Development of Environmentally Superior Technologies

Phase 2 Report

for Technology Determination per Agreements
Between the Attorney General of North Carolina and
Smithfield Foods, Premium Standard Farms and Frontline Farmers

July 25, 2005

TABLE OF CONTENTS

List of Tables (does not include Tables in the Appendices)

Page

List of Figures

July 25, 2005

TO ALL INTERESTED PARTIES:

This report was compiled pursuant to Sections III.B.5 and III.B.6 of Agreements, dated July 25, 2000, and September 30, 2000, between the Attorney General of North Carolina and Smithfield Foods, Inc. and Premium Standard Farms, Inc., respectively.

Copies of this report are transmitted on this date to the North Carolina Attorney General, Smithfield Foods, Premium Standard Farms, and Frontline Farmers. A copy is also transmitted to the North Carolina Environmental Review Commission. A full copy of this report is on file in the North Carolina State University (NCSU) Animal & Poultry Waste Management Center (APWMC) administrative office located in room 134, Scott Hall on the NCSU north campus.

A complete electronic copy of this report will be posted on the NCSU College of Agriculture and Life Sciences Waste Management Programs web site http://www.cals.ncsu.edu/waste_mgt/ within 15 business days of today's date.

Respectfully submitted,

C.M. (Mike) Williams, Ph.D.
Director APWMC, Agreements Designee

PREFACE

This report comprises the second in a series of technology determinations for candidate Environmentally Superior Technologies made by the Designee as described and mandated by agreements between the Attorney General of North Carolina, Smithfield Foods, Premium Standard Farms, and Frontline Farmers. A Phase 1 technology determination report was previously published.[1]

The determinations reported are based primarily on environmental performance data. Research teams comprised of faculty and staff from North Carolina State University, the University of North Carolina – Chapel Hill, Duke University, University of Georgia, and the United States Department of Agriculture conducted the studies reported herein. A full-service environmental and agricultural engineering firm, Cavanaugh & Associates, P.A., served as Project Technical Manager with responsibility of permit and construction management for the candidate technologies located on commercial scale farms.

An advisory panel appointed by the Designee has reviewed the determinations described in this report; their inputs contributed significantly to decisions made by the Designee regarding the technology determinations. The panel is made up of individuals with expertise in animal waste management as well as individuals with an interest in the development of Environmentally Superior Technologies. The panel's representation is comprised of academic research scientists, engineers, public health and public law experts, and economists. In addition, individuals representing community interests, environmental interests, North Carolina Department of Environment and Natural Resources, United States Environmental Protection Agency, agribusiness, farm owners and swine contract growers (Frontline Farmers), and the companies (Smithfield Foods and Premium Standard Farms) are on the appointed panel.

The following abbreviations and acronyms are used frequently throughout this report:

- Agreements – Agreements between the Attorney General of North Carolina and Smithfield Foods, Premium Standard Farms, and Frontline Farmers
- EST – Environmentally Superior Technologies
- Designee - C. M. (Mike) Williams, as appointed per the Agreements
- NCDENR – North Carolina Department of Environment & Natural Resources
- PSF – Premium Standard Farms
- Smithfield – Smithfield Foods and Subsidiaries

[1] See Development of Environmentally Superior Technologies: Phase 1 Technology Determination Report, published by NCSU College of Agriculture and Life Sciences, 941 pages, on file with NCSU Animal and Poultry Waste Management Center (July 26, 2004). Also available at www.cals.ncsu.edu/waste_mgt/

Summary

Research efforts to identify and implement "Environmentally Superior Technologies" (EST) were initiated in 2000 by the Attorney General of North Carolina through resources provided by Agreements with Smithfield Foods and with Premium Standard Farms. A third related agreement was established between the Attorney General of North Carolina and Frontline Farmers in 2002. The report herein comprises the second (Phase 2) in a series of technology determinations as described in the Agreements: "a written determination that contains a finding relative to a technology or combination of technologies candidacy as an Environmentally Superior Technology or Technologies."

The determinations reported are based on technical performance standards alone. Technical performance standards defined in the Agreements and previously established by the North Carolina General Assembly mandate that successful EST address: the discharge of animal waste to surface waters and groundwater; emission of ammonia; emission of odor; release of disease-transmitting vectors and airborne pathogens; and nutrient and heavy metal contamination of soil and groundwater.

As further described in the Agreements, unconditional EST must also be operationally and economically feasible as well as permittable by the appropriate regulatory agency. Data regarding operational requirements, costs, and the impact that the adoption of EST may have on the competitiveness of the North Carolina pork industry are included herein; however, determinations regarding operational and economic feasibility as well as the permittability of the EST are not finalized at this time but are anticipated to be made in a Phase 3 report to be released at a later date in 2005.

An advisory panel provides input and peer review for this overall initiative. The panel's representation is comprised of academic research scientists, engineers, public health and public law experts, and economists. Individuals representing community interests, environmental interests, North Carolina Department of Environment and Natural Resources, U.S. Environmental Protection Agency, agribusiness, farm owners and swine contract growers (Frontline Farmers), and the companies (Smithfield Foods and Premium Standard Farms) are also on the appointed panel.

Candidate EST technologies studied to date include a variety of waste treatment systems including a covered in-ground anaerobic digester with biological trickling filters and greenhouse vegetable production, mesophilic and thermophilic anaerobic digesters, a sequencing batch reactor, an upflow biological aerated filter system, a gasification system, belt manure removal systems, and wetland systems. In addition to these systems, technologies not funded directly by resources for this initiative but under development by Smithfield Foods in Utah (bio-diesel fuel from manure project), Premium Standard Farms in Missouri (manure to fertilizer project), Sustainable North Carolina and Frontline Farmers (closed loop swine waste management system located in eastern North Carolina) are being followed as potential EST. A Phase 1 Technology Determination Report, previously issued in July 2004 reported that of eight initial candidate EST studied, two were capable of meeting the Agreements' environmental performance standards and were declared to be contingent

EST. Those technologies were: 1) the solids separation/nitrification–denitrification/soluble phosphorus removal system ("Super Soils" technology) and 2) the high solids anaerobic digester system ("ORBIT" technology).

The report herein focuses on an additional eight candidate EST (Phase 2). The information and data provided indicates that three of the technologies studied under the Phase 2 determinations are capable of meeting the Agreements' technical performance standards that define an Environmentally Superior Technology. Those technologies are: 1) "Super Soil Systems" centralized composting system, 2) gasification for elimination of swine waste solids with recovery of value-added products system, and 3) "BEST" – fluidized bed combustion of solids system. The data also indicate that for some of the remaining candidate EST, technical modifications and/or combination of some of the technology unit processes, additional technologies considered in both the Phase 1 and Phase 2 determinations may meet the technical performance criteria.

Consistent with the goals and objectives outlined in the Agreements, the next steps and recommendations are provided:

1) Establish specific criteria to be used in making economic feasibility determinations, as described in the Agreements.

2) Complete the procurement of environmental performance data for all remaining candidate EST under evaluation in North Carolina not included in the Phase 1 and 2 determinations.

3) Initiate discussions, procedures, etc. with all applicable NCDENR divisions and agencies (Water Quality, Air Quality, Solid Waste, etc.) to determine permittability status of technologies and/or combination of technologies that are potential EST.

4) Continue efforts to procure technical and economic data relative to contingencies for technologies named in the Phase 1 and 2 determinations as EST.

5) Examine available objective technical and economic data for the Smithfield Foods "BEST Biofuels" Utah project and the Premium Standard Farms "Crystal Peak Farms" Missouri project and make technology determinations for North Carolina EST applications of these technologies.

6) Examine all available objective engineering, performance, and economic data for unit processes that comprise the candidate EST North Carolina projects and make determinations, if any are appropriate, relative to "combinations of technologies" as described in the Agreements.

7) Identify potential incentives, public policy, and markets related to the sale of byproducts (including energy) generated by candidate EST that are shown to meet the technical performance standards. Identify legal and institutional obstacles that must be addressed to maximize the revenue potential of these byproducts.

8) Initiate the development of NCDENR permit conditions as well as proposed National Pollutant Discharge Elimination System (NPDES) permit and/or air pollution emissions conditions (if required) for candidate EST that are shown to meet the technical performance standards.

9) Establish a long-term plan for implementation of EST that describes categories of farms for adoption and over what time profile. The plan should include a mechanism to monitor both environmental and economic performance, a phased schedule for implementation, and a discussion of how the timing of implementation affects the economic feasibility criteria as described in the Agreements.

1.0 Introduction and Overview of Project Status to Date

Agreements: Efforts to identify and implement "Environmentally Superior Technologies" (EST) onto swine farms in North Carolina were initiated in July 2000 by the Attorney General of North Carolina by an agreement with Smithfield Foods and its subsidiaries, and a similar agreement (in September 2000) with Premium Standard Farms. A third and related agreement was established with Frontline Farmers in 2002.[2]

Performance standards and economic feasibility: Performance standards defined in the Agreements, and previously established by the North Carolina General Assembly,[3] mandate that successful EST address environmental variables including the discharge of animal waste to surface waters and groundwater; emission of ammonia; emission of odor; release of disease-transmitting vectors and airborne pathogens; and nutrient and heavy metal contamination of soil and groundwater. Comprehensive determinations of economic feasibility are also mandated by the Agreements. Targeted economic variables include projected 10-year annualized cost for each technology; projected revenues from byproduct utilization; available cost-share monies; and the impact that the adoption of the EST may have on the competitiveness of the North Carolina pork industry as compared to the pork industry in other states.

Advisory panel: The Agreements mandate that an advisory panel provides input and peer review of this overall initiative. The panel is made up of individuals with expertise in animal waste management as well as individuals with an interest in the development of Environmentally Superior Technologies. The panel's representation is comprised of academic research scientists, engineers, public health and public law experts, and economists. In addition, individuals representing community interests, environmental interests, North Carolina Department of Environment and Natural Resources, U.S. Environmental Protection Agency, agribusiness, farm owners and swine contract growers (Frontline Farmers), and the companies (Smithfield Foods and Premium Standard Farms) are on the appointed panel (see Appendix C for names and specific affiliations of panel members).

Candidate technologies: Beginning in 2000 candidate EST technologies were competitively selected. They included solids separation systems, a covered in-ground anaerobic digester with biological trickling filters and greenhouse vegetable production, mesophilic and thermophilic anaerobic digesters, a sequencing batch reactor, an upflow biological aerated filter system, a gasification system, belt manure removal systems, and wetland systems. In addition to these systems, technologies not funded directly by this initiative but under development by Smithfield Foods in Utah (biodiesel fuel from manure project), Premium Standard Farms in Missouri (manure to fertilizer project and several other technologies per a consent decree between Premium Standard Farms and the state of Missouri and USEPA), Sustainable North Carolina and Frontline Farmers (closed loop swine waste management

---

[2] See Agreements between Attorney General of North Carolina and, SF, PSF, and Frontline Farmers (North Carolina Department of Justice, on file with Ryke Longest, 2000 & 2002). Also available at www.cals.ncsu.edu/waste_mgt/

[3] See General Assembly of North Carolina, Session 1997, Session Law 1998-188, House Bill 1480

system located in eastern North Carolina) are being followed as potential EST. Table 1 shows the technology names and July 2005 evaluation status. Detail progress reports describing the EST initiative between the dates of July 25, 2000 and July 25, 2003 have been published.[4] In July 2004 a Technology Determination Report was issued.[5] The Technology Determination Report comprised a written determination relative to a technology or combination of technologies candidacy as an EST. In brief, the July 2004 report focused on eight of the candidate EST that were targeted for an initial (Phase 1) technology determination. Two of the technologies considered in the Phase 1 determinations were shown to be capable of meeting the Agreements environmental performance standards and were declared to be contingent EST. Those technologies were: 1) the solids separation/nitrification–denitrification/soluble phosphorus removal system ("Super Soils" technology) and 2) the high solids anaerobic digester system ("ORBIT" technology). The data also indicated that, with technical modifications and/or combination of some of the technology unit processes, additional technologies considered in the Phase 1 determinations may meet the technical performance criteria.

Subsequent to July 2004 the "Super Soils" technology has continued to operate at the Goshen Farm facility in Duplin County. The management and technical team have also worked to design a lower costs second-generation technology. The "ORBIT" management and technical team have been awarded a contract by the State of North Carolina Green Energy Program that provides a 2.5-cent premium on power sales to the grid. The company has also worked with Progress Energy towards achieving grid connection and installation of a generator that can convert the plant's full output when operating at capacity (estimated approximately 10 tons per day). The company has also worked collaboratively with the NCSU Animal and Poultry Waste Management Center (APWMC) and the NCSU Department of Crop Science to evaluate ORBIT digestate for use on state roadside right-of-way for turfgrass establishment. That work is funded by the NC Department of Transportation.

Economic feasibility: For the mandated economic analysis, projected costs of retrofitting existing lagoon spray-field systems have been estimated for the eight Phase 1 candidate technologies and are provided in the report herein (see Appendix B.1). The impacts of adopting EST technologies on the competitiveness of the NC pork industry are also reported (see Appendix B.2). These data, and the methods utilized to derive them, are currently under review by an Economics Subcommittee comprised of 10 appointed members of the above referenced advisory panel. Interpretation of the economic feasibility criteria will be the subject of a forthcoming (later in 2005) recommendation document provided by the Economic Subcommittee.

[4] See Development of Environmentally Superior Technologies: One, Two, and Three Year Progress Reports, published by NCSU College of Agriculture and Life Sciences, on file with NCSU Animal and Poultry Waste Management Center (July 25, 2001; 2002; 2003). Also available at www.cals.ncsu.edu/waste_mgt/

[5] See Development of Environmentally Superior Technologies: Phase 1 Technology Determination Report, published by NCSU College of Agriculture and Life Sciences, 941 pages, on file with NCSU Animal and Poultry Waste Management Center (July 26, 2004). Also available at www.cals.ncsu.edu/waste_mgt/

Phase 2 technology determinations: The report herein focuses on an additional eight of the candidate EST (Phase 2). Descriptions of the technologies, methodology for determining the performance data, results, and basis of decisions for determining their current EST status and next step recommendations are provided.

2.0 Candidate Environmentally Superior Technology Descriptions

Concise descriptions, schematics, and figures for each of the Phase 2 candidate EST follow. Additional information related to the farm or experimental sites where the technologies were evaluated is provided in Table 2.

"Super Soils" Compost System – Timber Ridge Farms, Clinton, NC – Centralized site

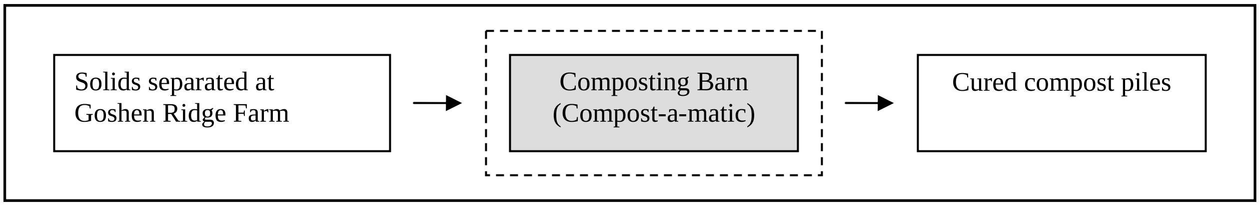


Figure 1. Process Flow Diagram of Super Soils Composting.

Figures 2 a, b, c, d & e. "**Super Soils" Composting facility, composting process, Compost-A-Matic™, and curing piles.**

The Super Soils composting facility is a centralized site receiving separated solids from a 4360 head - finisher farm located in adjoining Duplin County (2a). This technology involves mixing separated swine solids with certain bulking materials, such as cotton gin offal and wood chips, that promote the composting process (2b). A Compost-A-Matic™ is used to mix the composting material daily during the 30 day cycle (2c & 2d). Once the material has completed the composting process, the product is placed into curing piles which allow the product to stabilize (2e) and to be used in further processed blends which can be used for fertilizers or other soil amendment products.

2a.

2b.

2d.

2c.

2e.

Gasification of Solids – North Carolina State University (NCSU) Animal and Poultry Waste Management (APWMC) Waste Process Facility (WPF), NCSU Lake Wheeler Field Laboratories, Raleigh, NC – Research Facility

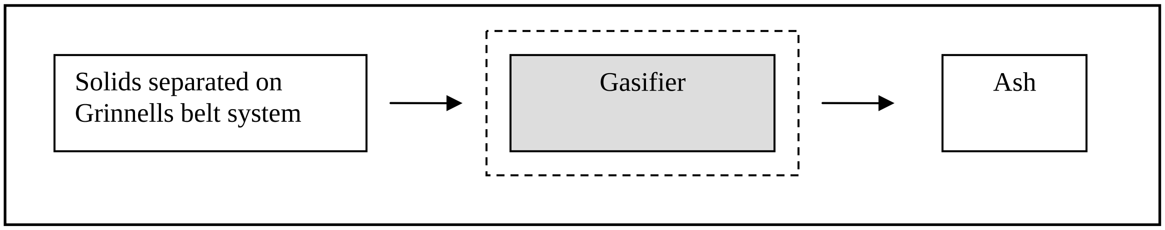


Figure 3. Process Flow Diagram of Gasifier.

4a.

4b.

Figures 4 a & b. Gasifier located at NCSU APWMC WPF.

The gasifier located at the NCSU APWMC WPF utilized solids collected from the Grinnells belt system (Phase 1 report) and is a centralized batch process technology (4a). Solids with a desired moisture content of 50% were loaded daily into the gasifier (4b) and heated to a temperature of 800^{o}C. By-products produced as a result of the gasification process include: product gases such as CO, CH_4 and CO_2 which could be used to sustain the reactions occurring in the gasifier; and ash which has the potential of being used as both a feed supplement and as a fertilizer amendment. Waste heat produced from the gasification process could also be utilized on site.

Insect Biomass from Solids – North Carolina State University Lake Wheeler Field Laboratories, Raleigh, NC – Research Facility

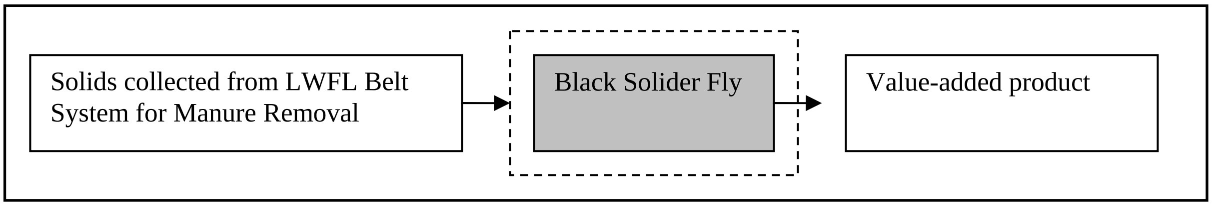
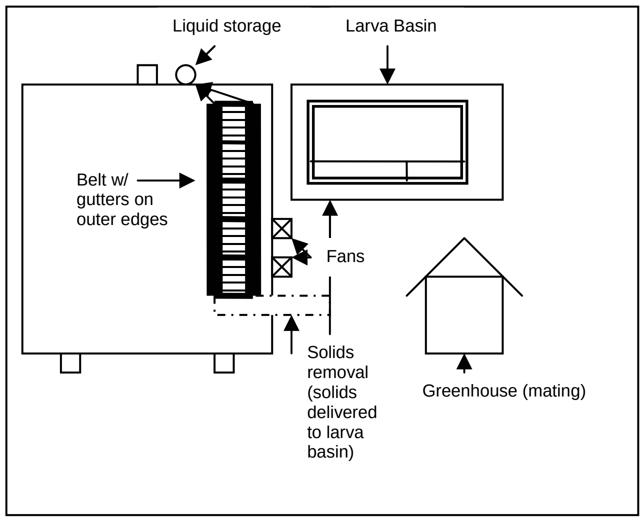


Figure 5. Process flow diagram of Insect (Black Solider Fly) Biomass from solids technology.



6 a.

6 b.

6 c.

Figure 6 a, b, & c. Black Solider Fly (BSF) schematic, BSF fly larvae, and pre-pupa.

The BSF technology located at the NCSU LWFL received solids from the Belt System for Manure Removal (6a). Black solider fly larva (6b) were harvested from the BSF mating house and placed in basins designed specifically for the daily feeding of the larva with the collected swine manure solids. Once fed the larva (pre-pupa stage (6c)) migrated to troughs located at each end of the basin and were collected in storage containers. These pre-pupa could potentially be used as a feed supplement to animal diets.

Solids Separation – Constructed Wetlands System – Brandon Howard Farm, Richlands, NC – 3520 head finisher

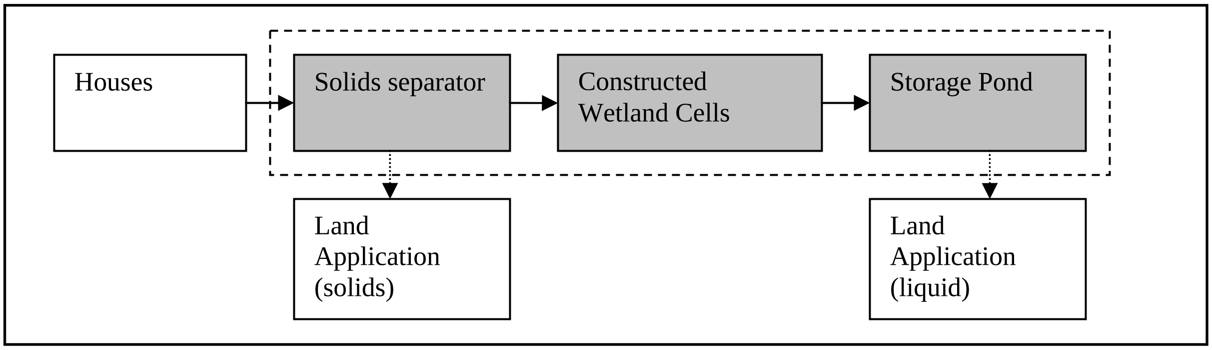


Figure 7. Process Flow Diagram of the Solid Separation / Constructed Wetlands technology.

8a.

Figures 8 a, b, & c. Aerial view of constructed wetlands technology, solids separator, and wetland cells.

The constructed wetlands (CW) technology consists of both mechanical and gravity solid separation (Andritz-Ruthner, Inc., Hydraieve static screen; dissolved air floatation (DAF); Brome Agri, Maximizer Unit) and nitrification-denitrification which is facilitated through the root system of the wetland vegetation as the waste stream flows through the CW cells (8a). Approximately 40,000 gallons of waste are processed daily. Waste from the houses is pumped to a solid separator (8b) and the liquid portion flows into the combined 8 acres of constructed wetland cells with an estimated 12 day retention time (8c).

Separated solids can be either land applied or utilized as a value – added by-product if further processed. The CW processed liquid is stored and can be land applied or used to recharge the barns as flush water.

8b.

8c.

Alternative Natural Technologies (ANT) Sequencing Batch Reactor System – AHA Hunt Farm – Pine Tops, NC – 12,999 head finisher

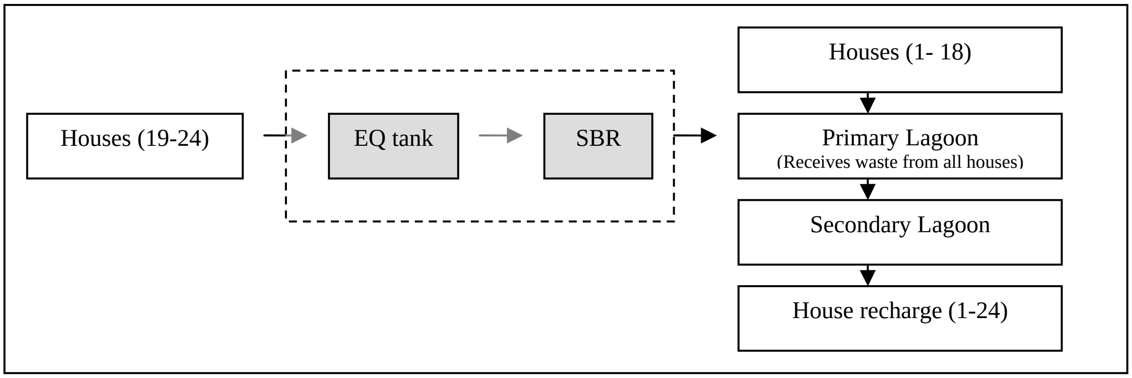
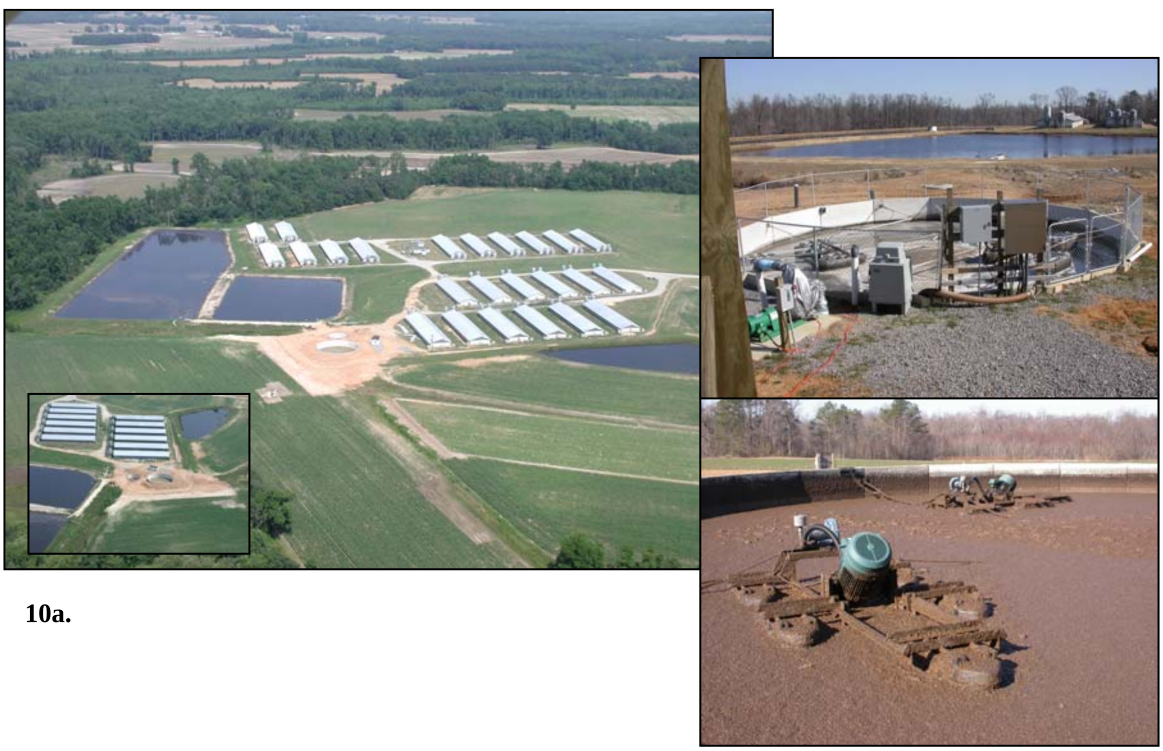


Figure 9. Process Flow Diagram of the "ANT" Sequencing Batch Reactor Technology.



10a.

10b.

10c.

Figures 10 a, b, and c. "ANT" Sequencing Batch Reactor (SBR) Technology.

The "ANT" sequencing batch reactor system (SBR) is a biological process consisting of an EQ tank with floating mixers and a reactor tank with 4 aerators and mixers (10a). The EQ tank (10b) received waste from 6 of the 24 houses on the farm site which was later pumped to the SBR (10c) for a series of cycles that included: Fill (receiving fresh wastewater); React (alternating aeration and non-aerated conditions to promote nitrification and denitrification); Waste (removal of excess biomass); Settle (settling of undigested solids & biomass); and Decant (removal of treated wastewater). All treated wastewater was pumped to the existing primary lagoon for storage.

**Innovative Sustainable Systems Utilizing Economical Solutions (ISSUES) –
Aerobic Blanket - Carroll's 2529 Farm – Warsaw, NC – 6480 head finisher; 1067 sow**

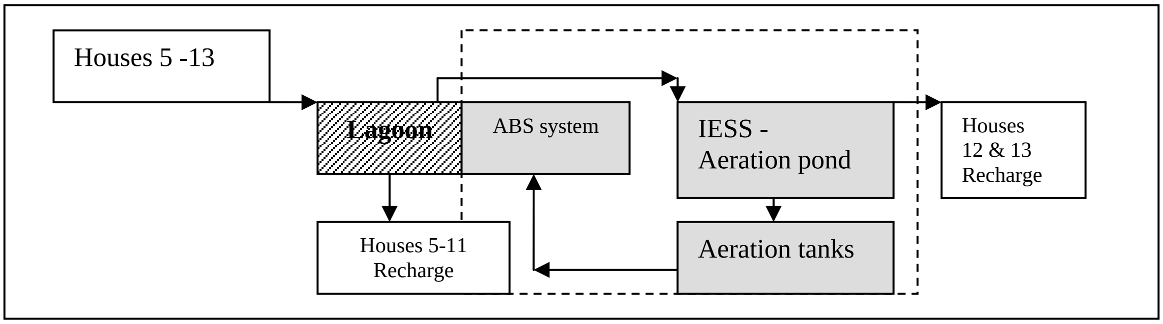


Figure 11. Process Flow Diagram of "ISSUES" Aerobic Blanket System (ABS) technology.

12a.

12b.

12c.

Figures 12 a, b, & c. "ISSUES" Aerobic Blanket System (ABS) technology.

The "ISSUES" Aerobic Blanket System (ABS) technology was designed to provide a light mist or "blanket" over the primary lagoon in efforts to reduce emissions (NH_3 and odor) from the existing primary lagoon. The ABS components included an aeration cell to promote nitrification and a misting or spray system which distributed the nitrified waste water over the primary lagoon (12a). Approximately 50,000 gallons of waste water was pumped daily from the primary lagoon into the aeration cell for nitrification and approximately 3,000 gallons of the nitrified waste water was utilized through the ABS (12b & 12c). The remaining treated waste water was used as flush water in 2 of the 9 finishing houses located on the farm facility.

Innovative Sustainable Systems Utilizing Economical Solutions (ISSUES) – Permeable Covered Lagoon – Harrell's Farm – Harrells, NC – 6120 head finisher

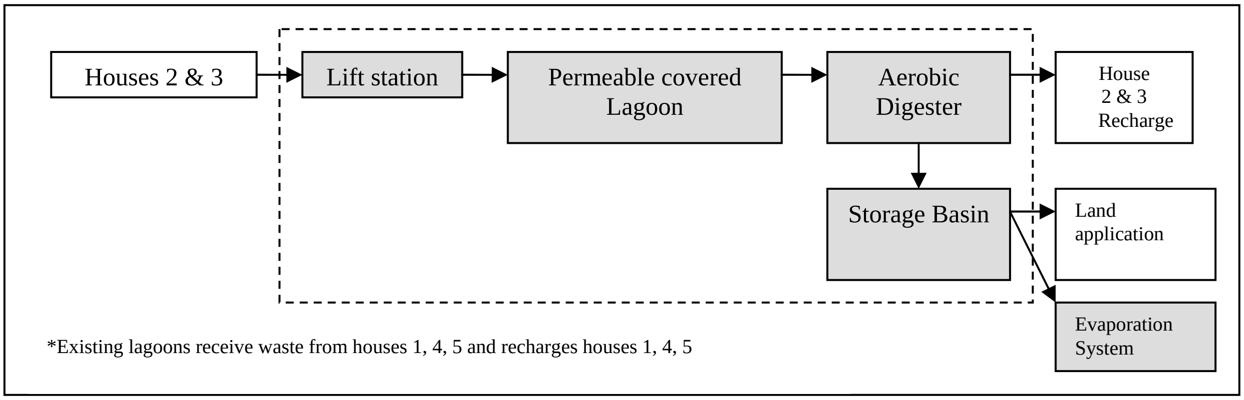
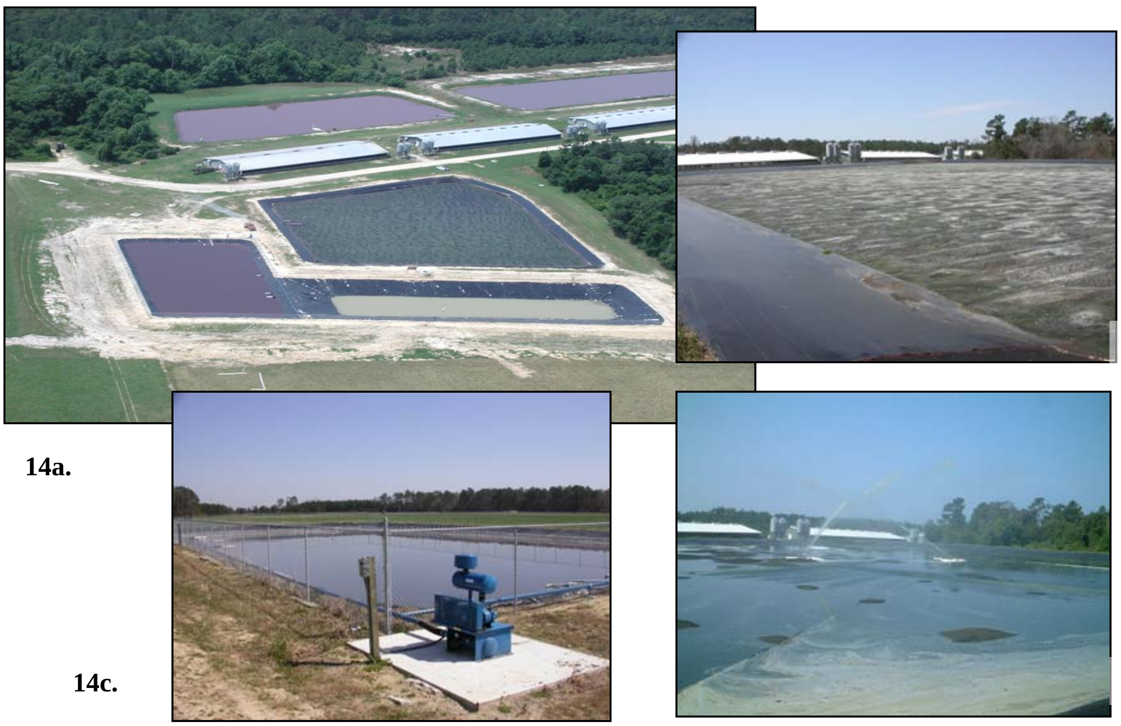


Figure 13. Process Flow Diagram of "ISSUES" Permeable Covered Lagoon technology.



14a. 14b. 14c. 14d.

Figures 14 a, b, c, & d. "ISSUES" Permeable Covered System (PCS), components, and evaporation system.

The Permeable Covered System (PCS) (14a) consisted of: (1) an in-ground lagoon with a floating woven polypropylene cover (BioCap^{TM}) (14b) designed to act both as a barrier and as a biofilter and/or matrix for aerobic bacteria in efforts to reduce lagoon emissions (odor and NH_3) and biofiltration respectively and (2) an aerobic digester (AED). Approximately 32,000 gallons of waste water was pumped daily from the PC lagoon to the aerobic digester (14c) with the goal of promoting nitrification. 28,000 gallons of aerated waste water was utilized in two of the 5 finishing houses with the additional 4,000 gallons being stored in the storage basin. The stored waste water was either land applied or irrigated through the evaporation system (14d) that was later installed over the PC lagoon.

Innovative Sustainable Systems Utilizing Economical Solutions (ISSUES) – Mesophilic digester, Microturbine, and Water Reuse System – Vestal Farm 1 & 2 – Kenansville, NC – 9792 head finisher

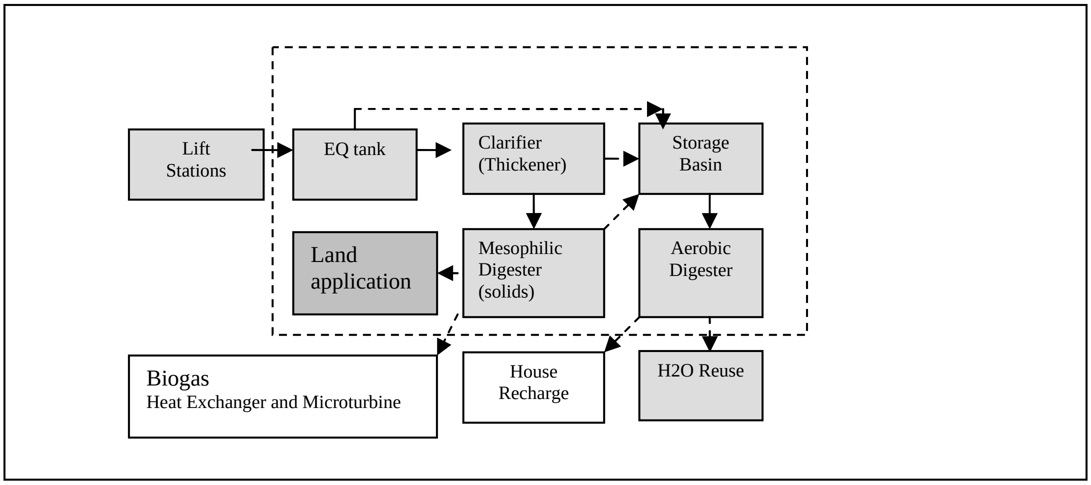


Figure 15. Process Flow Diagram of "ISSUES" mesophilic digester, microturbine, and water reuse technologies.

16a. 16b.

16c. 16d.

Figures 16 a, b, c, & d. "ISSUES" RENEW technology components.

The "ISSUES" technology components located on the Vestal farm (14a) included an equalization (EQ) tank; solids concentrator or thickener (16b); mesophilic digester (MD) (16b); microturbine electric generator (16b); aerobic digester (AED) (16c); and a storage basin (16d). A water reuse component was also installed to provide further treatment to the aerobic digester effluent to serve as animal drinking water. Approximately 77,000 gallons of waste water was pumped daily into the EQ tanks, through the thickener and into either the MD or storage basin. Approximately 55,000 gallons of water stored in the storage basin was pumped to the AED for nitrification and then transferred to the finishing houses and utilized for flushing. An additional 10,000 gallons of aerated water could be further processed into animal drinking water. Waste water stored in the storage basin was land applied. Biogas produced as a result of mesophilic digestion was flared, utilized as a heat source or could be used to produce electricity by the microturbine.

3.0 Technology Determinations Process and Performance Standards

Process: The 15-step systematic process for the competitive selection, site location determination, permitting, construction and evaluations (technical, operational, and economic) of candidate EST per the terms and conditions of the Agreements were previously described.[6] The Phase 2 technologies for which this process was applied and reported herein are shown in Table 2. Each candidate technology is assessed for technical, operational, and economic feasibility. The feasibility parameters are discussed below.

Technical performance standards: The Agreements specify that a successful EST must meet the following performance standards:

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

These performance standards were established by the North Carolina General Assembly[7] and used as the basis for technical environmental performance standards in the Agreements. An Engineering Subcommittee comprised of appointed members of the advisory panel referenced in Section 1.0 of this report worked in 2003 and 2004 to compile a recommendation document that served as the basis of further defining and quantifying the five performance criteria outlined above.[8] Interpretation and conclusions regarding the Engineering Subcommittee recommendations are discussed in Section 3.0 of the referenced July 26, 2004, report. In brief they are as follows:

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

All wastewater-holding structures must have a mechanism for containing the flow rate of the largest pump in the system for the maximum amount of time that an operator will not be on-site. Technologies should contain less than the volume equivalent of one month of flow in concentrated waste prior to complete treatment. Any earthen structures should be designed

---

[6] See Section 3.0, page 20 "Development of Environmentally Superior Technologies: Phase 1 Technology Determination Report", published by NCSU College of Agriculture and Life Sciences, 941 pages, on file with NCSU Animal and Poultry Waste Management Center (July 26, 2004). Also available at www.cals.ncsu.edu/waste_mgt/

[7] See General Assembly of North Carolina, Session 1997, Session Law 1998-188, House Bill 1480

[8] See Appendix D, "Development of Environmentally Superior Technologies: Phase 1 Technology Determination Report", published by NCSU College of Agriculture and Life Sciences, 941 pages, on file with NCSU Animal and Poultry Waste Management Center (July 26, 2004). Also available at www.cals.ncsu.edu/waste_mgt/

and constructed to current Natural Resource Conservation Service (NRCS) standards and have a maximum hydraulic conductivity of 1.25 x 10^{-6} cm/sec. Structures other than earthen should be designed and constructed using proper engineering practices to eliminate seepage. Solids storage structures should meet current NRCS design standards. Land application of treated wastewater or solids should be based on realistic crop yield expectations, land application setbacks, buffers, and hydraulic loading rates that at a minimum maintain compliance with current NRCS, local, state, and federal standards and/or requirements.

Substantially eliminate atmospheric emissions of ammonia.

Approximately 80% reduction, as compared to a typical swine farm, of ammonia emissions from waste storage/treatment components and land application areas. System must also target reduction of ammonia from the barns.

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.

Odor intensity levels, measured using an index scale from 0-8, should not exceed the established metric of 2 (or equivalent) at a property line on which the swine farm is located (see Table 4 and Appendix A.7 of report herein for specific description if index scale).

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

Approximately 4 log reductions of pathogens (microorganisms documented to be of human health concern) in the treated liquid and solid waste stream, as compared to concentrations of the pathogens in raw manure. All components of the waste management system (technology treatment, fate of farm generated solids, method and location of land application of liquid and/or solids, etc.) are considered factors for pathogen reductions.

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

System should reduce total nitrogen mass by 75% and total phosphorus, copper, and zinc mass by 50% from influent levels for the whole farm. Current NC NRCS Nutrient Management Standard 590 must be met, including added considerations of current realistic yield expectations, individual plant available nitrogen calculations, NC Phosphorus Loss Assessment Tool (PLAT) evaluation to determine phosphorus loss and application rates, and metal soil index threshold warnings. Where on-farm resources (i.e. available land) are not sufficient to meet these described standards, reductions may be met by transporting the nutrients off the farm, and/or animal diet modification.

Technical data analysis: The data considered for the technical analysis involved the candidate waste treatment system's performance in terms of: 1) partitioning, conversion, or removal of the waste stream solids and organic matter, nutrients (primarily nitrogen and phosphorus), and metals (copper and zinc); and 2) reducing emissions of odor, pathogens, and emissions of ammonia. The detail methods and results for the Phase 2 projects, relevant to the technical environmental performance data, are provided in the project investigator final reports (Appendix A). Data from these reports relative to the technical feasibility determinations are summarized in Tables 3-6.

Operational Feasibility: Specific factors for determining operational feasibility are not described in the Agreements. Inputs from the project investigators involved with the data collection and analysis of the candidate waste treatment systems as well as input from the technology suppliers were considered. Parameters such as: operator hours required per week; system inspection needs; maintenance of "moving parts;" required skills; trouble shooting pumps, equipment, and electrical controls, etc. were considered. In addition, NCDENR was consulted regarding operator certification and license requirements.

Operational feasibility information for the Phase 2 targeted technologies is provided in Table 7.

Economic Feasibility: The Agreements specify, "In determining whether it is economically feasible to construct and operate a particular alternative technology for a category of farms, the Designee will consider all relevant information including but not limited to the following factors:

1) the projected 10-year annualized cost (including capital, operational and maintenance costs) of each alternative technology expressed as a cost per 1000 pounds of steady state live weight for each category of farm system;
2) the projected 10-year annualized cost (including capital, operational and maintenance costs) per 1000 pounds of steady state live weight for each category of farm system of a lagoon and sprayfield system that is designed, constructed and operated in accordance with current laws, regulations, and standards, including NRCS design, construction and waste utilization standards;
3) projected revenues, including income from waste treatment byproduct utilization, together with any cost savings from the new technology;
4) available cost-share monies or other financial or technical assistance from federal, state or other public sources, including tax incentives or credits; and
5) the impact that the adoption of alternative technologies may have on the competitiveness of the North Carolina pork industry as compared to the pork industry in other states.

Economic data analysis: The project investigators conducting this work compiled extensive cost data for each candidate EST. The cost and returns analysis, reported herein as Appendix B.1, predicts the estimated costs and returns of retrofitting categories of North Carolina swine farms with candidate EST. The costs are projected as incremental costs, e.g., additional costs to the existing lagoon and spray field system. Projected revenues from by-products plus avoided costs in operating the lagoon and spray field system are considered in each case estimate. As mandated by the Agreements, the net costs are reported based on the following metric: $ per 1000 pounds steady state live-weight per year over a 10-year economic life. These cost data were subsequently utilized to predict the impacts of adopting EST technologies on the competitiveness of the NC pork industry, reported herein as Appendix B.2. An equilibrium displacement model was used in this study to estimate the economic impacts for different types of producers across farm operational size (farm categories) relative to prices and quantities of animals produced as projected for implementation of the candidate EST.

As noted previously, these reports are currently under review by members of the Agreements' appointed advisory panel. Interpretation of the economic feasibility criteria relative to the Agreements mandate for "determination of economic feasibility" will be the subject of a recommendation document and final report issued later in 2005.

4.0 Technology Permittability and Category or Categories of Farms

Permittability: The Agreements specify that any technology or combination of technologies that meet the EST standards must be "permittable by the appropriate governmental authority." In North Carolina the Department of Environment and Natural Resources (NCDENR) and its Division of Water Quality, Division of Air Quality, and Division of Waste Management are specifically involved with the permitting and regulatory aspects of the EST projects. NCDENR is represented (with two members) on the Agreements appointed advisory panel.

Category or Categories of Farms:[9] The Agreements reference, in several sections, EST for identified "category or categories of farms." Further, the Agreements specify "the categories may be determined based on farm size, geographic location, the geographic concentration of the hog population, the type of farm, and any other factors the Designee deems appropriate."

For the objectives related to the EST determinations, categories of farms are based on the types of North Carolina swine farms and the distribution of weight across these farms. This is based on input and study by the investigators conducting the economic feasibility analysis needed to partition the representative swine farms for the economic modeling of farm sizes to compute cost estimates and industry impact of adoption for all candidate EST technologies. The category distribution used and as described by the economic team investigators (see Appendix B.1) is summarized as follows.

The production process for market hogs is comprised of three primary stages — farrow-to-wean, wean-to-feeder, and feeder-to-finish. Farrow-to-wean farms house sows during their breeding, gestation, farrowing and nursing stages. Sows nurse newborn pigs until weaning, which typically occurs 18 to 23 days after a litter of pigs is born. The pigs may weigh 10-12 pounds at weaning. The weaned pigs are moved to a nursery facility to begin the second stage of the production process. Pigs will remain in the nursery (also called wean-to-feeder stage) for 7-10 weeks, enabling them to reach a weight of 45-55 pounds. Finally, the pigs are moved to another facility to enter the feeder-to-finish stage. In this stage, pigs will add approximately 200 pounds of bodyweight over a period of 16 weeks. At a live weight of approximately 260 pounds and an age of about 6 months, the pigs will be marketed for slaughter. Thus, the three primary stages of the hog production process can be combined to form five types of hog farming operations: 1) farrow-to-wean, 2) farrow-to-feeder, 3) farrow-to-finish, 4) wean-to-feeder, and 5) feeder-to-finish. The majority of North Carolina's hog farms concentrate on one stage of production, but some include two (farrow-to-feeder) or three (farrow-to-finish) stages.

Farms with inventories of greater than 250 hogs are required to obtain a permit through the NCDENR. Data recorded in the permit database include the permitted capacity of the farm in number of head of each type of pig (breeding animals, nursery pigs, and feeder to finish pigs) and the associated steady state live weight (SSLW). By partitioning the farm size into categories of 0-500 SSLW, 500-1000 SSLW, 1000-1500 SSLW, 1500-2000 SSLW, and

[9] Information in this section compiled, in part, from reports submitted by the project investigators conducting the economic feasibility determinations.

>2000 SSLW, and using the five types of hog farming operations described above, 25 possible combinations of farm size and type of operation result. These 25 possible combinations include all permitted hog farms in the state and are used as the basis for "category or categories of farms" as applicable to the Agreements.

5.0 Phase 2 Environmentally Superior Technology Determinations and Contingencies

Technology Determinations: Based on Designee responsibilities as described in the Agreements, review of project investigators-reported performance data, and Advisory Panel inputs, the following technology determinations are made at this time: 1) "Super Soil Systems" centralized composting system, 2) gasification for elimination of swine waste solids with recovery of value-added products system, and 3) "BEST" – fluidized bed combustion of solids system.[10] These technologies are determined to meet the EST technical feasibility performance criteria described in Section 3.0 of this report. It is noted that these determinations are specific for the treatment of swine manure solids only. Each of these technologies must be combined with a system that successfully removes solids and also successfully treats (meets EST performance criteria) liquid components of the waste stream (urine and/or flushed manure slurry).

Some of the candidate technologies evaluated as part of the Phase 2 determinations meet many of the technical feasibility performance criteria. This was also reported to be the case for several Phase 1 determinations as reported in July 2004. For these technologies it is possible that upon making technology modifications and/or combining treatment unit processes between other candidate EST these systems will also meet all of the EST technical feasibility performance criteria. As such, these technologies continue to be candidate EST pending further data review and/or technology modifications by the technology providers. Tables 8 and 9 provide an EST status overview for the Phase 2 and Phase 1 technology determinations, respectively. Further system modifications or unit combinations to meet all of the technical standards will be at the discretion of the technology providers. The Designee will consider a revised technology determination for these candidates based on available objective data and best professional judgment, after consultation with the project investigators and Advisory Panel.

Contingencies: Contingencies for conditional EST determinations refer to all feasibility criteria as defined in the Agreements: technical, operational, and economic. For each of the three EST candidates named above, information regarding operational and economic feasibility continues to be evaluated. To be identified as an unconditional EST pursuant to the terms of the Agreements, these technologies must also be determined to meet operational and economic feasibility criteria. Those criteria are yet to be finalized and defined in this overall initiative; however, it is anticipated to be established by the end of calendar year 2005.

The Designee will determine contingency status for these and any additional technologies so characterized based on available objective data, best professional judgment, and consultation with the Advisory Panel.

---

[10] See Appendix A.3 of "Development of Environmentally Superior Technologies: Phase 1 Technology Determination Report" for technical performance data related to this technology ("BEST" – fluidized bed combustion of solids system). Published by NCSU College of Agriculture and Life Sciences, 941 pages, on file with NCSU Animal and Poultry Waste Management Center (July 26, 2004). Also available at www.cals.ncsu.edu/waste_mgt/

6.0 Next Steps and Recommendations

The information and data provided herein and in the previously issued (July 2004) Phase 1 Technology Determination Report show that a total of five candidate EST meet the Agreements technical performance standards that define an Environmentally Superior Technology. One of the five technologies targets treatment of the flushed manure slurry and four of the technologies target treatment of separated swine manure solids. The data also show that, with technical modifications and/or combination of candidate EST technology unit processes, some of the additional technologies considered in the Phase 1 and 2 Reports may meet the technical performance criteria. Such modifications or combinations will be considered for these technologies prior to the anticipated completion of this overall initiative in 2005.

To date, all projects funded by Agreements monies have been evaluated under pilot or commercial scale conditions for the technical performance standards, with the exception of the "AgriClean" and "Environmental Technologies" systems, both located near Greenville, North Carolina. Economic costs and returns data procurement and analysis for all Phase 1 EST candidates and the projected impacts of adopting EST technologies on the competitiveness of the NC pork industry have been reported.

Next steps: Unconditional "Environmentally Superior Technologies," as mandated by the Agreements, must be technically, operationally, and economically feasible, and must also be permittable. Considering that the environmental performance data have been completed and interpreted for most candidate EST and that much information has been compiled regarding operational feasibility, priority is now focused on completing procurement of the economic cost and return data (for the Phase 2 and remaining technologies) and determination of economic feasibility as described in the Agreements for all EST that have been determined to meet the environmental performance data requirements. Concise descriptions of next steps (in priority order) follow.

1) Establish specific criteria to be used in making economic feasibility determinations, as noted in Section 3.0 of this report.

2) Complete the procurement of environmental performance data for the remaining two candidate EST technologies (noted above).

3) Initiate discussions, procedures, etc. with all applicable NCDENR divisions and agencies (Water Quality, Air Quality, Solid Waste, etc.) to determine permittability status of technologies and / or combination of technologies that are potential EST.

4) Continue efforts to procure technical and economic data relative to the contingencies for the "Super Soils" and "ORBIT" technologies, as noted and described in the July 2004 Technology Determination Report.[11]

5) Examine available objective technical and economic data for the Smithfield Foods "BEST Biofuels" Utah project and the Premium Standard Farms "Crystal Peak Farms" Missouri project and make technology determinations for North Carolina EST applications of these technologies.

6) Examine all available objective engineering, performance, and economic data for unit processes that comprise the candidate EST North Carolina projects and make determinations, if any are appropriate, relative to "combinations of technologies" as described in the Agreements.

Recommendations:

The following recommendations were noted in the July 2004 Technology Determination Report. They are, arguably, beyond the scope of EST determinations. However, they each may significantly impact a conversion process of implementing EST onto swine farms in North Carolina. As such, it is recommended that appropriate parties pursue these items concurrent with the next steps identified above relative to EST determinations.

1) Identify potential incentives, public policy, and markets related to the sale of byproducts (including energy) generated by candidate EST that are shown to meet the technical performance standards. Identify legal and institutional obstacles that must be addressed to maximize the revenue potential of these byproducts.

2) Initiate the development of NCDENR permit conditions as well as proposed National Pollutant Discharge Elimination System (NPDES) permit and/or air pollution emissions conditions (if required) for candidate EST that are shown to meet the technical performance standards.

3) Establish a long-term plan for implementation of EST that describes categories of farms for adoption and over what time profile. The plan should include a mechanism to monitor both environmental and economic performance, a phased schedule for implementation, and a discussion of how the timing of implementation affects the economic feasibility criteria as described in the Agreements.

[11] See Sections 5.0 and 6.0 of "Development of Environmentally Superior Technologies: Phase 1 Technology Determination Report" for technical performance data related to these technology ("BEST" – fluidized bed combustion of solids system). Published by NCSU College of Agriculture and Life Sciences, 941 pages, on file with NCSU Animal and Poultry Waste Management Center (July 26, 2004). Also available at www.cals.ncsu.edu/waste_mgt/

ACKNOWLEDGEMENTS

Acknowledgement and sincere appreciation are expressed to the following: Advisory Panel members; all project principal investigators, co-investigators, and collaborators; farm property owners and operators; technology suppliers; construction and permit on site project technical managers; Animal and Poultry Waste Management Center staff; North Carolina Department of Environment and Natural Resources; North Carolina Department of Justice; North Carolina State University administration; and finally, the companies that entered into the Agreements (Smithfield, PSF, and Frontline Farmers).

Without the resources, inputs, and support of these individuals, agencies, and organizations, the progress and accomplishments noted in this report would not have been possible.

Appreciation is also expressed to the NCSU College of Agriculture and Life Sciences Communication Services (Dave Caldwell, in particular) for assistance with format and Web copy compilation of this report.

C.M. Williams, Agreements Designee
July 25, 2005

Table 1. Environmentally Superior Technology candidate projects status (July 2005).

Technology	Environmental Performance Data Procurement	Economic Feasibility Determination
Ambient Temperature Anaerobic Digester and Greenhouse for Swine Waste Treatment and Bioresource Recovery at "Barham Farm"	Complete	Complete
"Ekokan" Biofiltration Technology	Complete	Complete
"ReCip" Solids Separation – Reciprocating Wetland	Complete	Complete
"Super Soils" Solids Separation / Nitrification-Denitrification / Soluble Phosphorus Removal / Solids Processing System	Complete	Complete
Belt System for Manure Removal / Gasification of Solids	Complete	Complete
Belt System for Manure Removal / Insect Biomass from Solids	Complete	Complete
"ORBIT" High Solids Anaerobic Digester	Complete	Complete
"BEST" Biomass Energy Sustainable Technology	Complete	Complete
Solids separation / constructed wetlands system	Complete	Complete
"ISSUES" Permeable cover / aerobic blanket / mesophilic digester / microturbine / water reuse system	Complete	Complete
"ANT" Sequencing batch reactor system	Complete	Complete
"AgriClean" Mesophilic digester and "AgriJet" flush system	In Progress	In Progress
"Environmental Technologies" - Sustainable NC and Frontline Farmers project	In Progress	In Progress
"Crystal Peak" – Manure to Fertilizer (PSF - MO)	In Progress	In Progress
"BEST" Biofuels – Manure to Biodiesel (SF - UT)	In Progress	In Progress

Table 2. Environmentally Superior Technology candidate projects experimental site location information (Phase 2 Technology Determinations).[12]

Technology	Farm type and approximate animal inventory	Houses ventilation type	Houses waste discharge type and approximate waste stream flow
Conventional Technology[13] (Stokes)	Finishing 5,000 head 4 houses	Natural	Flush 14,000 gal/d
Conventional Technology (Moore Bros.)	Finishing 7,000 head 8 houses	Tunnel	Pit recharge 70,000 gal/d
"Super Soils" Compost System	Centralized site (Received solids from 4,300 head finisher)	N/A	3 – 3.3 m^3/day solids processed (800 gal/d 17% DM)
Belt System/ Gasification of Solids	Centralized site (Received solids from belt system)	N/A	30 kg @ 50% DM/ batch (66 lbs./ batch)
Insect Biomass from Solids	Centralized site (Received solids from BELT (LWFL – research unit)	N/A	170 kg/45,000 larvae total; (45,000 larvae consumed 6.26 Kg/day)
Solids separation / constructed wetlands	Finishing 3,500 head 4 houses	Tunnel	Pit recharge 40,000 gal/d
"ANT" Sequencing batch reactor system	Finishing 13,000 head (4200 test) 24 houses (6 test)	Natural	Flush 26,000 – 39,000 gal/d
"ISSUES"- Aerobic blanket	Finishing 6,500 head 9 houses	Tunnel	Flush 43,000 – 50,000 gal/d
"ISSUES" – Permeable cover	Finishing 6,100 head (2400 test) 5 houses (2 test)	Natural	Flush 32,000 gal/d
"ISSUES" – mesophilic digester/ microturbine/ water reuse system	Finishing 9,800 head 8 houses	Natural	Flush 77,000 gal/d

[12] Approximate values derived primarily from Project Investigator Final Reports. Full reports contain more precise and detailed information and are available at http://www.cals.ncsu.edu/waste_mgt/ or upon request from the NCSU Animal and Poultry Waste Management Center, on file with C.M. Williams.
[13] Conventional Technology = Permitted lagoon sprayfield waste treatment system

Table 3. Environmentally Superior Technology candidate projects demonstrated performance for solids, organic matter and nutrients (Phase 2 Technology Determinations). Values shown are percent reductions and/or recovery.[14]

Technology	TAN[15]	TKN[16]	Solids[17]	COD[18]	BOD[19]	TP[20]	Cu	Zn
"Super Soils" Compost System	-	96.5 Recovery	-	-	-	100.0 Recovery	95.6 Recovery	99.6 Recovery
Belt System/ Gasification of Solids	-	-	92.5	-	-	-	-	-
Insect Biomass from Solids	-	55.1	56.0	-	-	44.1	45.8	45.1
Solids separation / constructed wetlands	-	57.0	97.0 (SS)	-	-	87.0	41.0	39.0
"ANT" Sequencing batch reactor system (w/biosolids separation)	96.8 96.8	83.0 90.0	60.0 (SS as COD) 89.7 (SS as COD)	63.7 84.0	-	35.0 36.5	69.0 76.1	75.0 81.4
"ISSUES"- Aerobic blanket	27.5	33.0	40.0	-	-	49.7	35.0	64.3
"ISSUES" – Permeable cover	46.3	51.5	81.3	-	-	81.0	86.3	93.7
"ISSUES" – mesophilic digester/ microturbine/ water reuse system[21]	85.5	70.1	60.5	-	-	44.6	49.7	47.8

[14] Values derived primarily from Project Investigator Final Reports. Full reports are available at http://www.cals.ncsu.edu/waste_mgt/ or upon request from the NCSU Animal and Poultry Waste Management Center, on file with C.M. Williams.
[15] TAN = Total Ammonia Nitrogen
[16] TKN = Total Kjeldahl Nitrogen
[17] Solids = Type reported, e.g. suspended, total, volatile noted within each table cell
[18] COD = Chemical Oxygen Demand
[19] BOD = Biochemical Oxygen Demand (5-d)
[20] TP = Total Phosphorus
[21] Values reflect reductions noted for primary technology only; water reuse not included

Table 4. Environmentally Superior Technology candidate projects demonstrated performance for odor reduction (Phase 2 Technology Determinations). Values shown are approximate average odor intensity ratings at 200 and 400 meters from the odor source during the day and night where 0=none at all; 1=very weak, 2=weak; 3=moderately weak; 4=moderate; 5=moderately strong; 6=strong; 7=very strong; and 8=maximal. The first value represents whole farm odor emissions / the second value represents partitioned emissions from the technology treatment components targeted in the experiment.[22]

Technology	Day values 200m	Night values 200m	Day values 400m	Night values 400m
Conventional Technology (Stokes)	1.4 / 1.7	4.0 / 4.2	.57 / .50	3.2 / 3.3
Conventional Technology (Moore Bros.)	1.5 / 1.2	4.2 / 3.6	.64 / .46	3.4 / 3.1
"Super Soils" Compost System	NA / .63	NA[23] / 2.7	NA / .04	NA / 1.9
Belt System/ Gasification of Solids	NA / 0	NA / .04	NA / 0	NA / 0
Insect Biomass from Solids	NA / 0	NA / 1.1	NA / 0	NA /.38
Solids separation / constructed wetlands	1.4 / 1.5	3.7 / 3.8	.70 / .67	3.0 / 3.1
"ANT" Sequencing batch reactor system	1.4 / 1.7	3.4 / 4.0	.65 / .79	2.9 / 3.4
"ISSUES"- Aerobic blanket (No IESS) (w/ IESS operational)	1.2 / 1.3 1.3 / 1.2	3.8 / 3.7 3.6 / 3.2	.57 / .46 .55 / .45	3.1 / 3.0 2.8 / 2.6
"ISSUES" – Permeable cover w/ Evaporation system	1.0 / 1.0 1.1 / 1.0	3.4 / 2.9 3.4 / 3.0	.45 / .33 .45 / .37	2.9 / 2.3 2.9 / 2.5
"ISSUES" – mesophilic digester/ microturbine/ w/ water reuse system	1.1 / 1.5 1.1 / 1.5	3.6 / 4.1 3.5 / 4.0	.47 / .58 .53 / .55	3.0 / 3.4 3.0 / 3.2

[22] Values derived from Project Investigator data reports.
[23] NA = not applicable.

Table 5. Environmentally Superior Technology candidate projects demonstrated performance for reductions in pathogenic microorganisms (Phase 2 Technology Determinations). Values shown are approximate Log_{10} reductions in liquid or solid waste (based on waste stream focus of technology).[24]

Technology	Fecal Coliforms	E. coli	Enterococci	Cl. perfringens	Coliphage	Salmonella
Conventional Technology (Stokes)	1.7	1.8	1.6	0.8	1.5	1.9
Conventional Technology (Moore Bros.)	1.4	1.3	1.0	0.6	1.2	0.4
"Super Soils" Compost System	-0.2	1.1	0.4	2.4	2.3	0.7
30 day + curing	3.4	3.9	2.4	3.9	2.7	1.2
Belt System/ Gasification of Solids	2.2	1.9	2.7	3.1	-	-
Insect Biomass from Solids (Combined w/ belt)	-3.7	-2.8	-5.0	-3.2	1.1	-1.0
	-3.6	-2.5	-4.7	-4.0	-0.2	-1.8
Solids separation / constructed wetlands	2.4	3.6	1.7	3.1	2.1	2.3
Liquid waste stream (only)	3.2	4.6	2.4	4.1	2.8	2.9
"ANT" Sequencing batch reactor system	1.7	1.7	2.8	0.6	1.9	0.9
SBR + Lagoons	3.1	2.9	3.1	0.5	1.9	1.2
"ISSUES"- Aerobic blanket	1.7	2.3	2.2	0.9	1.8	2.0
"ISSUES" – Permeable cover	4.1	4.1	3.3	1.9	3.3	0.5
w/ evaporation system	3.8	5.2	3.4	2.5	4.4	0.8
"ISSUES" – mesophilic digester/ microturbine	3.1	3.1	2.7	0.6	1.4	1.3
w/ water reuse system	6.5	6.5	6.7	3.9	5.9	2.1

[24] Values derived from Project Investigator Final Report.

Table 6. Environmentally Superior Technology performance for ammonia reduction (Phase 2 Technology Determinations). Values shown are % reductions as compared to ammonia emissions from comparable conventional technology sites[25] (positive values indicate reductions in emissions, negative values indicate enhancement of emissions). (Table derived from project investigators report, see Appendix A. 9).

Note – some of these values represent combined whole farm site emissions that are outside of the candidate EST unit process. For determination of EST for ammonia emissions, partitioned data regarding performance of the unit process was considered when possible.

<table>
<tr><th>Technology</th><th colspan="3">% Reduction in Emissions from Water Holding Structures[26]</th><th colspan="2">% Reduction in Barn Emissions</th><th colspan="2">Total % Emission Reduction at Technology site[27 28]</th></tr>
<tr><td></td><td colspan="7">--- Season ---</td></tr>
<tr><td></td><td colspan="2">Warm</td><td>Cool</td><td>Warm</td><td>Cool</td><td>Warm</td><td>Cool</td></tr>
<tr><td>Solids separation / constructed wetlands</td><td colspan="2">-41.8</td><td>-156.8</td><td>-59.4</td><td>-47.4</td><td>-50.9</td><td>-62.6</td></tr>
<tr><td>“ANT” Sequencing batch reactor system</td><td colspan="2">31.5</td><td>-23.5</td><td>-95.0</td><td>98.0</td><td>-4.9</td><td>67.2</td></tr>
<tr><td>“ISSUES”- Aerobic blanket</td><td colspan="2">86.7</td><td>47.2</td><td>-16.3</td><td>-10.1</td><td>49.5</td><td>8.1</td></tr>
<tr><td>“ISSUES” – Permeable cover / evaporation system[29]</td><td>-143.8</td><td>-1.4</td><td>44.7</td><td>0</td><td>81.0</td><td>-109.9</td><td>69.4</td></tr>
<tr><td>“ISSUES” – mesophilic digester/ microturbine</td><td colspan="2">48.8</td><td>22.0</td><td>-37.0</td><td>86.0</td><td>31.1</td><td>54.0</td></tr>
<tr><td>Super Soils Composting[30]</td><td colspan="2">-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Black Solider Fly[30]</td><td colspan="2">-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Gasifier – LWFL[30]</td><td colspan="2">-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
</table>

[25]Conventional technology sites included a primary anaerobic lagoon and either tunnel (Moore Brothers farm) or naturally (Stokes farm) ventilated houses.

[26]Percent reductions in water holding structures are based against average lagoon ammonia emissions measured at both conventional farm sites for the respective season. Percent reductions in barn emissions are based against the conventional technology using the corresponding housing ventilation technique.

[27]Percent emission reduction figures are calculated using a precise algorithm that is documented in the respective reports for each technology. The summary numbers provided in this table should not be averaged or combined in any fashion across components of the technologies or across season.

[28]Unless otherwise noted, percent reduction in emissions from water holding structures means emissions from all measured structures at a technology were combined together for a single season to arrive at the single percetn reduction figure.

[29]Right hand box represents the warm season evaluation of Harrell’s with the irrigation system. The total emissions were not calculated for this evaluation as no barn measurements were taken at this time

[30]This technology had no accompanying water holding structures nor animal barns. This was due to the configuration and location of the technology.

Table 7. Environmentally Superior Technology candidate project operational feasibility information (Phase 2 Technology Determinations).

Technology	Operator hours/week	Operator skills	Operator certification / license requirements
Conventional (Stokes)	10	Record keeping, irrigation equipment operation and maintenance. All aspects of planting, harvesting crops receiving lagoon effluent.	Licensed "Operator in Charge" per NCDENR requirements.
Conventional (Moore Bros.)	10	Record keeping, irrigation equipment operation and maintenance. All aspects of planting, harvesting crops receiving lagoon effluent.	Licensed "Operator in Charge" per NCDENR requirements.
"Super Soils" Compost System	13.3	HS education and mechanical skills	None. Operator receives 1-week training by company
Belt System/ Gasification of Solids	15 (farm) 40(centralized)	Record keeping, knowledge of gasification process, mechanical skills / more specialized for centralized facility	TBD
Insect Biomass from Solids	10-15	HS education, record keeping; some mechanical and equipment knowledge	TBD
Solids separation / constructed wetlands	10	HS education and mechanical skills	None.
"ANT" sequencing batch reactor system	< 20	HS education or higher with mechanical and electrical skills – working knowledge of physical and chemical lab tests – computer knowledge – capable of troubleshooting pumps and pipes	TBD – on-site training for 1 month
"ISSUES"- Aerobic blanket	5	HS education and mechanical skills– capable of troubleshooting pumps, pipes, and nozzles.	None.
"ISSUES" – Permeable cover	5	HS education and mechanical skills– capable of troubleshooting pumps, and pipes	None.
"ISSUES" – mesophilic digester/ microturbine/ water reuse system	30 - 40	HS education or higher with mechanical and electrical skills – computer knowledge – capable of trouble-shooting pumps and pipes	TBD (microturbine)