GERBIO
German Society for Sustainable Biogas and Bioenergy Utilisation

The mitigation of green house gas emissions from intensive livestock production in Thailand

FAO & Department of Livestock Development

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Biogas system from Livestock and Climate Protection Potential


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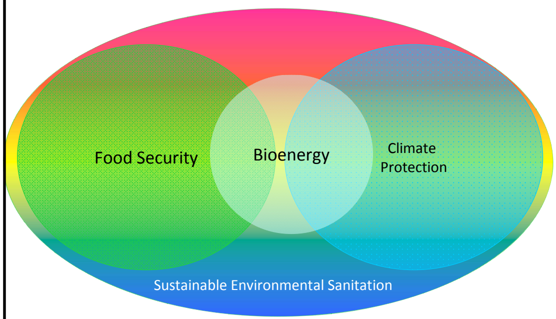
- Advicer of the „China Node for Sustainable Sanitation „(www.susanchina.cn)
- Studied energy and environmental engineering in Giessen, Germany (1980)
- Design, engineering and construction of constructed wetlands, sanitation engineerings and biogas systems since 1980
- Trained as waste water treatment plant operator (1990)
- Working for international development cooperation in biogas, biofuel, biomass energy, eco-sanitation, climate protection and organic food trade, since 1982 (through GTZ, CIM, FAO, IAEA, UNICEF, UNIDO, UNEP, CIM, KfW, ADB, EU, NGOs)
- Long term residences in Europe (Germany), Asia (China), Africa (Burkina Faso & Burundi), Latin America (Cuba, Jamaica & Bolivia)
- Member of www.iees.ch, www.iwahq.org , www.vdi.de , www.dwa.de
- Co-founder of www.biogas.org & www.germantoilet.org
- Co-founder and co-director of the „World Toilet College“ in Singapore, www.worldtoilet.org
- Vice-Chairman of the „German Society for sustainable Biogas and Bioenergy Utilisation“ www.gerbio.org

CSES Sector capacity building



Director: Prof. Dr.-Ing. Li Zifu

OUR VISION & MISSION

Contribution to the capacity building of Chinese and international Young Professionals in the area of environmental sanitation through „learning by doing“ in international team work together with experienced multidisciplinary Senior Experts from the integrated fields of

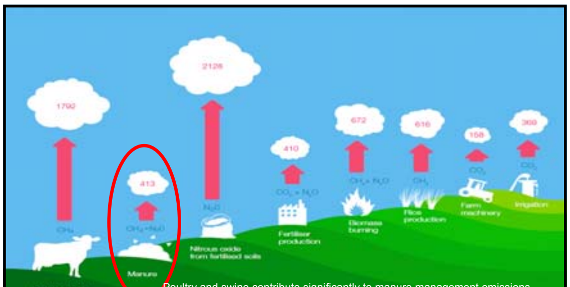
(1)wastewater management,

(2)biogas & waste,

(3)biomass energy,

(4)sustainable sanitation.

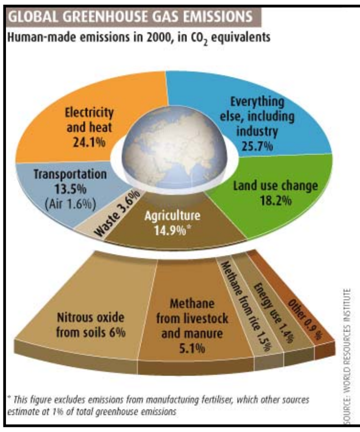
- Ecological sanitation, decentralized resource optimized waste and waste water management, biogas and biomass energy are among the key areas for sustainable development of all countries.
- To conserve nature and climate for future generations their intercultural and interdisciplinary management should be understood as fast and deep as possible by Young Professionals, the future decision makers.

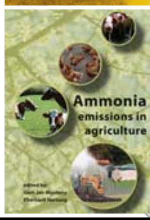


Poultry and swine contribute significantly to manure management emissions. Larger commercialized operations tend to utilize more liquid-based manure management systems, which generate more methane emissions than smaller, individual feedlot operations.

Enteric fermentation: Domesticated ruminants such as cattle, buffalo, sheep, goats, and camels account for the majority of methane emissions in this sector. Methane emission by ruminants represents an energy loss of 4 to 12% of gross energy intake. Diet intake and digestibility are factors that influence CH4 production.

Sources of agricultural greenhouse gases, excluding land use change - Mt CO2-eq
(Cool farming, published in January 2008 by Greenpeace International)

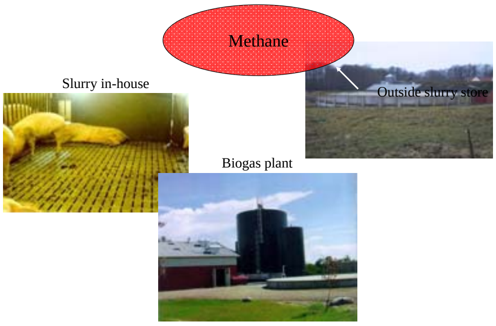


Managing Manure with Biogas Recovery Systems

- One of the biggest challenges that livestock producers face is managing manure and process water in a way that controls odours and protects environmental quality.

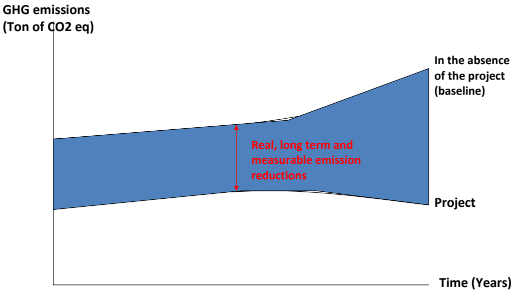
Sources of methane



Methane Emissions from Manure Management

Country	MtCO$_2$eq 1990	1995	2000	2005	2010	2015	2020
Cambodia	0.38	0.47	0.49	0.65	0.81	1.09	1.37
China	15.70	18.89	19.76	21.91	24.35	26.24	28.32
India	18.83	20.13	21.52	23.20	25.01	26.22	27.48
Indonesia	1.08	1.25	1.01	1.13	1.28	1.37	1.47
Laos	0.30	0.37	0.31	0.34	0.38	0.41	0.45
Myanmar	0.91	1.11	1.31	1.43	1.56	1.69	1.82
Singapore	0.05	0.03	0.03	0.03	0.04	0.04	0.04
Thailand	2.74	2.90	2.74	3.09	3.49	3.85	4.26
Viet Nam	2.21	2.85	3.47	3.92	4.42	4.86	5.33
Rest of SE Asia	2.35	2.72	2.27	2.47	2.69	2.88	3.08

Concept

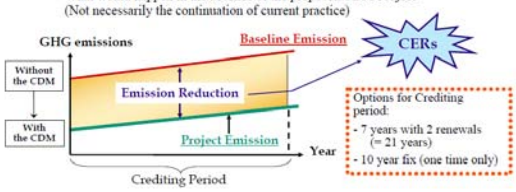


How to calculate the emission reductions?

CERs = Emission Reduction = Baseline Emission — Project Emission — Leakage

Baseline

- Hypothetical scenario
- What would happen in the absence of the proposed CDM Project (Not necessarily the continuation of current practice)



Baseline Scenario

- Marrakech accords*, modalities and procedures for CDM, article 48:

  a) Existing actual or historical emissions, as applicable; or

  b) Emissions from a technology that represents an economically attractive course of action, taking into account barriers to investment; or

  c) The average emissions of similar project activities undertaken in the previous five years, in similar social, economic, environmental and technological circumstances, and whose performance is among the top 20 per cent of their category

Baseline scenario should take into account national and/or policies and circumstances

*The **Marrakech Accords** from October of 2001 is a set of agreements reached at the Conference of the Parties 7 (COP7) meeting in 2001 on the rules of meeting the targets set out in the Kyoto Protocol.

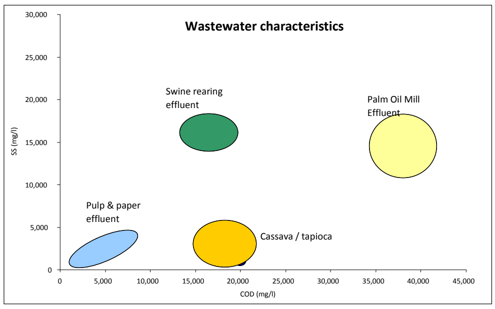
Baseline methodologies

- Industrial processes
  - HFC incineration, decomposition of N_2O from adipic acid production plants, use of renewable CO_2 in the production of inorganic compounds, Increased share of additive materials in cement production
- Waste management
  - Landfill gas capture and recovery, biomethanisation, forced methane extraction, organic waste composting
- Renewable energy
  - Electricity generation from renewable resources exported to the grid, biomass cogeneration, grid connected electricity generation from biomass residues
- Agriculture
  - Manure management systems, improved animal waste management
- Energy efficiency (including fuel switching)
  - Flared gas recovery, switching from coal and petroleum fuels to natural gas, natural gas cogeneration, steam efficiency improvements, steam optimization system, water pumping efficiency improvements, leak reduction from natural gas pipeline

Baseline example: Biogas projects

- Applicability: industrial/agricultural wastewater treatment
- Typical applications:
  - Palm oil mill effluent
  - Manure management
  - Tapioca/Cassava effluent
  - Pulp and paper mill effluent
- Anaerobic bacterial processes

Baseline example: Biogas projects



Source: Zakkour P, 2005

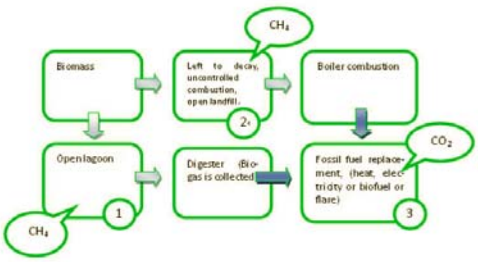
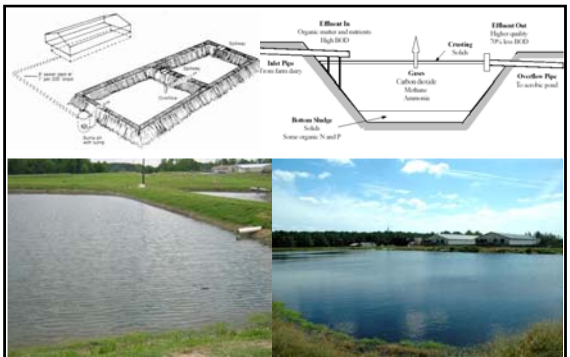


Figure 1: Biomass and biogas production process



Methodological choice

- Biomass baseline
  ⇒ Crediting based on the carbon content of the biomass (methane and ammonia emission)
  ⇒ High number of credits
  ⇒ Methodological challenges difficult to address

- Fossil fuel baseline
  ⇒ Renewable biomass increases long-term availability of a renewable energy and displaces in the longer term fossil fuels
  ⇒ Less credits than "biomass" baseline
  ⇒ Baseline does not reflect what happens on the ground
  ⇒ Methodological challenges are circumvented

Applicable CDM methodologies for biomass and biogas projects, incl. landfill

1. ACM0001 Consolidated baseline and monitoring methodology for landfill gas project activities, v 9.1
2. ACM0006 Consolidated methodology for electricity generation from biomass residues v 7
3. ACM0010 Consolidated baseline methodology for GHG emission reductions from manure management
4. AM0007 Analysis of the least-cost fuel option for seasonally-operating biomass cogeneration plants
5. AM0036 Fuel switch from fossil fuels to biomass residues in boilers for heat generation
6. AM0042 Grid-connected electricity generation using biomass from newly developed dedicated plantations, v 2
7. AM0053 Biogenic methane injection to a natural gas distribution grid, v1.1
8. AM0057 Avoided emissions from biomass wastes through use as feed stock in pulp and paper production or in bio-oil production
9. AM0073 GHG emission reductions through multi-site manure collection and treatment in a central plant, v1
10. AM0075 Methodology for collection, processing and supply of biogas to end-users for production of heat, v1
11. AMS II G Energy Efficiency Measures in Thermal Applications of Non-Renewable Biomass
12. AMS III D Methane recovery in animal manure management systems, v 14
13. AMS III E Avoidance of methane production from decay of biomass through controlled combustion
14. AMS III F Avoidance of methane emissions through controlled biological treatment of biomass, v 6
15. AMS III G Landfill Methane Recovery, v 6
16. AMS III H Methane Recovery in Wastewater Treatment, v 11
17. AMS III L Avoidance of methane production from biomass decay through controlled pyrolysis, v 2
18. AMS III R Methane recovery in agricultural activities at household or small farm level, v 1

How does "Biogas project" reduce GHG?

<Case of Biogas generated from wastewater treatment>

- Avoid/Recover CH4 emission in Biogas (AMS III.H.)

(i) Substitution of **aerobic** wastewater or sludge treatment system with **anaerobic** treatment with CH4 recovery and combustion

(ii) Introduction of **anaerobic** sludge treatment with CH4 recovery and combustion to existing wastewater treatment system without sludge treatment system

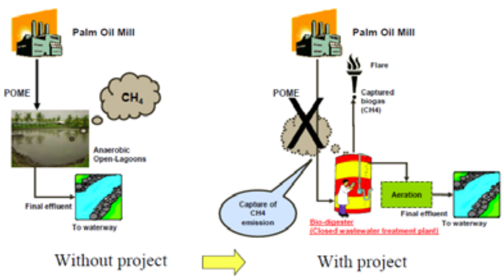
(iii) Introduction of CH4 recovery and combustion to existing sludge treatment system

(iv) Introduction of CH4 recovery and combustion to existing anaerobic wastewater treatment system such as anaerobic reactor, lagoon, septic tank or an on site industrial plant

(v) Introduction of **anaerobic** wastewater treatment with CH4 recovery and combustion with or without anaerobic sludge treatment, to untreated wastewater stream

(vi) Introduction of sequential stage of wastewater treatment with CH4 recovery and combustion, with or without sludge treatment, to existing **anaerobic** wastewater treatment system without CH4 recovery.

- Reduce fossil fuel consumption by supplying renewable energy
  - less coal consumption by generating steam from the biogas combustion
  - less diesel oil consumption for in-house power generation by utilizing biogas
  - less power generation of thermal power plant by supplying power to the grid

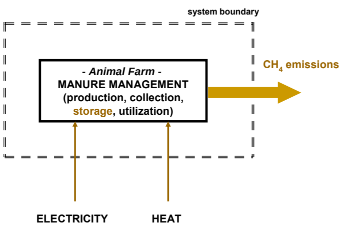


Baseline Emissions

$$BE_y = Q_{y,ww} * COD_{y,ww,untreated} * B_{o,ww} * MCF_{ww,treatment} * GWP\_CH_4$$

$Q_{y,ww}$	Volume of wastewater treated in the year "y" (m^3)
$COD_{y,ww,treated}$	Chemical oxygen demand of the treated wastewater in the year "y" ($tonnes/m^3$)[2]
$B_{o,ww}$	Methane producing capacity of the wastewater (IPCC default value for domestic wastewater of 0.21 kg CH_4/kg.COD)[2]
$MCF_{ww,treatment}$	Methane correction factor for the existing wastewater treatment system to which the sequential anaerobic treatment step is being introduced (MCF lower value in Table III.H.1.)
GWP_CH_4	Global Warming Potential for methane (value of 21 is used)

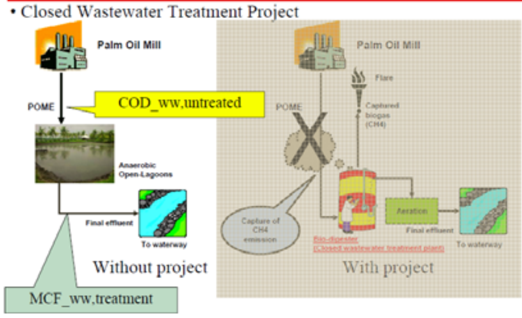
Baseline (Livestock Farming)



Part II

EXAMPLE FOR METHANE EMISSION REDUCTION PROJECT

- Closed Wastewater Treatment Project



- Which value for MCF of BE?

Table III.H.1. IPCC default values[1] for Methane Correction Factor (MCF)

Type of wastewater treatment and discharge pathway or system	MCF lower values	MCF higher values
Discharge of wastewater to sea, river or lake	0.0	0.2
Aerobic treatment, well managed	0.0	0.1
Aerobic treatment, poorly managed or overloaded	0.2	0.4
Anaerobic digester for sludge without methane recovery	0.8	1.0
Anaerobic reactor without methane recovery	0.8	1.0
Anaerobic shallow lagoon (depth less than 2 metres)	0.0	0.3
Anaerobic deep lagoon (depth more than 2 metres)	0.8	1.0
Septic system	0.5	0.5

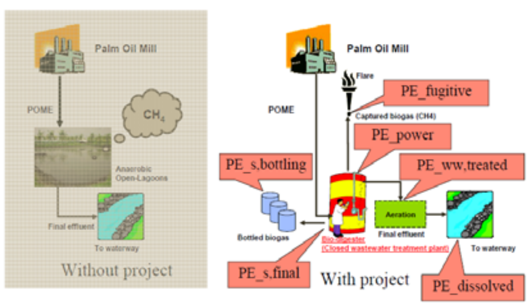
MCF_ww,treatment

Project Emissions

- Project emissions – 6 sources

$$PE_y = PE_{y,power} + PE_{y,ww,treated} + PE_{y,s,final} + PE_{y,fugitive} + PE_{y,dissolved} + PE_{y,bottling}$$

PE_y	Project activity emissions in the year "y" (tCO_2e)
$PE_{y,power}$	Emissions from electricity or diesel consumption in the year "y"
$PE_{y,ww,treated}$	Emissions from degradable organic carbon in treated wastewater in year "y"
$PE_{y,s,final}$	Emissions from anaerobic decay of the final sludge produced in the year "y". If the sludge is controlled combusted, disposed in a landfill with methane recovery, or used for soil application, this term can be neglected, and the final disposal of the sludge shall be monitored during the crediting period
$PE_{y,fugitive}$	Emissions from methane release in capture and utilization/combustion/flare systems in year "y"
$PE_{y,dissolved}$	Emissions from dissolved methane in treated wastewater in year "y". Project emissions from this source are only considered for project activities involving measures described in cases (i), (v) and (vi)
$PE_{y,bottling}$	Emissions related to the production, upgrading and use of the bottled biogas in year "y". (If the recovered methane is not upgraded for bottling this term can be neglected)



- Apply appropriate values for MCFs

$$PE_y = PE_{y,power} + PE_{y,ww,treated} + PE_{y,s,final} + PE_{y,fugitive} + PE_{y,dissolved} + PE_{y,bottling}$$

$$PE_{y,ww,treated} = Q_{y,ww} * COD_{y,ww,treated} * B_{o,ww} * MCF_{ww,final} * GWP\_CH_4$$

$Q_{y,ww}$	Volume of wastewater treated in the year "y" (m^3)
$COD_{y,ww,treated}$	Chemical oxygen demand of the treated wastewater in the year "y" ($tonnes/m^3$)[2]
$B_{o,ww}$	Methane producing capacity of the wastewater (IPCC default value for domestic wastewater of 0.21 kg CH_4/kg.COD)[2]
$MCF_{ww,final}$	Methane correction factor based on type of treatment and discharge pathway of the wastewater (fraction) (MCF Higher Value in table III.H.1 for sea, river and lake discharge i.e. 0.2)
GWP_CH_4	Global Warming Potential for methane (value of 21 is used)

$$PE_{y,fugitive} = \underset{(a)}{PE_{y,fugitive,ww}} + \underset{(b)}{PE_{y,fugitive,s}}$$

(a) $$PE_{y,fugitive,ww} = (1 - CFE_{ww}) * \underbrace{MEP_{y,ww,treatment}}_{Q_{y,ww} * COD_{y,ww,untreated} * B_{o,ww} * MCF_{ww,treatment}} * GWP\_CH_4$$

$MCF_{ww,treatment}$	Methane correction factor for the wastewater treatment system that will be equipped with methane recovery and combustion/flare/utilization equipment (MCF higher values in table III.H.1)

(b) $$PE_{y,fugitive,s} = (1 - CFE_s) * \underbrace{MEP_{y,s,treatment}}_{S_{y,untreated} * DOC_{y,s,untreated} * DOC_F * F * 16/12 * MCF_{s,treatment}} * GWP\_CH_4$$

$MCF_{s,treatment}$	Methane correction factor for the sludge treatment system that will be equipped with methane recovery and combustion/utilization/flare equipment (MCF Higher value of 1.0 as per table III.H.1).

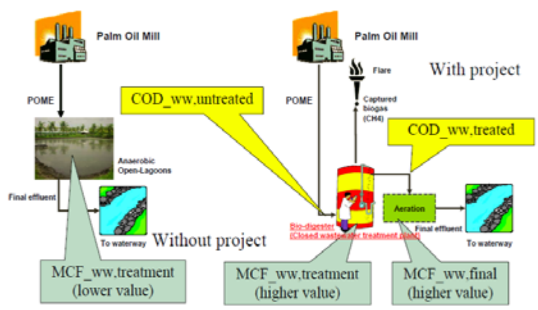
- Which value for MCF of PE?

MCF_ww,final

Table III.H.1. IPCC default values[1] for Methane Correction Factor (MCF)

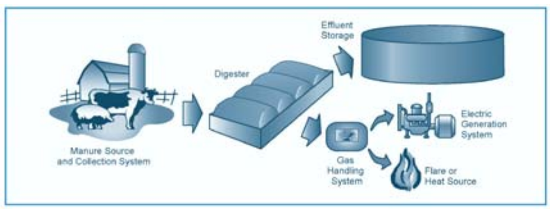
Type of wastewater treatment and discharge pathway or system	MCF lower values	MCF higher values
Discharge of wastewater to sea, river or lake	0.0	0.2
Aerobic treatment, well managed	0.0	0.1
Aerobic treatment, poorly managed or overloaded	0.2	0.4
Anaerobic digester for sludge without methane recovery	0.8	1.0
Anaerobic reactor without methane recovery	0.8	1.0
Anaerobic shallow lagoon (depth less than 2 metres)	0.0	0.3
Anaerobic deep lagoon (depth more than 2 metres)	0.8	1.0
Septic system	0.5	0.5

MCF_ww,treatment



Part III

EXAMPLE FOR METHANE EMISSION REDUCTION PROJECT



Baseline example: Biogas projects

- Technologies

- Low-rate systems / batch systems
  - Open lagoons (anaerobic/facultative) = biogas to atmosphere
  - Covered lagoons
  - [Sequencing] batch reactors; ASBRs / sludge digesters

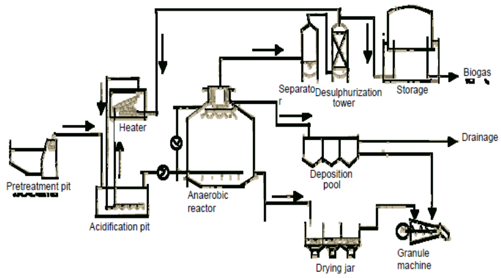
- High-rate systems
  - Continuous stirred tank reactor; CSTR
  - Upflow anaerobic sludge blanket; UASB
  - Anaerobic filters; AF
  - Anaerobic fixed-film reactors; AFFR
  - Anaerobic fluidised bed reactor; AFBR
  - Floc-based recycle systems (like an ASP)

-What is the project technologies?

-What was installed prior to the project?

-What would happen in the absence of the project?

Biogas plant flow chart



Project Activity (Biogas Plant)

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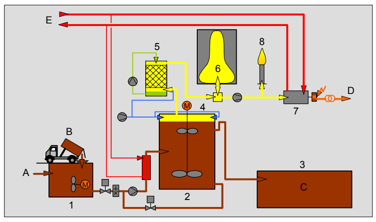
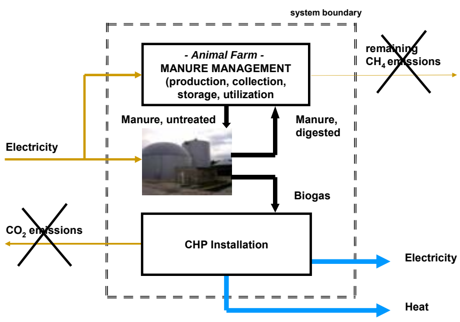


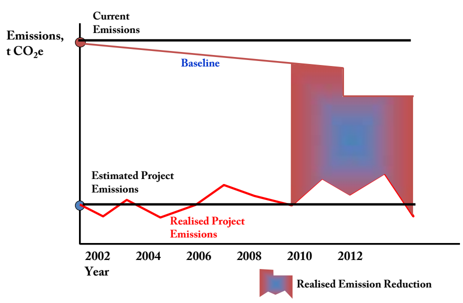
A Manure Input
B Co-Substrates (optional)
C Digestate
D Power
E Heat

1 Receiving / Mixing
2 Digester
3 Final Storage
4 Internal Desulphurisation
5 Biogas Purification
6 Gas Tank
7 Gas Engine

Project Activity (Biogas Plant)



Emission Reductions



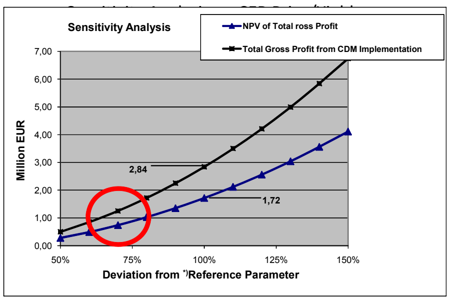
CER Yield of exemplary Biogas Project

Location	China, Piggery of 100000 tons od swine manure per year
Baseline Scenario	100000 tons of swine manure are stored in lagoons per year before final utilization; Fuel consumption for heating purposes of farm facilities
Project Scenario	Technical digestion of this 100000 tons of swine manure; Production von power and heat, and displacement of fuel
Annual Amount of Emission Reduction [t CO_2e]	1. CH_4 Reduction — 32000 t CO_2e/a 2. Heat (4000 MWh/a) — 1050 t CO_2e/a 3. Power (6000 MWh/a) — 4200 t CO_2e/a **Total** — **37250 t CO_2e/a**
CER Amount	37250 t CO_2e/a x 10 years = **372 500 t CO_2e**

P&L Statement Carbon Implementation

Index	0	1	2	3	4	5	6	7	8	9	10
CER Production through Project Operation	2.007	2.008	2.009	2.010	2.011	2.012	2.013	2.014	2.015	2.016	2.017
CER Delivery after Verifying; Reference Year of Cash-Flow	2.008	2.009	2.010	2.011	2.012	2.013	2.014	2.015	2.016	2.017	2.018
Annual CER Amount [t CO2e]		37.250	37.250	37.250	37.250	37.250	37.250	37.250	37.250	37.250	37.250
CER Transaction Price [EUR/ t CO2e]		9,00	9,00	9,00	9,00	9,00	9,00	9,00	9,00	9,00	9,00
Turnover CER Transaction		335.250	335.250	335.250	335.250	335.250	335.250	335.250	335.250	335.250	335.250
Preproduction costs, Baseline Study, PDD, etc.	-45.000										
Validation through DOE, Project Registration	-30.000										
Verification through DOE, CER accounting		-20.000	-20.000	-20.000	-20.000	-20.000	-20.000	-20.000	-20.000	-20.000	-20.000
Transaction Fees and Extras (7%)		-23.468	-23.468	-23.468	-23.468	-23.468	-23.468	-23.468	-23.468	-23.468	-23.468
Gross Profit from CDM Implementation [EUR]	-75.000	291.783	291.783	291.783	291.783	291.783	291.783	291.783	291.783	291.783	291.783

Total Gross Profit CDM Implementation	2.842.825	EUR
NPV (2007; 10%)	1.717.877	EUR



*) CER Yield: 37´250 t CO_2e/a
CER Price: 9,00 EUR per ton CO_2e

Financial Figures of Project Example (100 000 t /y of swine manure)

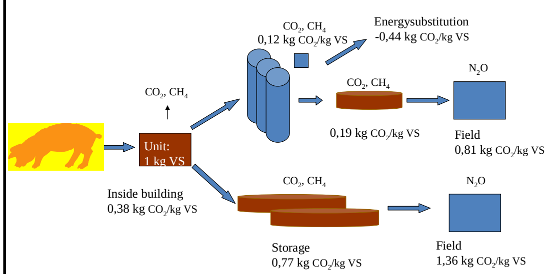
- Plant Magnitude (CHP Engine Power) — 1 MW-el
- Investment Costs Biogas Plant — **2,5 M€**
- Total CER Value (Forward) — **1,0 M€**
  - Cash-Flow Model 1 => 100% Upfront
  - Cash-Flow Model 2 => 50% Upfront + 50% Mezzanine (international)
  - Cash-Flow Model 3 => 100% Mezzanine (international)
- Remaining Capital Demand — **1,5 M€**
  - => 100% Equity
  - => 50% Equity + 50% Loan (local bank)
  - => 100% Loan (local bank)

Additionality

- Marrakech accords, modalities and procedures for CDM, article 43:

"A CDM project activity is additional if anthropogenic emissions of greenhouse gases by sources are reduced below those that would have occurred in the absence of the registered CDM project activity"

Greenhouse gasses
-effect of AD (example)



Tool to demonstrate additionality

- Identification of alternatives to the project activity;
- *Investment analysis to determine that the proposed project activity is not the most economically or financially attractive;*

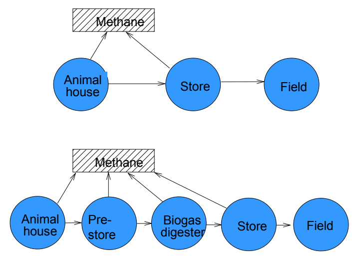
  and/or
- *Barriers analysis;*
- Common practice analysis; and
- Impact of registration of the proposed project activity as a CDM project activity

Leakage

- Marrakech accords, modalities and procedures for CDM, article 51:

  "Leakage is defined as the net change of anthropogenic emissions by sources of greenhouse gases which occurs outside the project boundary, and which is measurable and attributable to the CDM project activity"

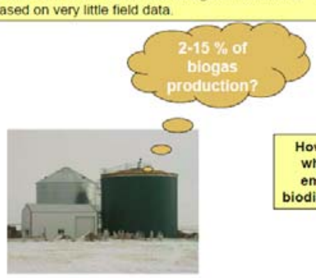
Sources of green house gas on animal farms with and without biogas digesters



Leakage

- In estimating leakage:
  - Clearly define the project boundary
  - In proposing new methodology: Requirement to elaborate leakage in a detailed manner
  - Pay attention to "indirect leakage"
    - Increased fossil fuel consumption at x due to utilisation of renewable energy at y

Typically, life cycle analysis of farm scale biodigesters assumes 2 to 13.5 % loss of biogas produced due to fugitive emissions. IPCC in the past has assumed 5 to 15 % loss due to fugitive emissions. These assumptions are based on very little field data.



How can we evaluate whole farm fugitive emissions from the biodigestion processes?

15

Gas tight concrete protection

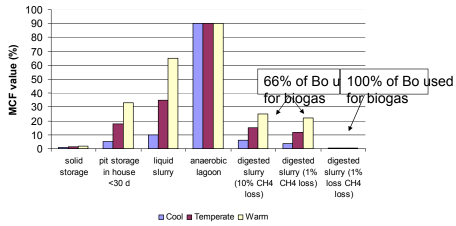
Concrete protection from	*Durability of a silo in years*				*Material costs per area [US$ m⁻²]*	*Working time per area [h m⁻²]*
	Without roof		*With roof*			
	bottom	*wall*	*bottom*	*wall*		
Bitumen	1	1–2	1–2	2	0.40–0.65	0.150
Plastic dispersion	1–2	3	2	3–4	1.25–2.30	0.125
Polyurethane (PUR)	3–4	5	5	6	1.25–3.60	0.075
Epoxide	4	5	5	6	1.90–3.75	0.150
Asphalt concrete	20		20		15.00	

Monitoring Methodology

- Monitoring plan:
  - Monitor baseline emissions
  - Monitor project emissions
  - Monitor leakages
  - Estimation and calculation of emission reductions
  - Address the uncertainty (data)
  - Quality assurance/Quality control
  - Monitoring management
  - Designated system/human resources

Be consistent with the algorithm/methodology used to estimate the Baseline and Project emissions

Calculating reduced methane emission



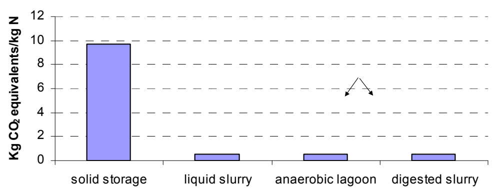
$$EF = VS \bullet 365 days/year \bullet Bo \bullet 0.68\, kg/m3 \bullet MCF$$

EMISSION FACTOR FROM MANURE MANAGEMEN AFTER DIGESTION

MCF = [(CH4 prod - CH4 used - CH4 flared + MCFstorage * (Bo - CH4 prod)]/ Bo] *100%

Calculating reduced Nitrous oxide emission

N_2O emissions during storage (Kg CO_2 equiv/kg N)



Monitoring requirement

- Exact measurement of biogas out of each digester
- After desulphurization, dehydration and purification, the biogas should be measured including pressure, flow, temperature, CH_4 fraction
- Exact input of biogas to generator and flow
- Install flow meter at the inlet of generator and flow respectively.
- Flare should operate in compliance with manufacture's specification
- Temperature, pressure or other parameters should be monitored
- Biogas flow and CH_4 fraction should be measured at 95% confidence level
- Ensure aerobic treatment of residues

Parameters monitored

- Electricity generated, reported monthly , recorded daily
- Electricity imported, reported monthly , recorded daily
- Animal number, animal number of each species in all pig barns, stock number, production number, inlet number of baby pigs. Monitored and reported monthly
- Animal weight, average weight of each species and age class. Monitored and reported monthly
- Fraction of manure handled in project activity. Monitored and reported monthly (by volume? How?)
- Biogas flow as well as gas press and temperature (four flow meters needed, one at outlet of each digester, one at inlet of generator, another at inlet of flare). Measured continuously, recorded daily, reported weekly, confidence level:95%
- Methane fraction (two measure devices needed, one at outlet of each digester), measured continuously, recorded daily, reported weekly, confidence level:95%
- Flare efficiency. Monitored when flaring, parameters: temperature and other described in specification.
- Feeding formula of each species and age class, monitored and reported monthly
- Proven document of generic source, reported annually
- Records of swine sales and records of food purchase, reserve all records.

Table 2. Monitored information based on the monitoring plan

DATA VARIABLE	DATA UNIT	DATA ORIGIN
Animal Population	Heads	Daily animal Stock and inlet progress of pigs (Not inlet considering mortality). Information managed by Agrosuper
Average Weight of Animals	kg	Pavilion test and growing tendency curves. Information managed by Agrosuper
Manure Flow After Aerobic Treatment Stage	m^3/day	This parameter is calculated with total inlet flow minus sludge volume
Manure Flow Before Aerobic Treatment	m^3/day	This parameter is monitored from a flow meter installed before the activated sludge
Flow of Sludge from Aerobic Treatment	m^3/day	Referential volume from sludge transportation requirements. Information managed by third party
5 days BOD in Manure after Aerobic Treatment Stage	mg/L	Activated Sludge monitoring registers, managed by third party
Total Nitrogen Content in Manure after Aerobic Treatment Stage	mg/L	Activated Sludge monitoring registers, managed by third party
Temperature of Manure after Aerobic Treatment Stage	°C	Activated Sludge monitoring registers, managed by third party
Biogas Flow Extracted by Digester	SCFM	Registers from the CLP. Information managed by Agrosuper
CO2 Concentration in Gas Flow	%	Registers from the CLP. Information managed by Agrosuper
Flare Efficiency	%	Design Combustion Efficiency. Provided by third party

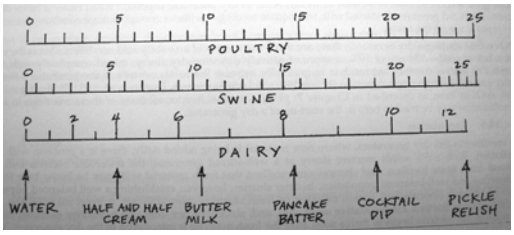
Table 2: Measured and Monitored Parameters

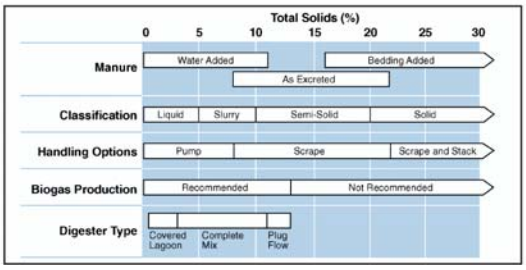
CCAR Parameter	Description	Data Source
L	Dairy Herd Inventory	Gallo Farms herd management software
$MS_{L,k}$	Fraction of manure from each livestock category managed in manure management system component	Estimated
P_L	Population	Gallo Farms herd management software
T	Temperature	Weather Service
V	Volume of biogas	Continuously monitored by three flow meters to each destruction device (see Table 6)
$CH_{4 fraction}$	Fraction of biogas that is CH_4	Quarterly laboratory analysis
QF_i	Fuel used by project for manure collection, transport, treatment storage and disposal	Gallo Farms internal fuel use tracking system

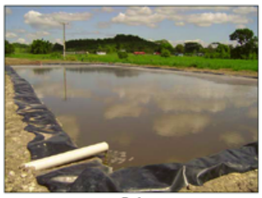
Monitoring Methodology

Data Type	Data Variable	Data Unit	Measured (m), calculated (c) or estimated (e)	Recording Frequency	Proportion of Data to be Monitored	How Will the Data be Archived (electronic/paper)	For How Long is the Archived Data Kept?	Comment	Method/instrument used to record

Dry matter content of manure

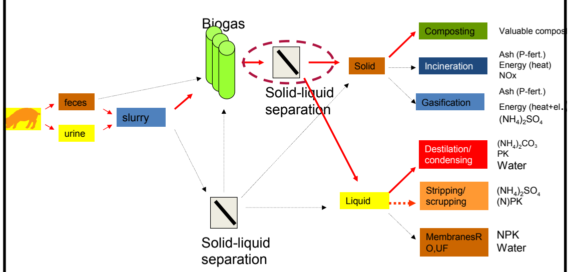





Before


After (projected)

Manure treatment concepts



Direct digestate application

Biology – properties of different manures

Liquid manure type	pH - Value	C/N	Properties
Cattle liquid manure	6.8 – 7	10 – 17	• Good buffering capacity • Rich in methane bacteria
Pig liquid manure	approx. 7	5 - 10	• Good buffering capacity • High proportion of heavy metals (Zn 700-2000; Cu 250-760 [mg/kg DM])
Poultry liquid manure	7 – 7.3	approx. 7	• Good buffering capacity • Strong sediment accumulation

Positive changes of liquid manure properties through fermentation

Decomposition of organic substance

- Decomposition rates oDM: of up to 40%
- The fermented liquid manure can pumped and sprayed better compared to the raw liquid manure
- The agitation is reduced before the application on land

Odor reduction

Reduction of the odor causing substances (humid acids, Phenols, Phenol derivate)

Sanitization

The degree of the sanitization depends on residence time, temperature and applied procedure

Positive changes of liquid manure properties through fermentation

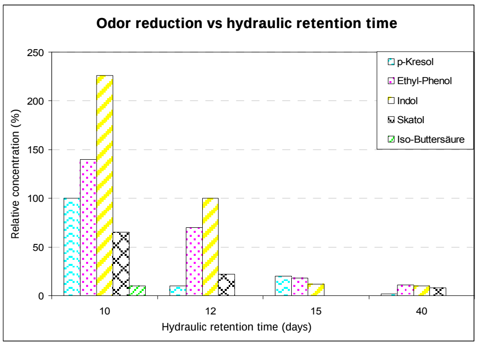
Destroying the weed seeds

The longer the seeds in the liquid manure are exposed to the process and the higher the temperature is, the more rapidly decreases the germination capacity

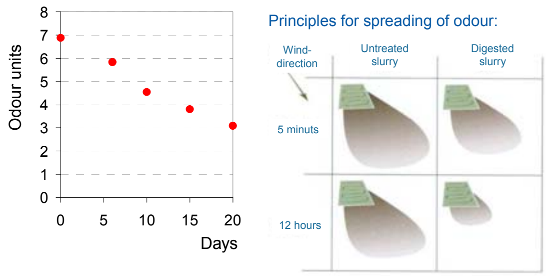
Avoidance of plant corrosion

Improvement of the fertilizer value

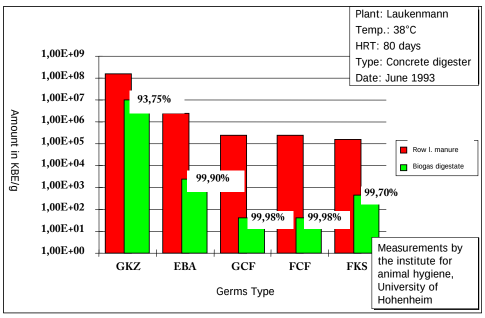
The fermented liquid manure has a better short term N-Fertilizer effect



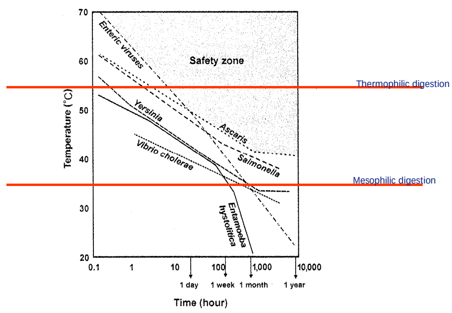
Digestion reduces odour



Reduction of pathogenic germs

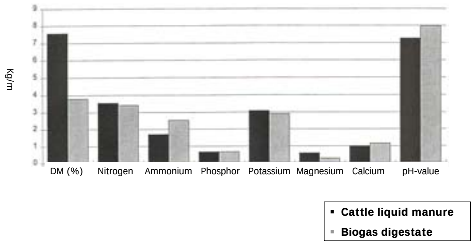


Inactivation of pathogens



Source: Strauch, D. 1991

Mean values of some samples from cattle liquid manure and biogas digestate – Oberlungwitz biogas plant study case



Source: Saxony Regional Office for Agriculture FB LB, Jäkel

Use of biogas digestate

Digestate can be spread on the fields

- no hygiene restrictions with animal slurry and plant material

Improved Fertilizer

- avoids nutrient losses
- reduces burning effect on plants
- improves flowing properties
- improves plant compatibility
- improves plant health
- reduces germination ability of weed seeds

Environmentally sound

- reduces the intensity of odor
- reduces air pollution through methane and ammonia
- reduces the wash out of nitrate
- sanitizes liquid manure
- recycles organic residues (co-fermentation)
- can avoid connection costs to a central sewer

Environmental friendly (ecological) liquid manure management

Very big quantities of liquid manure lead to:

- Off Odor impacts during treatment and production
- Spreading of pathogenic germs
- Damage of the botanical composition and building of a typical "Liquid Manure Flora" in the available grassland
- Worsen the soil properties
- Contamination of the ground and surface waters

Biogas technology can not substantially reduce liquid manure quantities. It OFFERS HOWEVER, different solutions for this problem, thanks to its positive energy balance from the **production of biogas**.

Liquid digestate processing and fertilization

Digestate storage

After the anaerobic treatment of liquid manure and during the storage nitrogen losses occur in form of ammonia

Digestate land application

During the application nitrogen losses can be presented in gaseous form (ammonia) and in mineral form (nitrate)

Land application techniques

Drag hose tractor: precise fertilization, around 41% lower NH_3 emissions

Fertilizer distributor tractor: strong smell and ammonia emissions, wind-sensitively

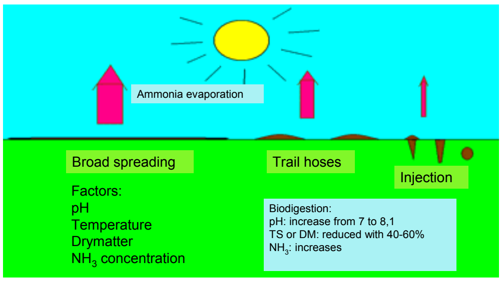
Measures during liquid digestate application

- No excessive agitation before the application
- Deploy cooled substrate from the final storage
- Spread using emission-reducing techniques (drag hose tractor, etc.), and
- Processing the digestate

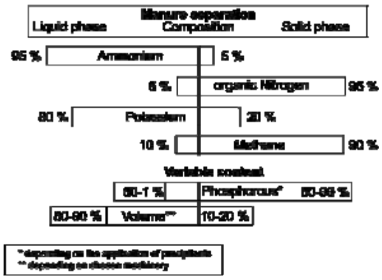
To prevent the nitrate leaching by liquid digestate fertilization other measures, besides the type of treatment must be taken into account:

- Sufficient storage capacity (at least 6 months)
- Periods of application
- Quantity of liquid digestate (and thus N-quantity) to be applied
- Spreading technology

Ammonia evaporation



Nutrient distribution



Reasons for processing digested slurry

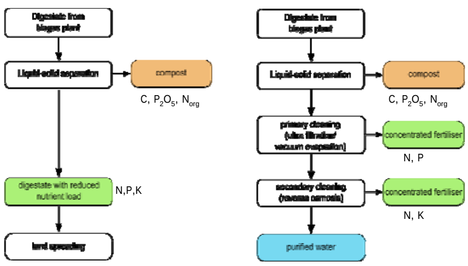
- Saves storage volume (liquid phase)
- Surplus of nutrients or lacking area for land spreading
  ⇨ Export of nutrients required
- Digestate contains 70-90 % of water
  ⇨ Removing water saves transport costs
- Reduced costs for land spreading
- Reduced environmental impacts
  - Nutrients release in the liquid phase
  - Reduction of volatile air pollutants
  - Odor reduction

Basic principles of digestate processing

- Physical
  - Liquid-solid separation
  - Membrane technology
  - Vacuum evaporation
- Chemical
  - Flocculation
  - Precipitation (MAP, Phosphate)
- Biological
  - Anaerobic digestion
  - Composting (aerobe)
  - Activated sludge process (aerobe)
  - Nitrification, denitrification

Processing strategies

1. Partial separation
   Elimination of P O
2. Complete separation
   Elimination of P O + N



Applied Technologies

- Liquid-solid separation
  - Screw press
  - Decanter centrifuge
  - Solar Drying
- Membrane technology
- Vacuum evaporation

Liquid solid separation – partial processing

- **Separation of solid contents**
- ⇨ **always the 1st processing step!!!**

Removal of:

- 20-80 % P_{tot}
- 10-20 % N_{tot}

plus:

- Production of compost
  ⇨ humus balance

Exemplary nutrient distribution

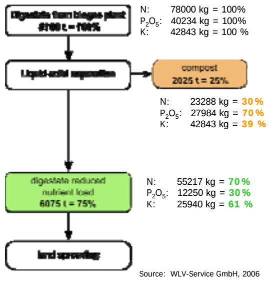
- Partial processing
- Centrifuge – WLV
- Goal: P_2O_5 elimination

⇩

Type of nutrients to eliminate leads to choice of technology/ strategy:

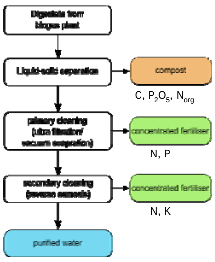
P_2O_5: partial processing

N: complete processing



Complete nutrient separation

⇨ Elimination of P_2O_5 + N



- Complex processes, requires sophisticated technology
- High energy demand
- Economically viable only at big biogas plants > 700 kW_{el}

Complete separation What's important?

- High energy demand for generating pressure or heat utilisation of surplus heat??
- Digested slurry might form crusts on the device, chose technology adapted to digested slurry
- Complete removal of particulate substances (> 0,2 mm) before entering membrane technology or vacuum evaporation

> ⚠ Inaccurate solids removal increases rate of failure
> ⇨ Cleaning & Repair might take days and leads to increased costs!

Separated material – and now???

- 1 substance ⇨ 2-4 different material flows
- Concentrated nutrients might contain high salt loads
- Concentrated nutrients allow specific fertilizer mixing
- Utilization on own farm (partial nutrient removal)
- Marketing?
- Marketing channels?
- Quality assurance and control

⇩

Requires good planning & strategic partners

Partial separation - profitability

Fertilizer value inprovement:

	Nitrogen	Phosphate	Potassium
Cost of nutrients (€/kg)	0,60	0,45	0,35

Nutrients	Amount C1 ($kg/t_{digestate}$)	Value C1 ($€/t_{digestate}$)	Amount C2 ($kg/t_{digestate}$)	Value C2 ($€/t_{digestate}$)	Δ Value C2 – C1 ($€/t_{digestate}$)
N	9,69	5,81	11,5	6,90	1,09
P_2O_5	4,97	2,24	13,82	6,22	3,98
K_2O	5,29	1,85	8,35	2,92	1,07
				Σ =	6,14

↳ In areas where P O is not required, the one step treatment and extern transport make sense and could be profitable.

Conclusion

- Nutrients = problem (surplus) ⇨ nutrient separation & export might be the only solution
- But: calculate carefully (expensive technolgy) and be aware that you might need to market nutrients
- Also: which nutrients do you need to get rid off – where are they?
  (nutrient distribution between liquid and solid phase)
- Complete nutrient removal is only viable at big biogas plants - not for plants < 1 MW
- Rising demand and increasing sizes of biogas plants might lead to decreasing technology prices

Environmental Effectiveness of Manure Management Options

Options	Odor Control	Greenhouse Gas Reduction	Water Quality Protection	Cost Range[††] (per 1,000 lbs/ live weight)
Covered lagoon digesters with open storage ponds	E	H	G	$150-400
Heated digesters (i.e., complete mix and plug flow) with open storage tanks	E	H	G	$200-400
Aerated lagoons with open storage ponds[†]	G-E	H	F-G	$200-450
Separate treatment lagoons and storage ponds (2-cell systems)	F-G	L	G	$200-400
Combined treatment lagoons and storage ponds	P-G	L	F-G	$200-400
Storage ponds and tanks	P-F	M-H	P-F	$50-500

Key: P=poor, F=fair, G=good, E=excellent, L=low, M=medium, H=high
[†]Aerated lagoon energy requirements add an additional $35-50 per 1,000 lbs/year.
[††]Cost ranges do not include annual operation and maintenance (O&M) costs.

Biogas Generation

- Capturing of Carbon Dioxide
- Preventing of pollution
- Additional Economic Benefit

Thanks for your attention!