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Cost and Returns Analysis of Manure Management Systems Evaluated in 2004 under the North Carolina Attorney General Agreements with Smithfield Foods, Premium Standard Farms, and Front Line Farmers

TECHNOLOGY REPORT: BEST IDAHO CENTRALIZED FLUIDIZED BED COMBUSTION FACILITY

Prepared as Part of the Full Economic Assessment of Alternative Swine Waste Management Systems Under the Agreement Between the North Carolina Attorney General and Smithfield Foods

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1. Summary

This report differs significantly from some of the other technology reports in this series. The differences arise from the facts that the evaluation was conducted in pilot scale rather than full prototype scale and that no invoiced construction costs were available. The technology providers and principal investigators provided their best estimates of expected construction costs of a centralized combustion and steam electric generating facility. Actual pilot scale performance data on fuel use, heat production, ash production, and other variables were applied in this cost and returns model. Annualized cost estimates of a full scale 15-megawatt facility were generated based on the information provided to the Task 1 team. In cooperation with the technology providers and the principal investigators, a substantial effort was made to include transportation costs of swine manure and turkey litter in the model of the 15-MW facility. Possible revenue predictions were made for electricity generated and for ash as a livestock feed supplement. Estimates of costs and returns are also presented in units of $ per 1,000 pounds SSLW and $ per ton of swine manure consumed. Results of these modeling efforts are described in this report.

The fluidized bed combustion technology was evaluated at Energy Products of Idaho (EPI) in Coeur d'Alene, Idaho. EPI received 115 tons of turkey litter and 60 tons of separated swine solids from BEST on-farm technology demonstrations in North Carolina for the evaluation. During the 15-day testing period, approximately 180,000 pounds of turkey litter and 86,000 pounds of separated swine solids were consumed at EPI. Five combinations of swine manure and turkey litter were tested. Those with higher percentages of swine solids required supplemental energy for the combustion process due to its' 58% moisture content. The turkey litter had 30% moisture content (Table BI.1). The turkey litter was 27% ash while the swine manure was 2.5% ash. It was estimated that 16.61% of the total wet weight consumed during the evaluation was ash. The phosphorus content of the ash (on an oxide basis) was 17.6% for turkey litter, 27.4% for swine manure solids, and 14.7% for a mixture of 75% turkey litter and 25% swine manure solids (Table BI.2). The ash also contains a significant fraction of calcium and some potassium and magnesium. Operating variables that were not entirely determined in the pilot-scale evaluation include: the ability to use waste heat to preheat intake air for the combustion process (to minimize propane consumption), the fraction of ash that would be captured and the form of that ash (cyclone, baghouse, or bottom ash), and the actual percent ash and nutrient composition of that ash given the actual combustion feedstocks to be used.

A future proposed development of the BEST combustion process was developed to allow cost and returns estimation for this technology. The proposed system relies on many unproven assumptions so the cost and returns estimates are highly speculative given the data included in this analysis. Some of the assumptions made for this cost and returns analysis follow. It was assumed that a centralized combustion facility would be modeled and that it would be sized to provide sufficient heat to power an attached 15-MW steam turbine electric generator. Based on the evaluation, the feedstock is assumed to be 25%

swine manure solids and 75% turkey litter. It was assumed that the feedstock would be 11.86% ash, which is a value more representative of conditions in southeastern North Carolina than the 16.61% ash content observed at EPI (Bock). It was also assumed that the swine manure solids are 70% moisture and the turkey litter is 30% moisture. Additional operating details including manure and litter transportation distances and costs are listed in Section 4 of this report and in Tables BI.5 through BI.14. A summary of the cost and returns estimates follows.

Total annualized cost is estimated at $115.98 per 1,000 lbs. SSLW (Table BI.12) for the proposed centralized combustion facility and 15-MW steam electric generator including collection and payments for feedstocks, but not including costs of on-farm separation. The physical characteristics calculations assume that the Filtramat + TFS separator is used. In the case where a solids separation unit had already been installed on farm and solids were being land applied, the cost of land application can be avoided if the solids are shipped to a combustion facility. After subtracting the predicted land application costs (BEST On-Farm system report), the predicted cost falls to $107.15 per 1,000 lbs. SSLW.

The modeled 15-MW facility is estimated to process 21,000 dry tons of swine solids per year. The predicted total annualized cost of the facility is $646.60 per dry ton of swine solids processed (Table B.12). After subtracting avoided land application costs, predicted total annualized cost falls to $597.38 per dry ton of swine solids processed.

Finally, breakeven costs are calculated for both electricity generation (Table BI.13) and ash production (Table BI.14). The breakeven costs for generated electricity (given an assumed price received for ash) range from $0.108 if the price of ash is $0, to $0.029 per kWh if the price received for ash is $300 per ton. These breakeven prices are based on assumed annual production of 126,000,000 kWh of electricity and 33,208 tons of ash.

2. Technology Overview

The BEST Idaho fluidized bed combustion facility is part of the overall BEST system for swine manure treatment. The first treatment step in the BEST process involves on-farm, 2-stage separation of swine manure. To perform this step, the BEST technology experimented with two solids separators: the FAN separator and the Filtramat separator. Each separator was used in conjunction with a tangential flow gravity-settling tank (TFS system). A detailed economic analysis of the two BEST on-farm technologies was conducted in 2004 by the economics team, and the results were combined into a single report (Final BEST Technology Report).

The second step of the BEST treatment process involves the transportation of separated swine solids to a centralized fluidized bed combustion facility. Poultry litter will be mixed with the swine solids in order to ensure a sufficiently dry feedstock for combustion. The heat produced from combusting this mixed feedstock will be used for direct drying or to provide process steam and/or electricity. The ash produced by the combustion process will be used as a feed ingredient (substitute for dicalcium phosphate).

Performance verification of the fluidized bed combustion technology was conducted at Energy Products of Idaho in Coeur d'Alene, Idaho. In order to conduct this testing and verification, EPI received 115 tons of turkey litter and 60 tons of separated swine solids from North Carolina farms. The testing process lasted 15 days, with combustion occurring for five days per week and 24 hours per day over the length of the verification period. Over the course of the 15-day demonstration, five different feedstock combinations of swine solids and turkey litter were combusted: 1.) 100% swine solids; 2.) 100% turkey litter; 3.) 25% swine solids/75% turkey litter; 4.) 33% swine solids/67% turkey litter; and 5.) 50% swine solids/50% turkey litter. During the 15-day testing period, approximately 180,000 pounds of turkey litter and 86,000 pounds of separated swine solids were combusted at EPI. For the feedstock blends with the higher percentages of swine solids, supplemental energy was required for the combustion process.

In the pilot-plant configuration at EPI, propane (supplemental heat) was used in order to preheat the combustion air. In a commercial system, the technology providers expect that low-grade heat from the backend of the combustion process could be used for preheating. At the EPI pilot plant, a majority of the ash was carried out of the combustor along with the hot flue gas. After exiting the combustor, the ash and hot flue gas passed through a cyclone which captured the coarser ash (cyclone ash) while allowing the finer ash to pass through. A portion of the finer ash would be diverted to the baghouse (baghouse ash) via a slipstream, while the rest exited the stack. Only a fraction of the finer ash was captured with the pilot-plant combustion configuration at EPI. In a commercial system, both the ash and the hot flue gas would go directly to the boiler where the coarse ash would drop out. All of the finer ash would be diverted to the baghouse in a commercial configuration. During the pilot testing at EPI, significant quantities of ash particles that were too large to exit the bed along with the flue gas would accumulate in the fluidized bed. In order to maintain a proper bed level, a portion of the bottom ash was periodically removed and collected in barrels. Although it was called bottom ash in the principal investigators' report, it actually contained a combination of ash and bed sand (mostly bed sand initially and, eventually, mostly ash).

Optimization of the combustion process at EPI involved using staged combustion, air preheat, and flue gas recirculation. When combusting wetter feedstocks (i.e., higher swine solids blends), supplemental energy (propane) in the form of air preheat was required to maintain minimum bed temperatures above 1,300°F for efficient combustion. It was found that the vapor space temperature must be at least 1,600°F to ensure efficient combustion. However, vapor space temperatures exceeding 1,800°F resulted in "slagging" of the furnace and cyclone and fouling of the heat exchanger. "Slagging" refers to the case when molten ash coats the boiler pipes as a result of the feedstock becoming too hot. For commercial configuration, the principal investigators recommend the use of an air-to-air heat exchanger that will allow low-grade heat from the back end of the combustion system to be used for preheating combustion air. It is also recommended that a staged combustion fluidized bed process utilizing flue gas recirculation be used at a commercial-scale facility (Bock(b)).

After combustion at EPI, ash was collected and sent to Applied Chemical Technology (ACT) for testing and granulation. Baghouse ash and cyclone ash from EPI were reacted with a 40% P_2O_5 phosphoric acid and anhydrous ammonia in order to produce granules. It was found that the physical properties of the granules produced at ACT using the ash collected from EPI were equivalent to a typical commercial fertilizer. The principal investigators concluded that the granulation demonstration at ACT verified that the ash produced at EPI could be granulated at a typical NPK granulation plant and be used as a fertilizer input.

3. BEST Idaho Performance Data from the EPI Pilot Plant (Tables BI.1-BI.4)

As described in Section 2, two feedstocks (swine solids and turkey litter) were sent to EPI to be used as fuel for the combustion process. These two feedstocks were combined to form five distinct recipes or mixtures. Table BI.1 lists the properties of the feedstocks prior to entering the combustion process. Turkey litter, the dryer of the two feedstocks, contains 30% moisture content and 27% ash. Swine solids are wetter, with 58% moisture content and 2.5% ash. Table BI.1 also shows the properties of two combinations of turkey litter and swine solids: a 75% TL / 25% SS mix and a 50% TL / 50% SS mix. The 50-50 mix has higher moisture content (50%) and lower ash content (15%) than the mixture that contains only 25% swine solids (44% moisture and 19% ash). Table BI.2 lists the results from the elemental analysis that was conducted at ACT using the ash produced from various feedstock mixtures. These analyses can be used to determine the fertilizer value of ash, as well as the potential of ash as a mineral supplement (replacing dicalcium phosphate) in livestock feed.

Table BI.3 lists the dates during which the five feedstock mixtures were combusted at EPI over the course of the 15-day performance verification. It also shows the distribution of ash balances among the types of ash described in Section 1. About 30% of the ash was demonstrated to be exiting through the stack at the EPI pilot plant. In a commercial-scale facility, this ash would be collected as baghouse ash. The total amount of baghouse ash collected at a commercial facility can be estimated to be the amount of baghouse ash collected at the EPI pilot plant plus the amount of ash exiting the stack. Ash balances from the 75% TL / 25% SS mixture are considered the most representative of a commercial facility (50% cyclone ash, 35% baghouse ash, 15% bottom ash). The ash balances for the 100% TL feedstock were achieved during start-up and before a steady-state was reached. With the 65% TL / 35% SS mixture, a system upset affected steady-state performance. Finally, the ash balances for the 50% TL / 50% SS and 100% SS feedstocks were obtained using supplemental propane heat (due to the relatively high moisture contents), which is not likely to represent the operating conditions at a commercial facility. For the economic analyses that follow, it was assumed that the mixture used for combustion fuel contained 75% TL / 25% SS (on a wet weight basis).

Table BI.4 shows a breakdown of ash production and collection during the 15-day performance verification at EPI. There were 17,963 pounds of cyclone ash, 2,456 pounds of baghouse ash, and 10,500 pounds of bottom ash collected. Additionally, an estimated 13,251 pounds of ash exited via the stack. Adding this estimate to the actual amount of baghouse ash collected results in a total of 15,707 pounds of potential baghouse ash. Summing across the three categories of ash, a total of 44,170 pounds of ash were collected at EPI. As a percentage of the 266,000 pounds of feedstock combusted (180,000 pounds of turkey litter and 80,000 pounds of swine solids), it was calculated that 16.61% (on a wet weight basis) will be produced and collected as ash. This estimated rate of ash production was for the entire 15-day verification at EPI and includes all five mixtures. Based on information provided by the principal investigator, a rate of 11.86% was used to represent ash production from the combustion of a 75% TL / 25% SS feedstock in southeastern North Carolina (Bock).

4. Modeled BEST Idaho Centralized Fluidized Bed Combustion and Steam Electric Generating Facility (15-MW) (Tables BI.5-BI.14)

Based on the performance verification at the EPI pilot plant, the economics team modeled a centralized facility that would be located in North Carolina. It was determined through conversations with the technology providers and principal investigators that the centralized facility should be 15-MW in size with electricity generated via a steam turbine. Also, it is assumed that the ash will be used as a feed supplement. Table BI.5 lists other modeling assumptions associated with the centralized facility. Assuming 15-MW of electricity generated per hour (for 24 hours per day) and 350 operating days per year, a facility of this size will generate 126,000,000 kWh of electricity per year. In order to fuel a facility of this size, it is assumed that 800 wet tons / day of feedstock are required. This assumption was based on conversations with the technology providers and principal investigators (Boyd, Miles, Bock(a)). At a 75 % TL / 25% SS ratio, 600 wet tons of turkey litter and 200 wet tons of swine solids are required per day. Assuming a 30% moisture content in turkey litter, 420 dry tons per day of this feedstock are needed. Assuming a 70% moisture content for swine solids (as demonstrated with the BEST on-farm systems), 60 dry tons per day will be needed. Annually, 21,000 dry tons of swine solids will be required to fuel a combustion facility of this size given the above assumptions. A facility of this size will produce 94.88 tons of ash per day (800 wet tons of feedstock * 11.86% ash production rate), or 33,208 tons of ash per year. The 75% TL / 25% SS mixture was chosen for the economic model because this blend resulted in the highest consistent fuel quality (as determined by lower heating value (LHV)) during the performance verification at EPI (see Table BI.3) (Miles).

Table BI.6 calculates the number of finishing pigs required to provide the necessary solids to fuel a 15-MW fluidized bed combustion and generation facility. This calculation is performed for each of the two separation systems used in the BEST on-farm performance verifications. According to the assumptions used in the Combined Appendices Report (Appendix A, Table A.25), a 4,320-head feeder-finish farm will produce 2.39 dry tons of solids per day or 872 dry tons of solids per year. On-farm verification showed that the FAN + TFS separator captured 10% of the predicted amount of solids, or 87.2 dry tons per year for a 4,320-head finishing farm. The Filtramat + TFS separator was demonstrated to be slightly more efficient, as it captured 12% of predicted solids (or 104.6 dry tons per year for a 4,320-head finishing farm). As shown above, a 15-MW combustion facility will require 21,000 dry tons of swine solids per year to fuel the combustion process. Based on these numbers, it was calculated that 241 farms (4,320-head feeder-finish) equipped with the FAN+TFS separator will be required to provide the necessary fuel for the modeled facility. If using the Filtramat + TFS separator, then 201 farms (4,320-head feeder-finish) will be required. Total number of head and pounds SSLW required were calculated similarly and are reported in Table BI.6.

Tables BI.7 and BI.8 report some summary statistics for the top hog-producing counties in North Carolina. For a visual depiction of the statewide distribution of DWQ permitted swine farms, see Figure BI.1. This summary data can be used to estimate the quantity of SSLW (or farms or hogs) that would be located within a specified radius from a centralized combustion facility. For example, assume that the modeled 15-MW facility will be located in Duplin County. The calculation for the amount of SSLW within an 11-mile radius of this facility using Tables BI.7 and BI.8 is as follows:

(1.) Area in a circle with 11-mile radius = pi * (11)(11) = 380.132 square miles
(2.) SSLW per square mile in Duplin County = 345,297 lbs. (see Table BI.8)
(3.) Total SSLW in a circle with 11-mile radius in Duplin County = (380.132) * (345,297) = 131,258,574 lbs. SSLW

This number can be compared to the amount of SSLW required to fuel a 15-MW facility as reported in Table BI.6. For the Filtramat + TFS separator, the number listed in Table BI.6 is 117,074,849 pounds of SSLW. It can be concluded that there are enough hogs located within an 11-mile radius of a hypothetical Duplin County 15-MW combustion facility to provide fuel for that site. The actual quantity of solids captured and percent moisture and hence the actual required trucking distance of solids and the number of farms required must be determined for prospective combustion/generation sites conditional on the separation technology selected.

Table BI.9 lists some of the cost assumptions used in the BEST Idaho centralized facility model. The costs reported in this table are based on meetings with the technology providers and principal investigators (Boyd, Miles, Bock(a)). Capital costs are reported on a per-MW basis, while operating and maintenance costs are reported on a per-kWh basis. Supplemental fuel costs are also given on a per-kWh basis. It is assumed that the centralized facility will use turkey litter to mix with the swine solids. On a wet weight basis, the mixture of feedstocks will include 75% turkey litter and 25% swine solids. The cost of swine solids and turkey litter is assumed to be solely comprised of the transportation cost of delivering these feedstocks to the facility. Per-truckload transportation costs and estimated number of truckloads (23-wet ton load) are reported in Table BI.9, as well as the resulting total transportation costs. The cost of separating solids on-farm is not reported in this model. The BEST (FAN + TFS and Filtramat +

TFS) Technology Report has predicted costs of the on-farm system including solids separation.

The numbers and assumptions reported in Table BI.9 are used to project the annualized costs of a centralized 15-MW fluidized bed combustion facility. The predicted annualized costs are listed in Table BI.10. Annualized capital costs are calculated using the standard assumptions reported in the Combined Appendices Report (e.g., 10-year economic life, 8% interest rate, etc.). Predicted annualized construction cost of the 15-MW facility is reported as $5,365,062. Operating costs are reported as $8,213,570. Total annualized costs for the centralized facility, as reported in Table BI.10, are $13,578,632. Again, the costs of on-farm solids separation are not reported in this table. A total system approach for this centralized facility would include the cost of on-farm solids separation (as reported in the BEST (FAN + TFS and Filtramat + TFS) Technology Report). For this model, the only costs associated with separated solids are the transportation costs of delivering them to the centralized facility.

Table BI.11 lists the annual returns associated with the 15-MW centralized fluidized bed combustion facility. This facility will have two potential revenue streams: electricity generation and ash production. There is also the avoided cost of on-farm land application of solids. The price received per-kWh of electricity generated is assumed to be $0.069 in this table. This price includes “green tags.” The price reported in Table BI.11 for a ton of ash is $184.72. This is based on a per-cwt price of $15 for dicalcium phosphate (Shurson) and an ash-to-dicalcium phosphate equivalency of 1.45 (1.45 tons of ash needed to equal the phosphorus contained in 1 ton of dicalcium phosphate) (Bock). A range of prices was found for dicalcium phosphate in the literature, ranging from a low of $12.50 / cwt (Shurson) to a high of $22.01 / cwt (Steevens and Olson). There is no established market for ash as a substitute for dicalcium phosphate, so all prices for this by-product are highly speculative. Avoided land application costs are calculated as the per-farm cost of land applying 697,400 pounds of separated solids ($5,143) multiplied by the number of farms providing solids to fuel the facility (201, assuming use of the Filtramat + TFS separator). Total annual returns for a 15-MW facility are calculated as $14,828,182 in Table B.11. The bottom line in Table B.11 shows annual returns of $15,861,925 if avoided land application costs are considered.

Table BI.12 reports the total annualized costs for a 15-MW facility using two different denominators: $ / 1,000 lbs. SSLW and $ / dry ton of swine solids processed. The costs in Table BI.12 are calculated based on numbers reported in Tables BI.6 and BI.10. The calculations assume that the Filtramat+TFS separator is used. The total annualized cost per 1,000 lbs. SSLW for a 15-MW centralized fluidized bed combustion facility is calculated as $115.98 in Table BI.12. If accounting for avoided land application costs, the cost $ / 1,000 lbs. SSLW for the facility is predicted to be $107.15. The 15-MW facility is estimated to process 21,000 dry tons of swine solids per year. The annualized cost of the facility per dry ton of swine solids processed is reported as $646.60 in Table B.12. This estimate includes the cost of acquiring turkey litter, but the denominator only includes the dry tons of swine solids being processed at the facility (not the total dry tons of feedstock being processed at the facility). When considering avoided land application costs, predicted cost is $597.38 per dry ton of swine solids processed.

Finally, breakeven costs are calculated for both electricity generation (Table BI.13) and ash production (Table BI.14). In Table B.13, the breakeven costs for electricity generation are reported given an assumed price received for ash. For example, if there is no market for combustion ash (i.e., $ / ton of ash is 0), electricity must sell for $0.108 per kWh in order for the 15-MW facility to cover its annualized costs. As the price received per ton of ash increases, the breakeven cost per kWh of electricity generation decreases. Table BI.14 shows a similar analysis for combustion ash. The breakeven costs for this by-product are reported given an assumed price received for electricity. For example, if the 15-MW facility can sell its electricity for $0.04 / kWh, the breakeven cost per ton of ash will be $257.13. As the price received per kWh of electricity increases, the breakeven cost per ton of ash decreases.

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Tables BI.1 through BI.4: Performance Data Tables for the BEST Idaho Technology as Tested at the EPI Pilot Plant

Table BI.1. Fuel Properties of Feedstocks Used in Combustion Tests at EPI (Bock(b))

	Moisture	Ash	Carbon	Hydrogen	Nitrogen	Sulfur	Oxygen
	(%, as received basis)						
Turkey Litter (TL)*	30.02	27.04	23.63	2.49	2.39	0.43	14.00
Swine Solids (SS)*	58.41	2.47	21.34	2.53	0.76	0.12	14.37
75 % TL / 25 % SS**	43.55	18.93	19.39	2.31	1.84	0.31	13.67
50 % TL / 50 % SS**	49.58	15.06	19.97	2.17	1.91	0.33	10.98

* Analysis of turkey litter and swine solids was performed in North Carolina, before being shipped to Idaho.

** Analysis of combined feedstocks was performed in Idaho, after being shipped from North Carolina.

Table BI.2. Elemental Analysis of Ash Produced from the Combustion of Various Feedstocks (Bock(b))

	P_2O_5	K_2O	CaO	MgO
	(%)			
Turkey Litter (TL)	17.64	8.26	13.90	3.57
Swine Solids (SS)	27.37	8.31	29.80	6.61
75 % TL / 25 % SS	14.67	8.43	14.20	3.97
50 % TL / 50 % SS	12.06	7.72	13.70	3.60

Table BI.3. Ash Balances from EPI Pilot Plant Tests Using Various Combinations of Turkey Litter (TL) and Swine Solids (SS) (Bock(b))

	100 % TL	**65 % TL / 35 % SS**	**75 % TL / 25 % SS**	**50 % TL / 50% SS**	**100 % SS**
Dates tested	7/29/03-7/31/03	8/1/03	8/4/03-8/7/03	8/8/03-8/15/03	8/1/03
Feedstock moisture (%)	40.4	42.7	41.0	50.0	69.2
Lower heating value (LHV), (MJ/kg)	4.8-6.7	6.1-6.9	5.7-7.0	5.2-6.2	4.4-4.7
Cyclone ash (%)	38.3	25.5	50.3	34.5	21.7
Baghouse ash (%)	2.9	8.6	4.2	8.2	12.4
Ash exiting stack (%)	29.2	30.7	30.5	34.5	65.9
Baghouse + exiting stack (%)	32.1	39.3	34.7	42.7	78.3
Bottom ash (%)	29.7	35.1	15.1	22.8	0.0

Table BI.4. Ash Production and Collection during the Pilot Plant Testing at EPI (Bock(b))

Feedstock Combusted	
Turkey litter	180,000 pounds
Swine solids	86,000 pounds
Total Feedstock Combusted	*266,000 pounds*
Ash Collected/Produced	
Cyclone ash	17,963 pounds
Baghouse ash	2,456 pounds
Estimated baghouse ash exiting the stack*	13,251 pounds
Bottom ash	10,500 pounds
Total Ash Collected/Produced	*44,170 pounds*
Ash Collected as a % of Total Feedstock Combusted	**16.61 %**

Tables BI.5 through BI.14: Predicted Costs and Returns Tables for the BEST Idaho Centralized Fluidized Bed Combustion and Steam Electric Generating Facility

Table BI.5. Modeling Assumptions for the BEST Idaho Centralized Fluidized Bed Combustion and Steam Electric Generating Facility (Boyd, Bock(a), Miles)

Size of facility	15 MW
Operating days / year	350 days
Source of electricity generation	steam turbine
Daily electricity generated	360,000 kWh
Annual electricity generated	126,000,000 kWh
Daily feedstock required	480 dry tons*
Feedstock recipe/mixture	25 % swine solids / 75 % turkey litter**
Daily amount of swine solids required	60 dry tons
Annual amount of swine solids required	21,000 dry tons
Steam flow	150,000 lbs. / hour
Daily ash produced/collected***	94.88 tons
Annual ash produced collected***	33,208 tons

* At 40% moisture content, or 800 wet tons per day

** On a wet weight (or as received) basis: 200 wet tons of swine solids (at 70% moisture content) mixed with 600 wet tons of turkey litter (30% moisture content)

*** Assuming that 11.86% of total wet weight feedstock is produced/collected as ash (Bock). This value differs from the one seen in Table BI.4 and is more representative of the ash content that would be expected in southeastern North Carolina.

Table BI.6. Number of 4,320-Head Feeder-Finish Farms Needed To Produce the Required Amount of Separated Solids to Fuel a 15-MW Combustion Facility

FAN + TFS separation efficiency*	10 %
Filtramat + TFS separation efficiency*	12 %
Daily total solids produced at a 4,320-head finishing farm**	2.39 dry tons
Annual total solids produced at a 4,320-head finishing farm	871.78 dry tons
Annual solids collected using the FAN + TFS separator	87.18 dry tons
Annual solids collected using the Filtramat + TFS separator	104.61 dry tons
Annual swine solids required to fuel a 15-MW combustion facility	21,000 dry tons
Number of 4,320-head farms required (FAN + TFS)	241 farms
Number of head required (FAN + TFS)	1,040,606 head
Amount of Steady State Live Weight (FAN + TFS)	140,481,762 lbs. SSLW
Number of 4,320-head farms required (Filtramat + TFS)	201 farms
Number of head required (Filtramat + TFS)	867,221 head
Amount of Steady State Live Weight (Filtramat + TFS)	117,074,849 lbs. SSLW

* See the BEST (FAN + TFS and Filtramat + TFS) Technology Report

** See Appendix A, Table A.25 of the Combined Appendices Report

Table BI.7. Number of Farms, Number of Hogs, and Amount of Steady State Live Weight (SSLW) in Selected North Carolina Counties (NC DENR DWQ Database)

	Number of Farms	Number of Pigs	Lbs. SSLW	Acres	Square Miles
Duplin County	503	2,183,796	282,394,836	523,411	817.83
Sampson County	449	1,788,105	265,999,401	605,133	945.52
Greene County	103	396,617	54,952,345	169,888	265.45

Table BI.8. Per Farm and Per Square Mile Averages for Number of Hogs and SSLW in Selected North Carolina Counties (NC DENR DWQ Database)

	Lbs. SSLW / Pig	Pigs / Farm	Lbs. SSLW / Farm	Pigs / Square Mile	Lbs. SSLW / Square Mile
Duplin County	129.31	4,342	561,421	2,670	345,297
Sampson County	148.76	3,942	603,426	1,891	281,326
Greene County	138.55	3,851	533,518	1,494	207,016

Table BI.9. Capital and Operating Cost Assumptions for the BEST Idaho Centralized Fluidized Bed Combustion and Steam Electric Generating Facility (Boyd, Bock(b), Miles)

Capital cost per MW	$2,400,000
Capital cost for a 15-MW facility	$36,000,000
Operating and maintenance cost per kWh	$0.039
Annual operating and maintenance cost for a 15-MW facility	$4,914,000
Supplemental fuel cost per kWh	$0.020
Annual supplemental fuel cost for a 15-MW facility	$2,630,000
Transportation cost per trip (23-ton truckload) to deliver swine solids/turkey litter	$55*
Annual number of 23-ton truckloads**	12,174
Annual transportation cost of delivery swine solids/turkey litter	$669,570

* Based on a quote provided by Noel Lyons. This quote assumes a trip of one hour or less (at a rate of $55 / hour).
** Based on 600 wet tons of turkey litter and 200 wet tons of swine solids being delivered daily to the facility (800*350 = 280,000 wet tons / yr.)

Table BI.10. Predicted Annualized Costs of the BEST Idaho Centralized Fluidized Bed Combustion and Steam Electric Generating Facility (15-MW)

Annualized capital costs (including contractor and engineering services and overhead)	$5,365,062
Total Construction Cost	*$5,365,062*
Operating and maintenance cost	$4,914,000
Supplemental fuel cost	$2,630,000
Transportation cost to deliver swine solids/turkey litter	$669,570
Total Operating Costs	*$8,213,570*
Total Annualized Cost of 15-MW Combustion Facility	**$13,578,632**

Table BI.11. Predicted Annual Returns of the BEST Idaho Centralized Fluidized Bed Combustion and Steam Electric Generating Facility (15-MW)

Annual electricity generated	126,000,000 kWh
Price received for electricity* (including "green tags")	$0.069 / kWh
Annual returns from electricity generation	$8,694,000
Annual ash produced/collected	33,208 tons
Price received for ash (as a mineral supplement replacing dicalcium phosphate)**	$184.72 / ton
Annual returns from ash production	$6,134,182
Avoided cost of land applying separated solids***	$1,033,743
Total Annual Returns of a 15-MW Combustion Facility (not including avoided land application costs)	**$14,828,182**
Total Annual Returns of a 15-MW Combustion Facility (including avoided land application costs)	**$15,861,925**

* Based on an estimate provided by Garth Boyd
** Based on a price reported by Shurson and an ash to dicalcium phosphate ratio provided by Bock.
*** Assuming nitrogen-based application to forage; total avoided cost is equal to a per farm (4,320-head feeder-finish) cost of $5,143 multiplied by the 201 farms that are required to fuel the combustion facility (with the Filtramat + TFS separator)

Table BI.12. Costs / 1,000 Pounds SSLW and Costs / Dry Ton of Swine Solids Received for the BEST Idaho Centralized Fluidized Bed Combustion and Steam Electric Generating Facility (15-MW)

Pounds of SSLW needed to fuel the facility*	117,074,849
Annualized costs $ / 1,000 lbs. SSLW*	$115.98
Avoided annual land application costs**	$1,033,743
Annualized costs $ / 1,000 lbs. SSLW less avoided land application costs	$107.15
Dry tons of swine solids processed per year	21,000
$ / dry ton of swine solids processed	$646.60
$ / dry ton processed less avoided land application costs	$597.38

* Assuming the Filtramat + TFS separator is used to collect swine solids
** Assuming nitrogen-based application to forages

Table BI.13. Breakeven Cost of Electricity Generation Assuming Various Prices Received for Combustion Ash*

	$ 0 / ton	$100 / ton	$150 / ton	$184.72 / ton**	$200 / ton**	$250 / ton	$300 / ton
Breakeven cost of electricity ($ / kWh)***	$0.108	$0.081	$0.068	$0.059	$0.055	$0.042	$0.029

* Assuming 33,208 tons of ash are produced/collected per year (see Table BI.5)
** Assumption used to calculate returns in Table BI.10
*** Assuming 126,000,000 kWh of electricity are generated per year (see Table BI.5)

Table BI.14. Breakeven Cost of Combustion Ash Assuming Various Prices Received for Electricity*

	$ 0 / kWh	$0.02 / kWh	$0.04 / kWh	$0. 069 / kWh**	$0.08 / kWh	$0.10 / kWh
Breakeven cost of ash ($ / ton)***	$408.90	$333.01	$257.13	$147.09	$105.36	$29.47

*Assuming 126,000,000 kWh of electricity are generated per year (see Table BI.5)
** Assumption used to calculate returns in Table BI.10
*** Assuming 33,208 tons of ash are produced/collected per year (see Table BI.5)

Figure BI.1. Location of North Carolina's Permitted Swine Farms (NCDENR DWQ Database)