig Population (millions)	Methane Emissions (Gg)
China[+]	47	1,197
Thailand	7	1,786
Vietnam	25	123
Total	79	3,106
as % of World	>50%	>25

[+] China is a current *Methane to Markets* Participant

Large Range in Farm Scale

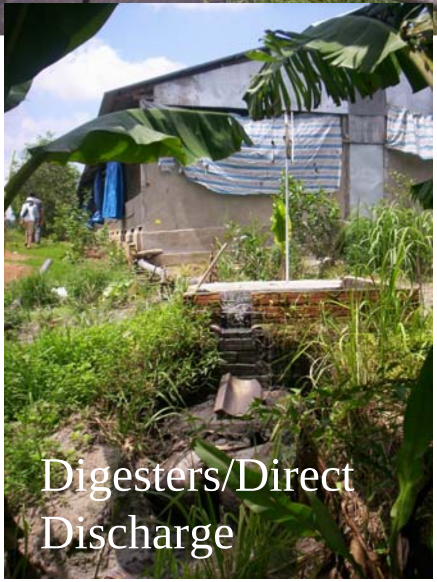
- Thailand
  - Very large corporate type farms >20,000 and very small family farms 10-50 pigs
- Vietnam
  - Very small family farms 10 – 200 pigs
- China
  - Moderate scale farm 100 – 2,000



Waste Handling and Collection

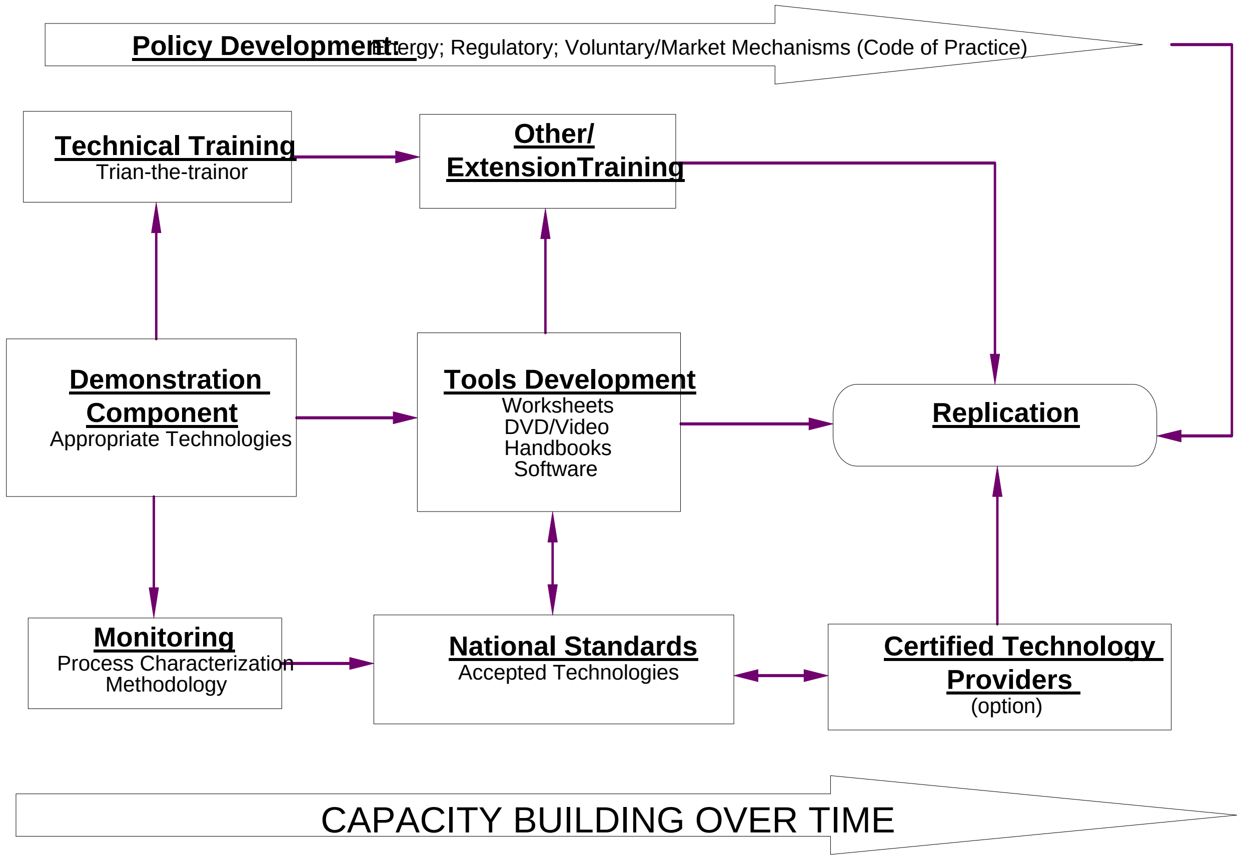
All countries solids collection and hose flush

Waste Management



1) Land application of nutrients limited to solids fraction only
2) Have discharge standards
3) Pollution load is catastrophic

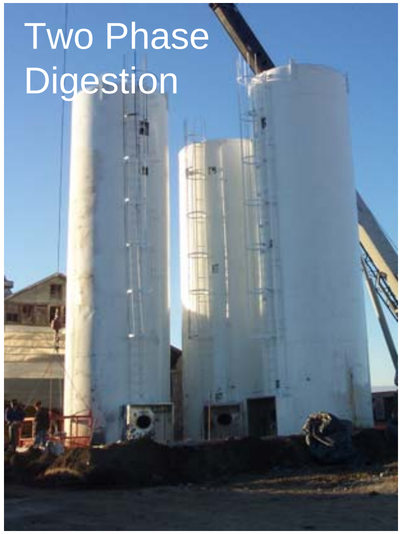
Project Design



Demonstration Overview

- Purpose is to demonstrate an array of systems that prevent water pollution
  - Greenhouse gas and air quality are not primary project objectives
  - Systems must be affordable – gas recovery component does this
    - All countries desire systems with gas recovery
- Many system types
  - Cost implications
  - Gas use options vary
- Projects are on-farm and communal
- Other processes also in technology mix
  - Two cell open lagoons
- Land application and nutrient management planning approaches are being introduced.
  - Long term implications for project
  - Some countries limited opportunity i.e., fish pond feed resource

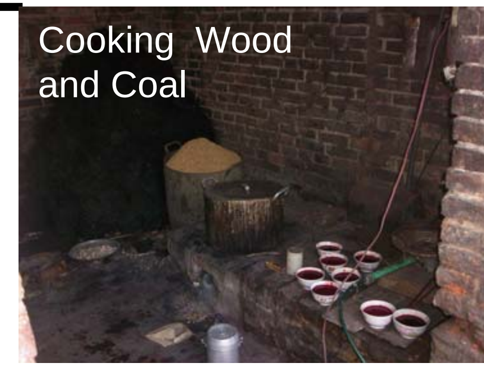
On-Farm Demonstrations

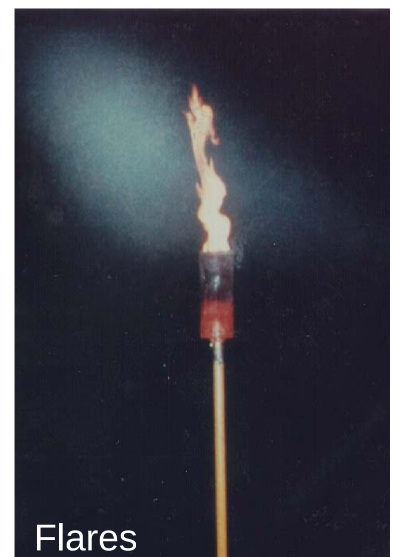


Communal Digester
N. Vietnam

- Social structure allows for communal development, operation, and management of covered lagoon
  - 200 families
  - @1,500 pigs
- Village waste canal to be constructed
  - Designed for rainfall exclusion
- Gas purchased and used as cook fuel for families
  - Distributed and measured in refillable bags

Gas Use Options





Nutrient Management – Tropical Climate Options

- Land application relative to crop need (N and P)
  - Most common approach includes temperate climate approaches – US, Europe
- Wetland
  - Aquatic crops remove nutrients
- Fish ponds
  - Waste used as fish feed resource – China, Vietnam, Thailand
- Treat and discharge - sewage
  - Livestock waste comparatively high strength very expensive
  - Understanding mass loading critical


Irrigated Rice


Tank hauling of liquid effluent


Fish Pond

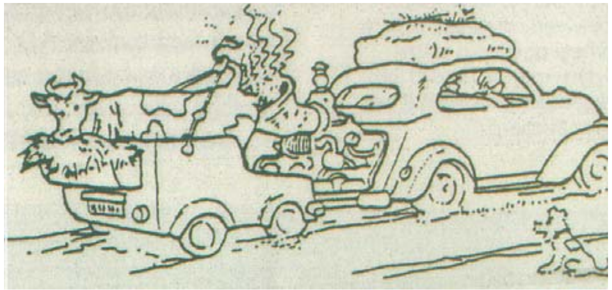
Affordability = Replication

- Demonstration has wide range in installed cost
  - $7-15 per pig (poly bags, fixed domes, covered lagoons)
  - China two phase system
  - $55-100 per pig
- Cost will effect replication potential
  - Project focused on @$15/pig or less
- Policy component
  - Energy financial incentives
  - Meat market pricing structure (Code of Practice)
  - GHG off-sets
  - Regulatory

Renewable Energy Costs kWh Output

Renewabl Energy Sources	PROJECT PARAMETERS Installed Cost $/kW	Capacity Total kW	Operational Factor	ENERGY OUTPUT kWh/hr Available	Total kWh/year	COST kWh
Wind Energy a	---	---	---	---	---	---
Wind-Small (1-100kW)	$4,000	50	30%	15	131,400	$0.15
Wind- Utiltity Scale (> 500 kW)	$1,200	500	30%	150	1,314,000	$0.05
Solar - PV b	---	---	---	---	---	---
.1 - 5 kW (Grid Connected)	$7,500	3	50%	1.5	13,140	$0.17
20 - 30 kW (Grid Connected)	$6,200	25	50%	12.5	109,500	$0.14
.1 - 5 kW (Non-Grid Connected)	$14,000	3	50%	1.5	13,140	$0.32
20 - 30 kW (Non-Grid Connected)	$14,000	25	50%	12.5	109,500	$0.32
Anaerobic Digesters c	---	---	---	---	---	---
Covered Anaerobic Lagoons (Meso. & Ambient)	$6,500	100	85%	85	744,600	$0.09
Complete Mix (mesophilic)	$6,000	100	85%	85	744,600	$0.08
Plug Flow (mesophilic)	$5,500	100	85%	85	744,600	$0.07
Attached Media (unheated)	$7,500	100	85%	85	744,600	$0.10

Sources:
a USDA-RUS from DOE Wind Powering America
b USDA-RUS from NREL/TP.620.29649
c AgSTAR Program



And that's all for now...

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Thank You