Appendix C: Engineering Subcommittee Report

January 10, 2006

EVALUATION OF UNIT PROCESS COMBINATIONS

RECOMMENDATION DOCUMENT

ADVISORY PANEL ENGINEERING SUBCOMMITTEE

Engineering Subcommittee Members

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Kim Colson, NC DENR
Bundy Lane, Frontline Farmers
Joe Rudek, NC Environmental Defense
Paul Sherman, NC DENR
Shihwu Sung, Iowa State University
John Sweeten, Texas A&M University
Dave Townsend, Premium Standard Farms
Phil Westerman, NC State University

SCOPE

This document represents the recommendations of the Engineering Subcommittee to the Designee regarding the evaluation of unit process combinations for the NC Attorney General Agreements with Smithfield Foods, Premium Standard Farms, and Frontline Farmers. This recommendation sets forth procedures for evaluating each unit process and possible combination of unit processes for making a determination of an Environmentally Superior Technology (EST). These procedures are not meant to define a specific combination of unit processes that meets EST criteria. Rather this procedure is meant to provide a tool for evaluating the performance of each unit process as well as the possible combinations of unit processes. Please note that the subcommittee has not evaluated all unit processes using this procedure but has provided specific examples to demonstrate the outputs. Attached to this document is a flow chart file that can aid in evaluating the data output from the recommended procedure.

APPROACH

The subcommittee discussed the possibility of recommending a combination of unit processes for consideration as an EST. These discussions resulted in the conclusion that the subcommittee should not recommend a specific combination of unit processes but instead should develop a process by which the unit processes could be evaluated as a component part of a technology as a whole. The subcommittee decided that developing a tool by which the Designee, or any other interested party, could evaluate the possible combinations of unit processes was the proper approach.

In order to evaluate the combination of any of the unit processes, the data used for comparison need to be in the same units and format. The subcommittee concluded that using a mass balance approach for the applicable environmental criteria is most appropriate. In order to construct a mass balance, there is the need for volume flow rates and corresponding concentrations of the various compounds for each of the systems' unit processes. Using this information, the reduction or treatment efficiency of each unit process can be determined, as well as for the entire system. These data are found, in varying levels of detail, within the Technology Project Investigator Technical Reports. The Ambient Temperature Anaerobic Digester and Greenhouse System was selected as the example system to evaluate because it has a high level of flow rate and concentration data. Mr. Julian Barham also provided annual irrigation totals, which were not included in the report.

The phosphorus, copper, zinc, total solids, and volatile solids mass balances are solely determined by the average wastewater flow rates and the average concentrations, since there is no volatilization of these compounds. For nitrogen, however, it was necessary to take into account volatilization of ammonia and the potential for release of nitrogen gas from denitrification. The ammonia-nitrogen emission rate reported by the OPEN team as a percentage of the calculated nitrogen excretion was converted into lbs/d and used to estimate the overall volatilization of ammonia from the storage pond. However, it is recognized that the OPEN team emission rates are not meant to be used for annual emission factors. Also, there is possibility of nitrogen gas losses other than ammonia-nitrogen. Thus, there is an "unaccounted-for" amount of nitrogen that could include unknown nitrogen gas emissions. A pathogen balance has not been constructed at this time. The Pathogen Emissions Report does not provide data for each of the unit processes, but with additional data there is potential for the construction of a balance based on colony-forming units (cfu) instead of mass. There was no attempt to put together an "odor balance" due to the nature of the odor model data. The model provides anticipated odor intensities at certain distances from the odor sources. It is possible for the model to break out the individual unit processes, but these data are not readily available and would not fit into a mass balance approach.

RESULTS

Attached to this recommendation by reference is a utility tool developed by Shihwu Sung and Thanapong Duangmanee of Iowa State University and reviewed by the subcommittee. The utility is a PowerPoint file that lists each of the projects and the individual unit processes evaluated during the EST process. Each unit process is displayed in a "flow chart" format that allows for different combinations of unit processes to be constructed and evaluated. The utility incorporates the procedures contained in this recommendation for evaluating each unit process in combination. The example evaluation for each of the unit processes utilized in the Barham Farm project is contained in the utility. This demonstrates how the utility can be used to evaluate different combinations of unit processes based on the recommended procedures.

Development of Environmentally Superior Technologies (ESTs)

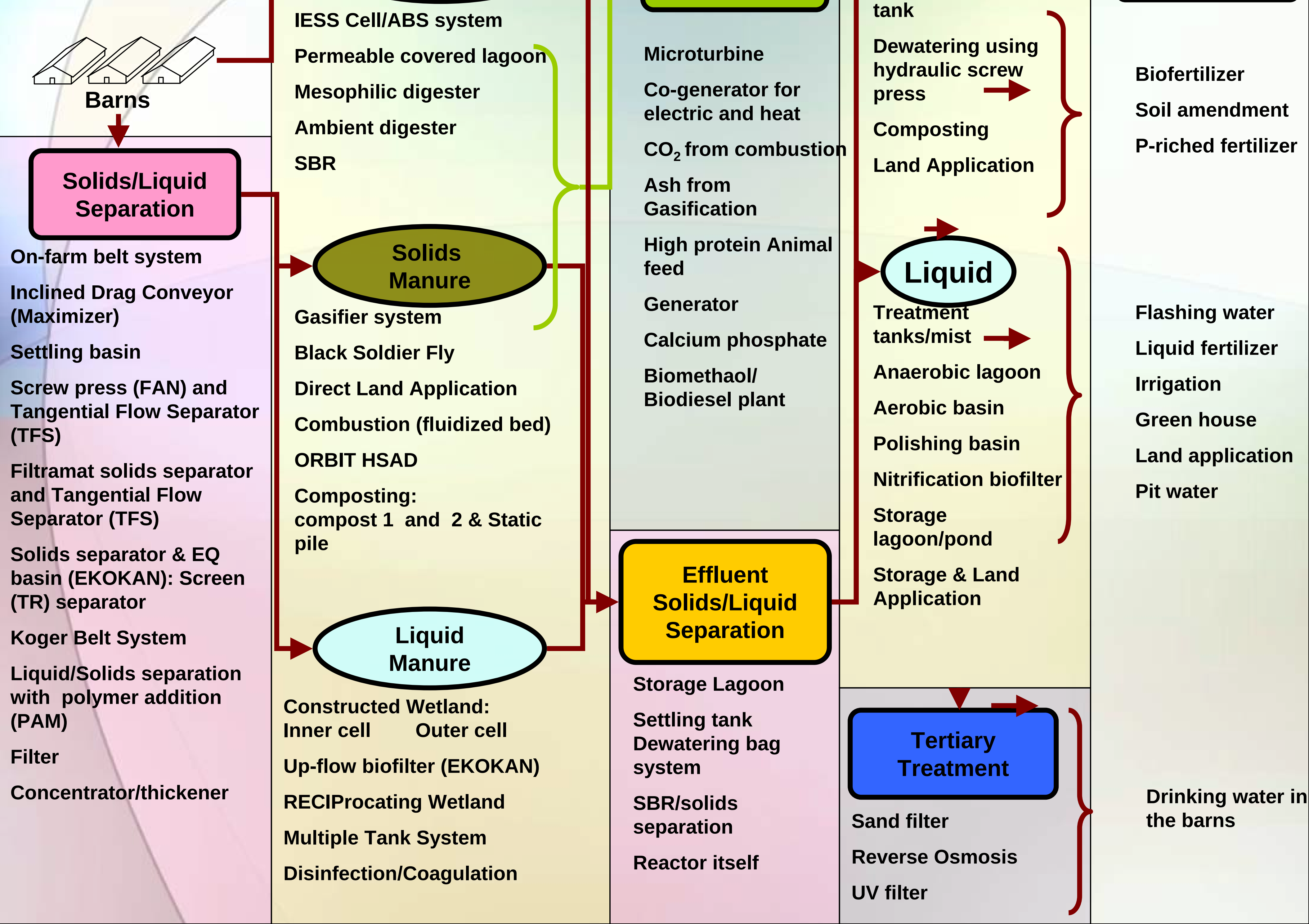
Shihwu Sung & Thanapong Duangmanee

January 10, 2006

Alternative Technologies

1. *Aerobic Blanket System and Aerobic Digester (Carrolls Farm)*
2. *Ambient Temperature Anaerobic Digester and Greenhouse for swine Waste Treatment and Bioresource Recovery (Barham Farm)*
3. *Koger Belt system (Grinnells lab, NCSU campus)*
4. *Black Soldier Fly (LWRFL site)*
5. *Constructed Wetlands (Howard Farm)*
6. *BEST (solids/liquids separation), Biomass Sustainable Technology (Corbett Farm #1) FAN ® +TFS*
7. *BEST (solids/liquids separation), Biomass Sustainable Technology (Corbett Farm #4) Filtramat™ + TFS*
8. *BEST incinerator*
9. *EKOKAN Up-flow Biofilter (Murphy-Brown Farm#93)*
10. *Gannet-Fleming Belt and Gasification (LWRFL site)*
11. *ORBIT High Solids Anaerobic Digester (Timber Ridge Farm, Clinton, NC)*
12. *Permeable Cover Anaerobic Digester with Aerobic Digester (Harrells Farm)*
13. *ReCip Solids Separation—Reciprocating Wetland (Corbett Farm #2)*
14. *RENEW: Mesophilic Digester and Aerobic Digester (Vestal Farm)*
15. *Sequencing Batch Reactor (SBR) and Equalization tank (Andrew Hunt Farm)*
16. *Super Soils Solids Separation/Nitrification-Denitrification/Soluble Phosphorus Removal/ Solids Processing System (liquid) (Goshen Ridge Farm)*
17. *Super Soils Composting site (solids) (Timber Ridge Farm, Clinton, NC)*
18. *BEST Biofuel*

Flowchart


Barns
Solids/Liquid Separation
On-farm belt system
Inclined Drag Conveyor (Maximizer)
Settling basin
Screw press (FAN) and Tangential Flow Separator (TFS)
Filtramat solids separator and Tangential Flow Separator (TFS)
Solids separator & EQ basin (EKOKAN): Screen (TR) separator
Koger Belt System
Liquid/Solids separation with polymer addition (PAM)
Filter
Concentrator/thickener
Combined manure
IESS Cell/ABS system
Permeable covered lagoon
Mesophilic digester
Ambient digester
SBR
Solids Manure
Gasifier system
Black Soldier Fly
Direct Land Application
Combustion (fluidized bed)
ORBIT HSAD
Composting: compost 1 and 2 & Static pile
Liquid Manure
Constructed Wetland: Inner cell Outer cell
Up-flow biofilter (EKOKAN)
RECIProcating Wetland
Multiple Tank System
Disinfection/Coagulation
Byproduct Recovery
Microturbine
Co-generator for electric and heat
CO_2 from combustion
Ash from Gasification
High protein Animal feed
Generator
Calcium phosphate
Biomethaol/ Biodiesel plant
Effluent Solids/Liquid Separation
Storage Lagoon
Settling tank Dewatering bag system
SBR/solids separation
Reactor itself
Solids
Sludge thickening tank
Dewatering using hydraulic screw press
Composting
Land Application
Liquid
Treatment tanks/mist
Anaerobic lagoon
Aerobic basin
Polishing basin
Nitrification biofilter
Storage lagoon/pond
Storage & Land Application
Tertiary Treatment
Sand filter
Reverse Osmosis
UV filter
Final use
Biofertilizer
Soil amendment
P-riched fertilizer
Flashing water
Liquid fertilizer
Irrigation
Green house
Land application
Pit water
Drinking water in the barns

Five criteria for being EST Candidate

1. **Eliminate the discharge of animal waste to surface waters and groundwater through direct discharge, seepage, or runoff**

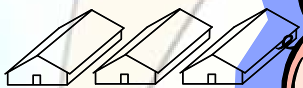
2. **Substantially eliminate atmospheric emissions of ammonia.**

3. **Substantially eliminate the emission of odor that is detectable beyond the boundaries of the parcel or tract of land on which the swine farm is located**

4. **Substantially eliminate the release of disease-transmitting vectors and airborne pathogens**

5. **Substantially eliminate nutrient and heavy metal contamination of soil and groundwater.**

Hypothetical Mass Balance Approach



Barns

TS 1000 lb/day Vol. 6000 gal/day 2% TS

- N 150 lb/day
- P 50 lb/day
- Cu 1.0 lb/day
- Zn 2.0 lb/day

Separation

Unit process 1

- N 0%
- P 0%
- Cu 0%
- Zn 0%

Solids

TS 500 lb/day Vol. 1000 gal/day 6% TS

- N 75 lb/day
- P 25 lb/day
- Cu 0.75 lb/day
- Zn 1.50 lb/day

Unit process 2

- N 80%
- P 80%
- Cu 90%
- Zn 90%

Emission

N 50 lb/day AN
50 NO_3 0.00

TS 300 lb/day Vol. 1000 gal/day 3.5% TS

- N 15 lb/day
- P 5 lb/day
- Cu 0.075 lb/day
- Zn 0.15 lb/day

Liquid

TS 500 lb/day Vol. 5000 gal/day 1% TS

- N 75 lb/day
- P 25 lb/day
- Cu 0.25 lb/day
- Zn 0.5 lb/day

Unit process 3

- N 90%
- P 90%
- Cu 90%
- Zn 90%

TS 50 lb/day Vol. 5000 gal/day 0.1% TS

- N 7.5 lb/day
- P 2.5 lb/day
- Cu 0.025 lb/day
- Zn 0.05 lb/day

Total

Total mass 1000 lb/day
Vol. 6000 gal/day

	% Removal	lb/day
N	85%	22.5
P	85%	7.5
Cu	90%	0.1
Zn	90%	0.2

Pass or Fail ?

Example of Mass Balance Determination

Ambient Digester

Location

- Julian Barham Farm, near Zebulon, NC

Combined Treatment

- **Covered Ambient Temperature Anaerobic Digester**
- In-ground installation without prior solids/liquid separation

Energy Recovery System

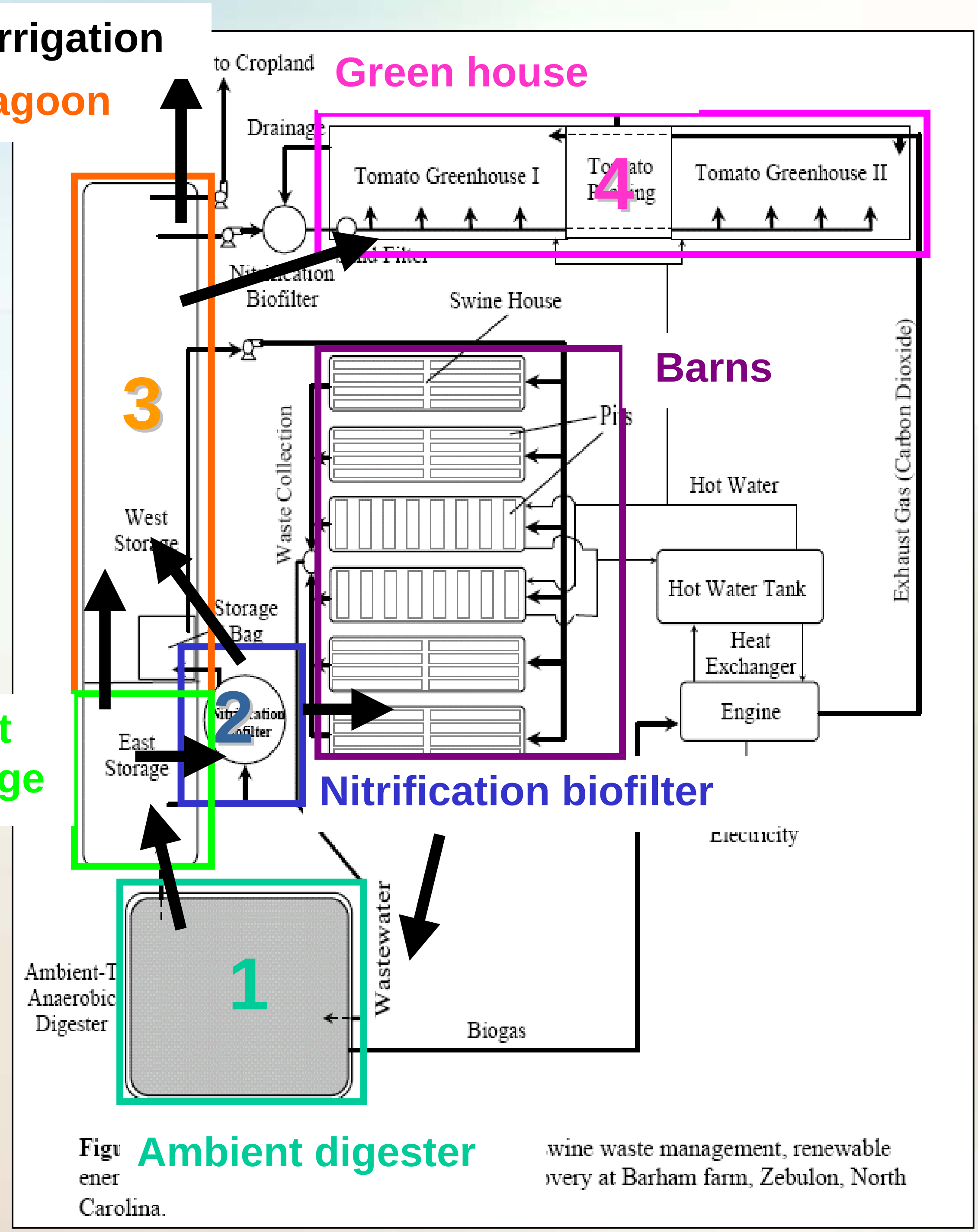
- Electricity production: **Methane-fed generator**
- Hot water for on-farm usage: **Heat exchanger**
- Exhaust gas (CO_2) for tomato greenhouses

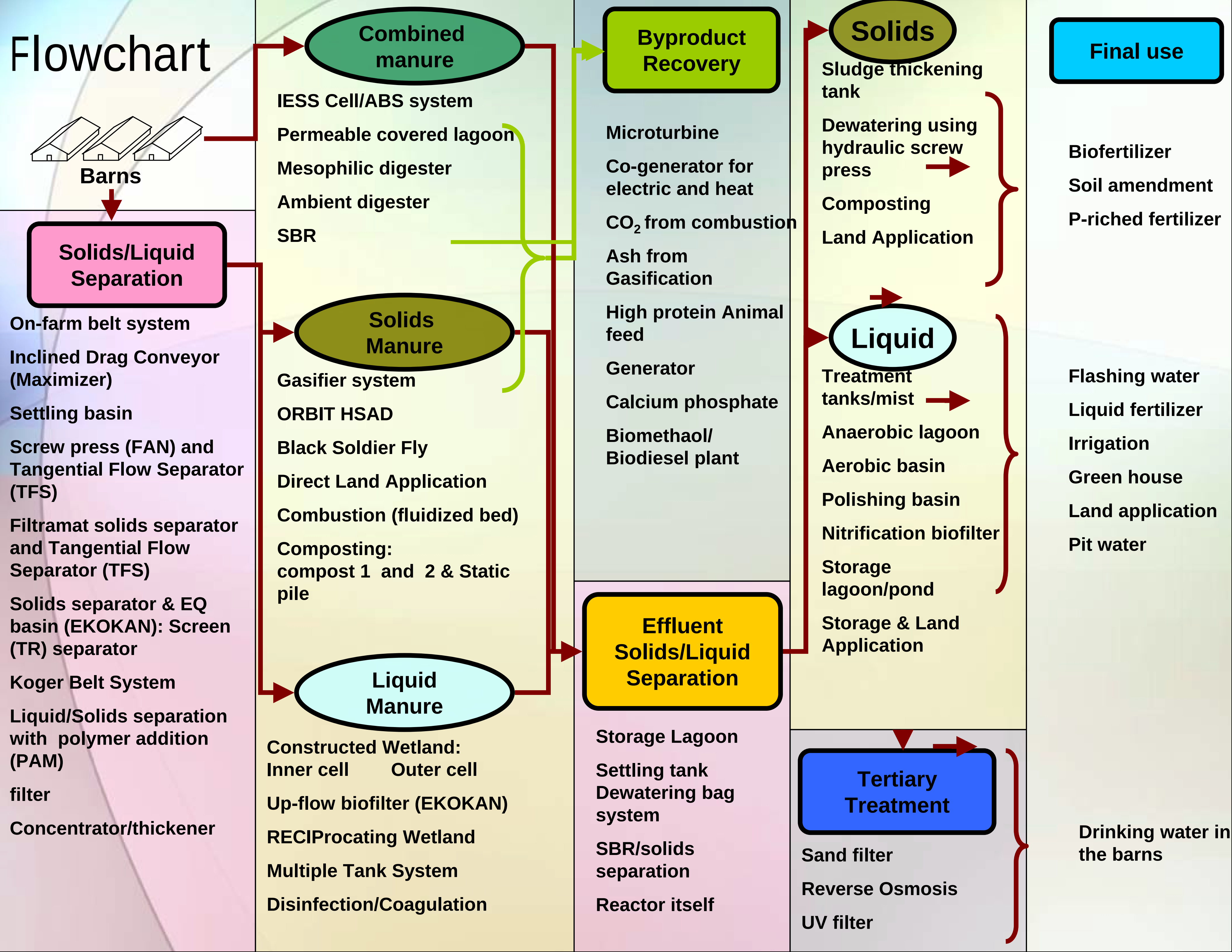
Solids/liquid separation (after main treatment)

- Storage lagoon

Treated liquid

- **Land application/irrigation**: **Nitrification Biofilter** system to treat effluent from storage lagoon for tomato **greenhouses** and Coastal Bermuda grass land
- **Flashing water** in swine houses: Effluent from storage lagoon




Flowchart
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On-farm belt system
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Up-flow biofilter (EKOKAN)
RECIProcating Wetland
Multiple Tank System
Disinfection/Coagulation
Byproduct Recovery
Microturbine
Co-generator for electric and heat
CO_2 from combustion
Ash from Gasification
High protein Animal feed
Generator
Calcium phosphate
Biomethaol/ Biodiesel plant
Effluent Solids/Liquid Separation
Storage Lagoon
Settling tank Dewatering bag system
SBR/solids separation
Reactor itself
Solids
Sludge thickening tank
Dewatering using hydraulic screw press
Composting
Land Application
Liquid
Treatment tanks/mist
Anaerobic lagoon
Aerobic basin
Polishing basin
Nitrification biofilter
Storage lagoon/pond
Storage & Land Application
Tertiary Treatment
Sand filter
Reverse Osmosis
UV filter
Final use
Biofertilizer
Soil amendment
P-riched fertilizer
Flashing water
Liquid fertilizer
Irrigation
Green house
Land application
Pit water
Drinking water in the barns

Biofilter in

TS 409 lb/day VS 100 lb/day Vol. 17860 gal/day 0.27% TS

N 58 lb/day AN 48 NO_3 0.15
P 6 lb/day
Cu 0.004 lb/day
Zn 0.045 b/day

Nitrification biofilter

N -3%
AN 21%
NO_3 -9320 %
P 11%
Cu 33%
Zn 7%

Biofilter out

TS 428 lb/day VS 116 lb/day Vol. 17860 gal/day 0.28% TS

N 60 lb/day AN 38 NO_3 14
P 5 lb/day
Cu 0.003 lb/day
Zn 0.042 b/day

Out to Storage lagoon (WS)

TS 37 lb/day VS 10 lb/day Vol. 1560 gal/day 0.28% TS

N 6 lb/day AN 3 NO_3 1.23
P 0.4 lb/day
Cu 0.000 lb/day
Zn 0.004 b/day

Combined in Storage lagoon (WS)

TS 1068 lb/day VS 360 lb/day Vol. 20420 gal/day ?%TS

N 422 lb/day AN 386 NO_3 1.23
P 25.4 lb/day
Cu 0.04 lb/day
Zn 0.54 b/day

Storage lagoon

N 77%
AN 77%
NO_3 36%
P 77%
Cu 88%
Zn 93%

Emission

N 51 lb/day AN 51 NO_3 0.00

Green house (100% removal)

TS 34 lb/day VS 9 lb/day Vol. 1716 gal/day 0.26% TS

N 4 lb/day AN 3 NO_3 0.06
P 0.53 lb/day
Cu 0.000 lb/day
Zn 0.004 b/day

ES

Out to Barns

TS 391 lb/day VS 106 lb/day Vol. 16300 gal/day 0.28% TS

N 56 lb/day AN 36 NO_3 12.9
P 4.6 lb/day
Cu 0.003 lb/day
Zn 0.038 b/day

From Storage lagoon (ES)

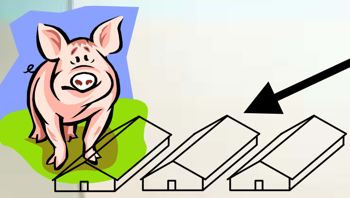
TS 1030 lb/day VS 350 lb/day Vol. 18860 gal/day 0.65% TS

N 417 lb/day AN 383 NO_3 0.00
P 25 lb/day
Cu 0.04 lb/day
Zn 0.54 b/day

Accm. in storage lagoon

TS 648 lb/day VS 263 lb/day Vol. 1091 gal/day 7% TS

N 325 lb/day AN 297 NO_3 0.39
P 19.5 lb/day
Cu 0.04 lb/day
Zn 0.50 b/day



Barns

TS 5961 lb/day VS 3753 lb/day Vol. 36720 gal/day 2% TS

N 663 lb/day AN 415 NO_3 0.02
P 158 lb/day
Cu 0.449 lb/day
Zn 4.368 lb/day

Ambient digester

N 28%
AN -3%
NO_3 100%
P 81%
Cu 90%
Zn 87%

Digester out

TS 1439 lb/day VS 450 lb/day Vol. 36720 gal/day 0.46% TS

N 476 lb/day AN 431 NO_3 0.00
P 31 lb/day
Cu 0.046 lb/day
Zn 0.581 b/day

Pass or Fail ?

Overall removal

TS 5313 lb/day VS 3490 lb/day Vol. 35629 gal/day

% Removal		lb/day
N	51%	339
P	88%	139
Cu	92%	0.41
Zn	89%	3.87

Field (100% removal)

TS 382 lb/day VS 89 lb/day Vol. 17613 gal/day 0.26% TS

N 43 lb/day AN 35 NO_3 0.63
P 5.41 lb/day
Cu 0.004 lb/day
Zn 0.004 b/day